Application for a

Section 91 Licence

under the *Threatened Species Conservation Act 1995* to harm or pick a threatened species, population or ecological community* or damage habitat.

1. Applicant's Name ^: *(if additional persons require authorisation by this licence, please attach details of names and addresses)*	Andrew Walsh on behalf of the Lord Howe Island Board	
2. Australian Business Number (ABN):	33 280 968 043	
3. Organisation name and position of applicant ^: *(if applicable)*	Lord Howe Island Board **Project Manager - Rodent Eradication**	
4. Postal address ^:	PO Box 5, Lord Howe Island, NSW 2898	Telephone ^: B.H. **02 65632066** A.H.
5. Location of the action *(including grid reference and local government area and delineated on a map).*	**Lord Howe Island NSW, 2898**	

* A threatened species, population or ecological community means a species, population or ecological community identified in Schedule 1, 1A or Schedule 2 of the *Threatened Species Conservation Act 1995.*

^The personal details of all Section 91 licences will be displayed in the register of Section 91 licences required under Section 104 of the *Threatened Species Conservation Act 1995.* See notes.

6. Full description of the action and its purpose *(e.g. environmental assessment, development, etc.)*	**Please see attached Species Impact Statement**
7. Details of the area to be affected by the action *(in hectares)*.	**Please see attached Species Impact Statement**
8. Duration and timing of the action *(including staging, if any).*	**Please see attached Species Impact Statement**
9. Is the action to occur on land declared as critical habitat*? *(tick appropriate box)*	☐ Yes ☒ No

* Critical habitat means habitat declared as critical habitat under Part 3 of the *Threatened Species Conservation Act 1995*.

<table>
<tr><td>10. Threatened species, populations or ecological communities to be harmed or picked.</td><td><u>Scientific name</u>

Please see attached Species Impact Statement</td><td><u>Common name</u>
(if known)</td><td><u>Conservation status</u>
(i.e. critically endangered, endangered or vulnerable)</td><td><u>Details of no. of individual animals, or proportion and type of plant material</u>
(e.g. fertile branchlets for herbarium specimens or whole plants or plant parts)</td></tr>
<tr><td>11. Species impact:
(please tick appropriate box)
a) For action proposed on land declared as critical habtat;
or
b) For action proposed on land <u>not</u> declared as critical habitat.</td><td colspan="4">an SIS is attached ☐ Yes ☐ No

Items 12 to 25 have been addressed ☒ Yes ☐ No</td></tr>
</table>

N.B: Provision of a species impact statement is a statutory requirement of a licence application if the action is proposed on critical habitat.
The provision of information addressing items 12 to 17 is a statutory requirement of a licence application if the action proposed is <u>not</u> on land that is critical habitat. Information addressing any of the questions below must be attached to the application.

12. Describe the type and condition of habitats in and adjacent to the land to be affected by the action.	**Please see attached Species Impact Statement**
13. Provide details of any known records of a threatened species in the same or similar known habitats in the locality *(include reference sources).*	**Please see attached Species Impact Statement**
14. Provide details of any known or potential habitat for a threatened species on the land to be affected by the action *(include reference sources).*	**Please see attached Species Impact Statement**
15. Provide details of the amount of such habitat to be affected by the action proposed in relation to the known distribution of the species and its habitat in the locality .	**Please see attached Species Impact Statement**

16. Provide an assessment of the likely nature and intensity of the effect of the action on the lifecycle and habitat of the species.	**Please see attached Species Impact Statement**
17. Provide details of possible measures to avoid or ameliorate the effect of the action.	**Please see attached Species Impact Statement**

N.B: The Director-General must determine whether the action proposed is likely to significantly affect threatened species, populations or ecological communities, or their habitats. To enable this assessment the Applicant is required to address items 18 to 24. Any additional information referred to in addressing these items must be attached to the application.

18. In the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction.	**Please see attached Species Impact Statement**

19. In the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction.	**N/A**
20. In the case of an endangered ecological community or critically endangered ecological community, whether the action proposed: (i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or (ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction.	**Please see attached Species Impact Statement**
21. In relation to the habitat	

of a threatened species, population or ecological community: (i) the extent to which habitat is likely to be removed or modified as a result of the action proposed, and (ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and (iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality.	**Please see attached Species Impact Statement**
22. Whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly).	**N/A**
23. Whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan.	**Please see attached Species Impact Statement**
24. Whether the action	

proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.	**Please see attached Species Impact Statement**

Important information for the applicant

Processing times and fees

The *Threatened Species Conservation Act 1995* provides that the Director-General must make a decision on the licence application within 120 days where a species impact statement (SIS) has been received. No timeframes have been set for those applications which do not require a SIS. The Director-General will assess your application as soon as possible. You can assist this process by providing clear and concise information in your application.

Applicants may be charged a processing fee. The Director-General is required to advise prospective applicants of the maximum fee payable before the licence application is lodged. Therefore, prospective applicants should contact the Office of Environment and Heritage (OEH) prior to submitting a licence application.

A $30 licence application fee must accompany a licence application.

Protected fauna and protected native plants*

Licensing provisions for protected fauna and protected native plants are contained within the *National Parks and Wildlife Act 1974.* However, a Section 91 Licence may be extended to include protected fauna and protected native plants when these will be affected by the action.

If you are applying for a licence to cover both threatened and protected species please provide the information requested in Item 10 *as well as* a list of protected species and details of the number of individuals animals or proportion and type of plant material which are likely to be harmed or picked.

Request for additional information

The Director-General may, after receiving the application, request additional information necessary for the determination of the licence application.

Species impact statement

Where the application is not accompanied by a SIS, the Director-General may decide, following an initial assessment of your application, that the action proposed is likely to have a significant effect

* Protected fauna means fauna of a species not named in Schedule 11 of the *National Parks and Wildlife Act 1974.*
Protected native plant means a native plant of a species named in Schedule 13 of the *National Parks and Wildlife Service 1974.*

on threatened species, populations or ecological communities, or their habitats. In such cases, the *Threatened Species Conservation Act 1995* requires that the applicant submit a SIS. Following initial review of the application, the Director-General will advise the applicant of the need to prepare a SIS.

Director-General's requirements for a SIS

Prior to the preparation of a SIS, a request for Director-General's requirements must be forwarded to the relevant OEH Office. The SIS must be prepared in accordance with section 109 and 110 of the TSC Act and must comply with any requirements notified by the Director-General of OEH.

Disclosure of Personal Information in the Public Register of s91 Licences

The Public Register provides a list of licence applications and licences granted. A person about whom personal information is contained in a public register may request that the information is removed or not placed on the register as publicly available.

Copies of all applications and licences issued under section 91 and certificates issued under section 95 of the Act are available on the OEH website at
www.environment.nsw.gov.au/threatenedspecies/S91TscaRegisterByDate.htm
or in hardcopy form from The Librarian, OEH, 59 Goulburn St, Sydney.

Certificates

If the Director-General decides, following an assessment of your application, that the proposed action is not likely to significantly affect threatened species, populations or ecological communities, or their habitats, a Section 91 Licence is not required and the Director-General must, as soon as practicable after making the determination, issue the applicant with a certificate to that effect.

N.B: An action that is not required to be licensed under the Threatened Species Conservation Act 1995, may require licensing under the National Parks and Wildlife Act 1974, if it is likely to affect protected fauna or protected native plants.

I confirm that the information contained in this application is correct. I hereby apply for a licence under the provisions of Section 91 of the *Threatened Species Conservation Act 1995.*

Applicant's name *(Please print)*	**Andrew Walsh**
Applicant's Position & Organisation *(if relevant)* *(Please print)*	**Project Manager- Rodent Eradication** **Lord Howe Island Board**
Applicant's signature	A. Walsh
Date	**15 February 2017**

For more information or to lodge this form, contact the nearest branch of OEH's Conservation and Regulation Division:

Metropolitan Branch
P: 02 9995 6802
F: 02 9995 6900
PO Box 668
Parramatta
NSW 2124

North East Branch
P: 02 6640 2500
F: 02 6642 7743
PO Box 498
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NSW 2460

North East Branch
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NSW 2830

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P: 02 6122 3100
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PO Box 622 Queanbeyan
NSW 2620

Office of Environment and Heritage (NSW)
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Email: info@environment.nsw.gov.au

Lord Howe Island

Rodent Eradication Project

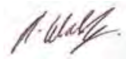
NSW Species Impact Statement

"This project is jointly funded through the Lord Howe Island Board, the Australian Government's National Landcare Programme and the New South Wales Government's Environmental Trust."

Quality Information

Document	Lord Howe Island Rodent Eradication Project Species Impact Statement
Date	15 February 2017

Revision History

Revision	Revision Date	Details	Authors	Authorised	
				Name/Position	**Signature**
00	15 February 2017	SIS submitted to OEH	See Section 9.1 for all contributing authors	Andrew Walsh Project Manager Rodent Eradication LHIB	

Requests for information or comments regarding this Report are best directed to:

Project Manager - Rodent Eradication

Lord Howe Island Board

Bowker Avenue

(PO Box 5)

Lord Howe Island NSW 2898

Phone: (02) 6563 2066

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This Plan should be cited as follows:

Lord Howe Island Board, (2017). Lord Howe Island Rodent Eradication Project – NSW Species Impact Statement, Lord Howe Island Board, Lord Howe Island.

February 2017

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Executive Summary

Introduction

The Lord Howe Island Board (LHIB) is proposing to undertake the Lord Howe Island Rodent Eradication Project (LHI REP) which aims to eradicate introduced rodents: the Ship Rat (*Rattus rattus*) and the House Mouse (*Mus musculus*) from the World Heritage listed Lord Howe Island Group (LHIG).

The sub-tropical LHIG, comprised of Lord Howe Island (LHI) and its associated islands and rocky islets, is located 780 kilometres north-east of Sydney and is part of the State of New South Wales. It supports a diverse flora and fauna with a high degree of endemic species and communities and numerous threatened and migratory species.

A settlement of approximately 350 inhabitants is located in the northern section of LHI and covers about 15% of the island. The rest of the island, all outlying islands, islets and rocks are protected under the Permanent Park Preserve (PPP), which has similar status to that of a national park.

Tourism is the most significant industry and major source of income on the Island and is heavily focused around the world heritage values of both the terrestrial and marine environments. Export of the Lord Howe Kentia Palm has also been a major industry since the late 1800s.

Since their arrival on LHI, introduced rats and mice have had and continue to have a significant impact on the World Heritage, biodiversity, community and economic values of the island. Mice probably arrived on LHI by the 1860s; rats arrived in 1918 with the grounding of the SS Makabo.

Project Need and Benefits

The devastating impacts of introduced rodents on offshore islands around the world are well documented. The presence of exotic rodents on islands is one of the greatest causes of species extinction in the world. Ship rats alone are responsible for the severe decline or extinction of at least 60 vertebrate species and currently endanger more than 70 species of seabird worldwide. They suppress plants and are associated with the declines or extinctions of flightless invertebrates, ground-dwelling reptiles, land birds and burrowing seabirds. Mice have also been shown to impact on plants, invertebrates and birds.

Predation by exotic rats on Australian offshore islands of less than 1000 km2 (100,000 ha) is listed as a Key Threatening Process under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). *Predation by the Ship rat on Lord Howe Island* is listed as a Key Threatening Process under the NSW *Threatened Species Conservation Act 1995* (TSC Act)

On LHI, rats are implicated in the extinction of five endemic bird species, at least 13 species of endemic invertebrates, and two plant species. Rodents are also a recognised threat to at least 13 other bird species, 2 reptiles, 51 plant species, 12 vegetation communities, and seven species of threatened invertebrates on LHI. Rodents have therefore not reached equilibrium with native species on LHI.

The LHIB currently maintain a rodent control program that aims to keep the negative effects of rodents under control, but its ongoing nature brings with it a constant financial burden and potential human health and environmental risks from ongoing presence of poison in the environment. Under the current control program, neither the rat or mouse population is being reduced to a level that reduces landscape scale ecological impacts.

Globally, eradication has become a powerful tool to prevent species extinctions and to restore damaged or degraded ecosystems. The biodiversity benefits of removing rodents from islands are well recognised and have been shown to be both significant and immediate. Benefits include:

- significant increases of seeds and seedlings of numerous plant species on islands after the eradication of various rodent species
- rapid increases in the number of ground lizards (e.g. geckos, skinks) following removal of rats – including a 30-fold increase in one case
- dramatic increases in the numbers of breeding seabirds and fledging success
- rapid increases in forest birds and invertebrates.

After completing a Feasibility Study in 2001, the LHIB has carefully considered and evaluated the eradication of rats and mice on the LHIG. Due to developments in eradication techniques during the past 20 years, particularly the refinement of aerial baiting methods, the eradication of both rats and mice on the LHIG in a single operation is now feasible and achievable. The eradication of rodents will also present an opportunity to simultaneously eradicate the introduced Masked Owl.

Eradication (rather than ongoing control) is expected to provide the following benefits:

- Removal of a key threat to many island species resulting in significant biodiversity improvement including threatened species recovery and reintroduction
- Removal of ongoing poison in the environment and associated control costs. It also removes the risk of rodent resistance to poisons
- Long term positive impacts for tourism through protection and enhancement of World Heritage values and improved visitor experience
- Increased productivity for the Kentia Palm industry
- Elimination of current health and amenity impacts from rodents.

The eradication of rodents is consistent with numerous local, state, commonwealth and international plans and obligations. Eradication of exotic rodents from high priority islands (including LHI) is the first objective in the Commonwealth *Threat Abatement Plan to Reduce the Impacts of Exotic Rodents on Biodiversity on Australian Offshore islands of Less than 100 000 Hectares*. The action is in accordance with the principles of ecologically sustainable development.

Failure to proceed with the REP will result in continuing adverse consequences to biodiversity, World Heritage and socio-economic values through:

- Ongoing impacts to biodiversity (including potential population decreases and extinctions) as a result of rodent predation and competition.
- Continuation of the current rodent control program (and the continuous presence of poison baits in the environment) essentially in perpetuity. This presents an ongoing risk of poisoning for non-target species and potential for development of rodent resistance to poison.
- Potential further degradation of World Heritage values (including endemic and threatened species) and the potential for the LHIG to be inscribed on the “World Heritage in Danger List”.
- Ongoing socio-economic impacts associated with rodents.

Project Description

The one-off eradication proposes to distribute a cereal-based bait pellet (Pestoff 20R) containing 0.02g/kg (20 parts per million) of the toxin, Brodifacoum across the LHIG (excluding Balls Pyramid). Methods of distribution will be dispersal from helicopters using an under-slung bait spreader bucket in the uninhabited parts of the island (most of the LHIG) and by a combination of hand broadcasting and the placement of bait in trays and bait stations in the settlement area. In the outdoor areas of the settlement baits will be dispersed by hand and/or placed into bait stations. In dwellings (e.g. in ceiling spaces or floor spaces) bait trays and bait stations will be used. Bait stations will also be used around pens for any remaining livestock.

The bait will be distributed at a nominal dose rate of 20 kg (12 kg + 8 kg) of bait (or 0.4 g of poison) per hectare. At this rate, a maximum of 42 tonnes of bait (containing 840 g of Brodifacoum) will be required to cover the total island group surface area of 2,100 ha. The proposal is for aerial and hand baiting to be carried out twice, the applications separated by about 14 -21 days (depending on the weather).

The baiting is planned to occur in winter (June - August) of 2018 but may extend into September if there are problems such as unfavourable weather conditions. June - August is preferred because this is the time of the year when the rodents are at their most vulnerable due to the relatively low abundance of natural food. Many of the seabird species are also absent from the island at this time of year. This is also the low season for tourists on LHI. The operation will take place in a single year, targeted for winter of 2018 (June to August) however, to allow operational flexibility and to account for unforeseen delays, approval is sought for at least a two year period, June 2018 to December 2019.

Post eradication, a rodent detection monitoring network including the use of detector dogs will be established to allow detection of any potentially surviving rodents. If the network does not detect any rodents within two years, the eradication will be declared a success.

To prevent reinvasion from rodents and to improve Biosecurity on the island more generally, the LHIB is updating the Island’s Biosecurity system concurrently with the proposed REP although upgrades will occur regardless of whether the REP goes ahead. Surveillance monitoring and rodent prevention measures will be on going post eradication as part of the island’s permanent rodent detection and prevention system.

As a result of the proposed rodent eradication, there is also an opportunity to concurrently eradicate the Masked Owl, which was introduced to LHI to controls rats in the 1920s and 1930s. Rodents currently make up the Masked Owl’s main prey base on the Island, and during the rodent eradication it is expected that most owls are likely to succumb to secondary Brodifacoum poisoning by ingestion of poisoned rodents. To avoid any remaining owls switching to a diet of solely native species in the absence of rodents, it is proposed to eradicate remaining owls via hunting or trapping before, during and after the baiting proposal.

A range of mitigation will be put in place to minimise impacts to the environment and the community. This includes captive management of at risk species (LH Woodhen and LH Pied Currawong), an extensive suite of environmental monitoring and monitoring for non-target species impact.

A Biodiversity Benefits monitoring program associated with the rodent eradication project has been established to assess and document the biodiversity benefits of removing rats and mice from the World Heritage Lord Howe Island. The program provides a measure of the return on investment. It also allows an evaluation of status of species prior to and following the eradication so any impacts of the eradication of rodents on key non-target species can be tracked during their recovery. Over time, results from the various monitoring components can be integrated to identify and explore changes to ecosystem processes

The REP is currently in the planning and approvals stage. The final decision by the LHIB to proceed with the eradication or not will be informed by the technical, social and financial feasibility. This will include the status of approvals, level of community support and recommendations from the Independent Human Health Risk Assessment.

Alternatives Considered

Systematic techniques for eradicating rodents from islands were first developed in New Zealand in the 1980s. Since then techniques have improved significantly, and eradications are now being attempted and achieved on increasingly larger and more complex islands, including those with human populations.

Aerial broadcasting of bait using helicopters has become the standard method used in eradications, particularly those on large islands with steep topography. This method has proven to be a more reliable and more cost-effective option than the previous ground based techniques. The majority of successful eradications on large islands have used aerial baiting with Brodifacoum in cereal pellets. Rat eradications on islands over the period 1997- 2014 using this bait and method have been 98% successful (37 of 39 attempts). The success rate for mouse eradications on NZ islands using aerially applied Pestoff 20R with 20ppm Brodifacoum (the bait to be used on Lord Howe) from 1997 - 2014 is 100% or 11 from 11 attempts.

A range of alternatives for eradicating rodents were considered for LHI including alternate techniques and mortality agents. Many were considered to have fatal flaws and were unsuitable for use for eradication on LHI either because the technique was not suited to the terrain or size of the island, they did not ensure that all individuals would be killed or they were too experimental. The method chosen proposes to distribute highly palatable bait pellets containing Brodifacoum using a combination of aerial and hand broadcasting together with bait stations and trays. This approach will maximise chances of success whilst minimising risks to non-target species and the community and was considered the only method capable of removing every rat and mouse on LHI. Whilst Brodifacoum is the preferred toxicant because it is has been well tested and proven successful in numerous rodent eradication projects throughout the world. The eradication techniques proposed for LHI are neither novel nor experimental. They are the culmination of more than 30 years of development and implementation involving more than 380 successful rodent eradications worldwide.

Threatened Species and Ecological Communities

A wide range of threatened species and ecological communities listed under the TSC Act either reside on LHI or are considered regular or irregular visitors to the LHIG.

Threatened species occurring or with the potential to occur in the project area include 30 birds, 7 invertebrates, 2 land reptiles, 10 plant species, 6 marine mammals and 3 marine reptiles. Two threatened ecological communities are recorded.

Many of these bird species and marine animals are considered irregular visitors or vagrants that are present in very low numbers or not present at all during the proposed eradication period. Many of the listed threatened seabirds have only been observed at sea in the waters of the LHIG.

Potential Impacts to Threatened Species and Ecological Communities

The potential impacts arising from the proposed REP were assessed. These included:

- Pollution of soil, air or water
- Bioaccumulation
- Mortality of non-target species due to primary poisoning from consumption of bait pellets
- Mortality of non-target species due to secondary poisoning from consumption of poisoned rodents, fish or invertebrates

- Bird strikes and collisions from helicopter activity
- Disturbance from helicopter activity
- Potential impacts as a result of handling and captive management during the captive management program
- Long term changes to ecological relationships affecting threatened species following the eradication of rats, mice and owls.

Potential impacts to Air, Soil or Water and Bioaccumulation

Based on evidence from similar eradications on other islands, the physical and chemical properties of the bait and toxin and the relatively small quantity used in a one-off eradication, the risk of pollution impacts to soil, air or water were considered to be very low. Similarly whilst bioaccumulation could occur, the risk of impacts was considered low. In the unlikely event that impacts occurred they would be highly localised and short term in nature

Potential Impacts to Threatened Bird Species

Risks to non-target bird species during an eradication programme are a function of the species present on the island group and their behaviour, susceptibility of those species present to the poison, composition and delivery method of the bait and the probability of exposure to the poison either directly or indirectly.

Land Birds

Many land bird species are not expected to consume pellets or sufficient numbers of invertebrates to be at risk from primary or secondary poisoning.

The REP poses a significant risk to the LH Pied Currawong (LHPC) from secondary poisoning and the LH Woodhen (LHW) from primary and secondary poisoning. To mitigate potential impacts to these species, large numbers: up to 80% of the LHW population and 50-60% of the LHPC population will be taken into captivity during the eradication period. Both species have previously been held in captivity before with no observable ill effects.

In the absence of mitigation, a significant impact to woodhens is likely to occur from the LHI REP. However with the mitigation proposed in place, it is considered unlikely that either long term population decrease or major disruption to a breeding cycle will occur. Impacts are likely to be temporary. It is therefore considered unlikely that the REP will have a significant impact on woodhens

In the absence of mitigation, a significant impact to LHPC is likely to occur from the LHI REP. With the proposed mitigation in place, it is considered possible that the REP will still have a significant impact on LHPC through the temporary disruption of a breeding cycle, although it is unlikely that a long-term population decrease will occur. Any potential impacts will be temporary.

Non-seabird migrants

The number of individuals of each of the regular migrant shorebird species on the LHIG is insignificant at a regional, state, national and international scale as the timing of baiting operations coincides with a period when the abundance of these species on the LHIG is lowest. Therefore, the proposed REP is highly unlikely to have a significant impact on these species.

Irregular or vagrant non-seabird migrants

Many of the listed non-seabird species occur as irregular migrants or vagrants on LHIG have been recorded on five or fewer occasions since ornithological records commenced in the early 1900s. The other species have recorded dates outside of the proposed bating operation. None of the species have been recorded breeding on the LHIG and the small number of individuals of each species that have been recorded indicate the LHIG population is not significant at a regional, state, national or international scale. A significant impact of the REP to these listed species is therefore assessed to be highly unlikely.

Seabirds

All listed seabird species are carnivorous and obtain all their prey at sea; they are not known to consume any food on land and as such they are highly unlikely to consume cereal bait pellets distributed on land or poisoned rodent carcasses.

As many of the threatened seabird species are either not present during the eradication period or not present in significant numbers they will not be exposed to either primary or secondary poisoning or helicopters. The risk to many species was considered negligible.

Only two seabird species occur regularly on or around the LHIG in winter when baiting operations will be undertaken: Masked Booby and Providence Petrel. Breeding colonies of both species will be baited using a helicopter; as such they are not at risk of disturbance from human presence within the colonies. Records of helicopter strikes or disturbance from aerial eradication operations are very rare. Nonetheless, mitigation measures will be in place to minimise disturbance and the risk of collision. Specifically, helicopter flight times over Masked Booby colonies will be restricted to periods when birds are less likely to be leaving or arriving at the colony (movements are greatest shortly after dawn and in the late afternoon) and helicopters will be restricted to flying at a height of >30 m above colonies. Providence petrels breed principally in the southern mountains, particularly the two mountain summits. From March to November annually they arrive at LHI from mid-afternoon onwards to display in the airspace above the breeding sites, find mates and visit burrows. Helicopter strike with Providence Petrels involved in courtship and incubation will be avoided by restricting helicopter flights around the southern mountains to before midday on each day of baiting. The majority of returns from foraging to provision chicks occur after early July (Marchant and Higgins 1990) avoiding any overlap with proposed helicopter movements. The risk of absorption of Brodifacoum via contact with the skin is extremely low for birds as almost all of their external body surface is covered by a thick layer of feathers (particularly seabirds) or cornified keratinocytic tissue, thereby virtually eliminating contact with the skin.

Potential Impacts to Threatened Marine Species

Potential impacts to TSC Act Listed threatened marine species are limited to accidental bait entry into the water (either through aerial distribution or a spill) leading to pollution of water, primary or secondary poisoning.

Pollution of marine water resulting in impacts to threatened marine species is considered extremely unlikely considering the minimal amount of bait likely to enter the water, the low solubility of Brodifacoum and the huge dilution factor.

There is no realistic pathway by which threatened marine mammals can be significantly exposed to rodenticide at the LHIG as a result of the proposed aerial baiting with Pestoff® 20R. The combination of Brodifacoum being practically insoluble in water, the infinitesimal amount of Brodifacoum that may land in the sea and the huge dilution factor preclude any significant effect upon marine mammals. Marine mammal species are also rare visitors to LHI waters, passing through on the annual migration and are therefore unlikely to encounter the bait.

Marine reptiles are also very unlikely to have significant exposure to bait directly or prey items that have ingested rodenticides.

Potential Impacts to Threatened Invertebrates

The only potential to impact on TSC Act listed terrestrial invertebrates is through direct consumption of bait (primary poisoning). From other studies around the world, most snail species studied have been shown to either not consume bait or have little mortality associated with bait consumption as they have different blood clotting systems to mammals and birds.

Negligible risk posed to *Placostylus bivaricosus* by the proposed eradication operation as the probability of a significant proportion of the Placostylus bivaricosus population consuming and dying from toxic baits in the wild is extremely unlikely. Three of the critically endangered land snails, minute to small leaf litter-dwellers with small activity ranges (*Mystivagor mastersi*, *Peudocharopa ledgbirdi*, *P. whiteleggei*) were considered at moderate risk of exposure to bait placed (i.e. some but not all individuals may get in contact with baits). Susceptibility to Brodifacoum was unknown. The fourth species *Gudeconcha sophiae magnifica*, a large ground-dwelling species with large activity ranges was considered to be at high risk of exposure to bait.

The one endangered snail (*Placostylus bivaricosus)* and four species of critically endangered land snails on LHI: Masters' charopid land snail, Mount Lidgbird charopid land snail, Whitelegge's land snail and *G. sophiae magnifica* are highly threatened by rat predation and it is likely that if rats are not removed these species will become extinct; some may already be extinct. The extreme rarity of these species precludes any testing of their susceptibility to Brodifacoum, or capturing the species to safeguard them in captivity. Whilst it is possible that some individuals of these species may be at risk of poisoning, this possibility must be weighed up against the threats associated with not removing rodents including almost certainty that predation by rats will result in the extinction of these species. Therefore a significant impact to these species is not expected from the REP when compared to not proceeding with the eradication.

The LHI earthworm and the wood feeding cockroach are not considered susceptible to poisoning but are however highly impacted by rodent predation.

Potential Impact to Threatened Reptiles

There are two native species of terrestrial reptiles on LHI, the LHI Skink *Oligosoma lichenigera* and the LHI Gecko *Christinus guentheri*, both listed a Vulnerable under the TSC Act. Both species occur on the offshore islets around LHI but were once widespread across the main island. Predation by introduced rodents is regarded as the major threat to these species. REP activities with the potential to impact on TSC listed terrestrial reptiles include distribution of the bait through primary poisoning (direct consumption) and secondary poisoning (consumption of poisoned invertebrates). Each species is considered to be at low risk of poisoning, and both are likely to substantially increase in abundance following the removal of rodents.

Potential Impacts to Threatened Terrestrial Plants

REP activities with the potential to impact on threatened plants are: works associated with building the captive management facility and bait distribution (through potential uptake of Brodifacoum by plants).

The captive management facility construction will occur through modification of existing greenhouses structures at the nursery site. If needed, previously cleared land at the nursery within the lowland settlement area will be used. No clearing of land is proposed.

Brodifacoum is not herbicidal, is highly insoluble and binds strongly to soil particles, therefore it is not likely to be transported through soils and taken up by the roots of plants into plant tissues. There is no identified chemical process that would allow Brodifacoum to impact on plants. No evidence of Brodifacoum uptake or impact to any plants species was identified in the available literature.

Therefore no impact is expected to listed plant species. Conversely removal of rodents is expected to significantly benefit individual species (such as the Little Mountain Palm and Phillip Island Wheat Grass) and many vegetation communities through reduced predation on seeds, seedlings and stems of palm-leaf fronds.

Potential Impacts to Threatened Ecological Communities

Potential impacts to threatened ecological communities are considered unlikely as there are not expected to be impacts to component flora or fauna species. In contrast the Mossy Cloud Forest community is threatened by rodents as rats eat the seeds and leaf stems of the two of the dominant species, the endemic palms *Hedyscepe canterburyana* and *Lepidorrhachis mooreana*, and also the seeds of other species.

Potential Long Term Ecological Changes

While it is difficult to predict the long term ecological changes that are expected to occur on LHI following successful rodent eradication, evidence from rodent eradication projects elsewhere has shown that a wide range of taxa benefit from the eradications of invasive mammals. Where rodent eradications have been reviewed, they have demonstrated benefits included population recoveries, re-colonisations and re-introductions, and increases to vegetation cover. It is expected that LHI populations of seabirds, land birds, invertebrates and vegetation would similarly benefit in the long-term from the eradication of rodents.

Whilst some negative impacts on native populations have also been reported following rodent eradications, most negative impacts are due to poisoning either from consumption of baits or through secondary poisoning following consumption of poisoned rodents. Such impacts are usually short term and populations recover once the baiting operations have ceased. Species at risk of being affected by bait consumption or secondary poisoning that occur in the LHIG include the Lord Howe Woodhen and the Lord Howe Pied Currawong. Risk to both species will be managed through captive management.

Potential Cumulative Impacts

Potential cumulative impacts from the REP were considered with:

- Other potential actions - the proposed wind turbines and ;
- Other key threatening processes on the island such as weeds, habitat clearing and degradation, other human related threats and anthropogenic climate change.

As the LHI currawong is the only species on which the REP will have a potential significant impact (temporary disruption to one breeding cycle) and the wind turbine is unlikely to have an impact on currawongs, no significant cumulative impacts are expected from the wind turbines and REP.

When potential impacts of the REP are considered with other threats, no significant cumulative impact is expected. This is due to the localised and short term nature of potential impacts from the REP and expected long term benefits to species and ecosystem recovery in the absence of rodents.

When considered as one action out of many related conservation and recovery actions currently being implemented or planned by the LHIB, the REP will add significant contribution to net positive cumulative impacts for species and biodiversity for the LHIG.

In contrast, not proceeding with the REP would allow continued impacts from predation and completion by rodent on a range of species, increasing cumulative impacts with other threats.

Proposed Mitigation

A range of mitigation measures are proposed to mitigate potential impacts of the REP.

Mitigation of risks has been considered through planning and development of the operation though choice of methodology, toxin and bait; through proposed timing of the operation; through the combination of bait delivery methods selected; and through the development of baseline monitoring programs and trial programs.

During the operation, mitigation will include captive management of at risks species; extensive environmental and non-target species monitoring and collection of carcasses where possible.

Post operational monitoring will track predicted species recovery (or potential impacts)

Conclusion

This Species Impact Statement provides a demonstrated need for the REP based on documented evidence of significant impacts of rodents both globally and on LHI. It presents evidence of ongoing impacts at the species and ecosystem level on LHI even in the presence of ongoing rodent control. It demonstrates support for the REP through a range of legislative instruments, recovery plans and the like and outlines the unacceptable consequences of failing to proceed. It also provides evidence of expected benefits.

Detailed consideration of alternatives assessed is provided together with justification of why continuing with the current control program is unacceptable. It provides evidence of why other methods were considered unsuitable for an eradication on LHI and why the toxin, bait and delivery methods were selected based on over 30 years of lessons and experience globally.

It outlines the project details and mitigation and considers in detail, potential risks to threatened species based on results from numerous similar eradications around the world.

It concludes that significant impacts are highly unlikely for most threatened species. Species considered most at risk are the LH Woodhen and the LH Pied Currawong (LHIPC). In the absence of mitigation, a significant impact to woodhens is likely to occur from the LHI REP. However with the mitigation proposed in place, it is considered unlikely that either long term population decrease or major disruption to a breeding cycle will occur. Impacts are likely to be temporary. It is therefore considered unlikely that the REP will have a significant impact on woodhens

In the absence of mitigation, a significant impact to LHPC is likely to occur from the LHI REP. With the proposed mitigation in place, it is considered possible that the REP will still have a significant impact on LHPC through the temporary disruption of a breeding cycle, although it is unlikely that a long-term population decrease will occur. Any potential impacts will be temporary.

The REP is essential and beneficial. Risks have been addressed through proposed mitigation to the point where they are considered to be very low. Any potential impacts are localised and short term and far exceeded by the benefits that will be provided by implementation of the REP. Potential impacts of the REP are also considerably less than the ongoing impact of failing to proceed.

Glossary, Definitions and Abbreviations

Abundance	A quantification of the population of the species or community
Activity	Has the same meaning as in the EP&A Act.
Affected Species	Subject species likely to be affected by the proposal.
Aerial Broadcast	Distribution of the pelletised bait by helicopter with an underslung bait spreader bucket.
Anticoagulant	Having the effect of inhibiting the coagulation of the blood
APVMA	Australian Pesticides and Veterinary Medicines Authority
Bait Station	A contained compartment housing for distributing rodenticide
Biosecurity	Procedures or measures designed to protect Lord Howe Island against harmful biological or biochemical substances
Brodifacoum	A second generation rodenticide and the active ingredient present in the proposed bait
Conservation Status	Regarded as the degree of representation of a species or community in formal conservation reserves
Control	To regulate, restrain, or hold in check
DA	Development Application Number
Development	Has the same meaning as in the EP&A Act.
Director General	The Director General of the Department of Premier and Cabinet, Office of Environment & Heritage (OEH).
DP	*Deposited Plan* which is the Plan number given to a subdivision that is registered by the Land Property Information.
EPA	Environment Protection Authority (formerly part of the OEH
EPBC Act	*Environment Protection and Biodiversity Conservation Act* 1999
ESD	Ecologically Sustainable Development
Eradication	The intentional total extermination of a species or population
Hand Broadcast	The scattering of Pestoff20R pellets by hand or machine rather than aerial distributing via helicopter
IUCN	International Union for Conservation of Nature
LGA	Local Government Area.
LHI	Lord Howe Island
LHIB	Lord Howe Island Board
LHIG	Lord Howe Island Group
Locality	The area within a 5 km radius of the study area.
NES	Matters of National Environmental Significance
OEH	NSW Office of Environment and Heritage
PER	Public Environment Report
Pestoff 20R	The proposed cereal based bait to be used during the proposed Rodent Eradication Project. Manufactured by Animal Control Products Ltd as either a 10mm or 5mm pellet containing the active Ingredient

	Brodifacoum at a concentration of 20 parts per million (20 milligrams per kilogram)
ppm	Parts per million
PPP	Permanent Park Preserve
Region	Same meaning as contained in the TSC Act.
Resistance	The ability not to be affected by something, especially adversely like rodenticides
REP	Rodent Eradication Project
Significant Species	Species not listed in the TSC Act but considered to be of regional or local significance.
Study Area	Subject site and any other additional areas which are likely to be affected by the proposal either directly or indirectly.
Subject Site	The area which is proposed for development/ activity.
Subject Species	Threatened and significant species, populations and ecological communities which are known or considered likely to occur in the study area.
Threatening Process	Same meaning as contained in the TSC Act; the definition is not limited to key threatening processes.
TSC	NSW Threatened Species Conservation Act 1995
World Heritage Area	An area recognised as being as of outstanding international importance and therefore deserving special protection.

1 Form of the Species Impact Statement

The Lord Howe Island Board (LHIB) is proposing to undertake the Lord Howe Island Rodent Eradication Project (LHI REP) which aims to eradicate introduced rodents: the Ship Rat (*Rattus rattus*) and the House Mouse (*Mus musculus*) from Lord Howe Island (LHI) and its associated islands and rocky islets (excluding Balls Pyramid), hereafter referred to as the Lord Howe Island Group (LHIG).

As part of the approvals for the project, a Species Impact Statement (SIS) is required under the NSW *Threatened Species Conservation Act 1995* (TSC Act). The form and content of the SIS has been determined though the Director General's Requirements (DGRs) issued for the project on 27 June 2016 (included as Appendix A). The DGRs set out the information required so that the Chief Executive of the Office of Environment and Heritage (OEH) can gauge the effect of the LHI REP on the environment. DGRs are prepared in accordance with Sections 109 and 110 of the TSC Act, which describe the form and content of a Species Impact Statement. Pursuant to Section 111(3) of this Act, the form and content of some Species Impact Statement requirements have been limited or modified.

The purpose of this Species Impact Statement (SIS) is to:

- identify and ameliorate possible harm to the listed *threatened* species of Lord Howe Island and its associated islands and islets resulting from the proposed eradication of introduced rodents from these islands using the anti-coagulant Brodifacoum in cereal baits that will be dispersed over the islands from the air, broadcasted by hand and deployed in bait stations and bait trays; and
- assist the Chief Executive of the OEH in the assessment of Section 91 Licence applications lodged under the TSC Act.

This SIS addresses the DGRs for the project. A checklist to ensure all matters are addressed is provided in Appendix B – DGRs Checklist. Names, qualifications and input of authors of this SIS are provided in 9.1.

1.1 Declaration

Section 109 (1) and (2) of the TSC Act states that:

*1.1 A species impact statement must be in writing (*Section 109 (1))*;*

1.2 A species impact statement must be signed by the principal author of the statement and by:

(a) the applicant for the licence, or

*(b) if the species impact statement is prepared for the purposes of the Environmental Planning and Assessment Act 1979, the applicant for development consent or the proponent of the activity proposed to be carried out (as the case requires) (*Section 109 (2))*.*

Accordingly, the following declarations are made:

I, Andrew Walsh, (being the principal author of this Species Impact Statement) declare that it is, to the best of my knowledge, true and correct.

Signature:

Date: 15 February 2017

I…Andrew Logan, (on behalf of the Lord Howe Island Board, and acting in the capacity of Chief Executive Officer of the Lord Howe Island Board), of Bowker Avenue Lord Howe Island, being the proponent of the proposed eradication of introduced rodents from the Lord Howe Island Group using the anti-coagulant Brodifacoum, have read and understood this Species Impact Statement. I understand the implications of the recommendations made in the statement and accept that they may be included as concurrence conditions for the proposal.

Signature:

Date: 15 February 2017

2 Contextual Information

Rodents are currently having significant impacts on World Heritage values including impacts to a range of TSC Act listed species. The eradication of rodents will also present an opportunity to simultaneously eradicate the introduced Masked Owl.

The one-off eradication proposes to distribute a cereal-based bait pellet (Pestoff 20R) containing 0.02g/kg (20 parts per million) of the toxin, Brodifacoum across the LHIG (excluding Balls Pyramid). Methods of distribution will be dispersal from helicopters using an under-slung bait spreader bucket in the uninhabited parts of the island (most of the LHIG) and by a combination of hand broadcasting and the placement of bait in trays and bait stations in the settlement area. In the outdoor areas of the settlement, baits will be dispersed by hand and/or placed into bait stations. In dwellings (e.g. in ceiling spaces or floor spaces) bait trays and bait stations will be used. Bait stations will also be used around pens for any remaining livestock (e.g. the remaining dairy herd, goat or horse containment areas).

Given the size and rugged terrain of the LHIG, the exclusive use of baits stations is not feasible for the eradication.

The operation is targeted for winter of 2018 (June to August) however to allow operational flexibility and to account for unforeseen delays, approval is sought for at least a two year period, June 2018 to December 2019.

2.1 Project Background

2.1.1 Proponent Details

Proponent	Lord Howe Island Board
ABN	33 280 968 043
Address	PO Box 5, Lord Howe Island, NSW 2898
Phone	02 65632066
Contact Details	Mr Andrew Walsh Project Manager – Rodent Eradication Project andrew.walsh@lhib.nsw.gov.au

The LHI REP has received significant funding ($9M) in 2012 for planning and implementation from the Federal Government's former Caring for Our Country Program (now National Landcare program) $4,500,000 and the NSW Environment Trust $4,542,442.

2.1.2 Project Objectives

The primary objectives of the proposed project are to:

- Eradicate (see box below) all ship rats and house mice from the LHIG to permanently remove the impacts of rodents on biodiversity, World Heritage and socio-economic values of the LHIG.
- Ensure safety of humans and the environment.
- Provide a secure environment for populations of threatened and endemic plants and animals currently present on the LHIG
- Minimise impacts to non-target species, livestock and pets.
- Eliminate the current ongoing rodent control program and therefore eliminate the need for ongoing use of rodent poison on LHI.

Control = to regulate, restrain or hold in check Eradicate = the intentional total extermination of a species or population

There are five principles to achieving eradication that must be met in every case, for all target species (Parkes, 1990, Bomford and O'Brian, 1995):

1. All individuals can be put at risk by the eradication technique(s);
2. They can be killed at a rate exceeding their rate of increase at all densities;
3. The probability of the pest re-establishing is manageable to near zero;
4. The project is be socially acceptable to the community involved;
5. Benefits of the project outweigh the costs.

Secondary objectives are to:

- Eradicate Masked Owls from the LHIG and permanently remove their impacts on the fauna of the island
- Establish a sustainable and robust biosecurity system to prevent the reinvasion of rodents and other biosecurity risks. Strengthened biosecurity measures for the Island will protect and enhance LHI's World Heritage status and continue to increase tourism interest for this unique pest free environment.

2.1.3 Project History

Lord Howe Islanders and the LHIB have been involved in the control of rodents (rats and mice) on LHI since about 1920, highlighting both the long recognised impacts of rodents and difficulty in achieving outcomes through ongoing control on the island. Methods included a bounty on rat tails, hunting with dogs, introduction of cats and owls and the use of various poisons including barium chloride, diphacinone, and warfarin. Further detail on previous control efforts is found in Section 2.8.2.

Internationally (particularly in New Zealand), eradication of rodents from islands started to gain momentum following the successful eradication of rats from Maria Island/Ruapuke Island in 1959 and the invasion by rats on Big South Cape Island in 1963 (Russell and Broome, 2016). Incremental work over many decades, starting with small islands and gradually increasing scale and building capacity led to the desire and ability to tackle larger, more complex islands (ibid). The breakthrough which allowed these advances was the development of slow acting second generation anticoagulants in the late 1970s. For the first time rodents could eat a lethal dose in a single or many small meals yet not feel the effects for several days. Poison shyness, which hampered earlier eradication attempts with toxicants, was eliminated. The first successes from deliberate attempts in the 1980s opened the minds of many to the conservation possibilities. The old adage 'success breeds success' held true for rodent eradications with a surge of projects in New Zealand in the 1990s (ibid).

This led to a chain of events, both locally on LHI and within state and federal Government in Australia that would lead to development of the idea of rodent eradication on LHI. These are summarised below.

In 2000, the NSW Scientific Committee, made a Final Determination to list *Predation by the Ship Rat* Rattus rattus *on Lord Howe Island* as a Key Threatening Process under the NSW *Threatened Species Conservation Act 1995* recognising the impact of rats to species and biodiversity on LHI. It recommended augmentation of the existing control program and to investigate long term impacts of ongoing control.

A proposal to eradicate rodents was submitted to the LHIB in 2001. The proposal called for LHIB support and funding to undertake a feasibility study and further support for the eradication, subject to findings of the feasibility study.

In 2001, the LHIB commissioned a feasibility study (Saunders and Brown, 2001) that looked at a long-term solution to the rodent problem on LHI, through a program of total eradication. The study concluded that rodents were having a significant impact on LHI particularly to biodiversity and the palm industry and that control of rodents was unsustainable. It also concluded that eradication on LHI was feasible using a combination of aerial broadcast, hand broadcast and bait stations using a Brodifacoum based product. The study identified additional further gaps that needed to be addressed and risks to be mitigated and recommended key next steps.

A Cost Benefit Analysis (Parkes *et al.* 2004) which looked at additional feasibility, risks and benefits of eradication on LHI again confirmed that eradication was feasible and highly beneficial, provided risks (non-target impacts, bait palatability and efficacy, and community support) could be appropriately managed and funding and approvals obtained.

In March 2006, the Commonwealth Minister for the Environment listed *Predation by exotic rats on Australian offshore islands of less than 1000 km^2 (100,000 ha)* as a Key Threatening Process under *the Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The listing advice (TSSC, 2006) provided examples of rodent impacts on LHI species in support of the listing. It also recommends that eradication of rodents, where feasible, was a preferred outcome to ongoing control.

In 2007 the *Lord Howe Island Biodiversity Management Plan* (BMP) (DECC, 2007) was developed as a key overarching document providing holistic management of key threats and protection of the island's biodiversity. It also constitutes the formal recovery plan for many threatened species. The eradication of rodents is one priority conservation management action listed in the BMP.

In 2007, a non-toxic bait uptake trial (DECC, 2007a) was undertaken on LHI that examined rodent and non-target species uptake of the bait pellets, bait breakdown in the environment and spread of the bait using helicopter. The study concluded that bait was highly palatable to both rats and mice and that sufficient bait would be available for both species to receive a lethal dose under eradication conditions. It found bait breakdown in the environment was approximately 100 days. It also found that four bird species (the LH woodhen, buff banded rail and two introduced species) consumed bait along with some invertebrates.

A further study in 2008 (DECC, 2008) examined bait sizes. Both small (5.5 mm) and large (10 mm) baits were shown to be palatable to rats and mice. Consequently, either baits would be appropriate for use in an eradication operation on LHI, however large baits are recommended for aerial operations, and small baits for hand broadcasting where it is critical to increase bait encounter rates for mice.

The early studies on LHI and growing government recognition of wide spread rodent impacts, led to development of a Draft LHI Rodent Eradication Plan in 2009. The Draft Plan was externally peer reviewed by the Island Eradication Advisory Group (IEAG) of the New Zealand Department of Conservation; the Invasive Species Specialist Group of the Species Survival Commission of the World Conservation Union; the Worldwide Fund for Nature (WWF), Australia; Birds Australia; Landcare Research, New Zealand; CSIRO and Professor Tim Flannery. Public comment on the Draft Lord Howe Island Rodent Eradication Plan was sought in November 2009 and 83 submissions were received.

A Human Health Risk Assessment was undertaken in 2010 (Toxikos, 2010). The study found the risks to human health from the eradication are negligible with the proposed mitigation in place.

The LHIB received significant funding to implement the REP from the New South Wales Government's Environment Trust and the Australia Government's Caring for Our Country Program in 2012.

A range of additional studies and consultation have been undertaken since then that provide the basis for the current rodent eradication proposal and this PER. These include:

- Baseline biodiversity benefits monitoring (see Section 2.2.1.7)
- Additional studies on key species such as Currawong (Carlile and Priddel, 2006), LHI *Placostylus (*Wilkinson and Hutton, 2013)*,* Masked Owl (Milledge, 2010 and Hogan *et al.* 2013) and Land Snails (Kohler *et al.* 2016)
- Captive management trials in 2013 (Taronga Conservation Society Australia, 2014) that showed woodhen and currawongs could be successfully held in captivity for extended periods of time (see section 2.2.1.2
- Rat and mice bait toxicity trials in 2013 (Wheeler and Carlile, 2013) and 2016 (O'Dwyer *et al.* 2016) that showed rats and mice on LHI would be able to receive a lethal dose of poison on eradication conditions (see section 2.11.2.1).

2.1.4 Related Actions

LHI has a demonstrated history of positive environmental management and conservation actions to protect the unique values of the island. The proposed REP is essentially an extension of an integrated and much broader conservation and ecological restoration program on the LHIG. Historic related conservation actions included:

- Control of rodents from as early as the 1920s. Methods tried included a bounty on rat tails, hunting with dogs, introduction of cats and owls and the use of various poisons including barium chloride, diphacinone, and warfarin
- Eradication of feral pigs in the early 1980s
- Eradication of feral cats in the 1980s as part of the Lord Howe Woodhen recovery program
- Eradication of feral goats in 2002 (a small number of non-reproductive animals remain as pets)
- Culling of introduced masked owls.

Current environmental management and conservation programs underway include:

- The Lord Howe Woodhen recovery program implemented since the 1980s
- The Lord Howe Island *Placostylus* recovery program
- The Lord Howe Phasmid recovery program
- African Big Headed Ant eradication
- Eradication of over 60 priority weeds from the LHIG including Weeds of National Significance such as Ground Asparagus, Bridal Creeper, African Boxthorn, Tiger Lilly, Bitou Bush, Ochna and Cherry Guava

- Ongoing rodent control program using coumatetralyl
- Strict biosecurity policies and protocols to prevent incursion and establishment from a range of biosecurity risk species.

The *Lord Howe Island Biodiversity Management Plan* (BMP) (DECC, 2007) is the key overarching document related to management of key threats and protection of the island's biodiversity and it constitutes the formal recovery plan for many species. It is a holistic management document, encompassing many of the programs listed above to protect the islands biodiversity with particular focus on rare and significant species. The eradication of rodents is therefore one of many related conservation actions and is listed as a priority action in the BMP.

More directly related to the proposed REP is the *Pilot Study for captive management of LHI Woodhen and LHI Currawong* which was referred to the Commonwealth Department of the Environment under the EPBC Act in 2013). This action was declared "not a Controlled Action" in June 2013. The pilot study showed that woodhens and currawongs could be held in captivity in large numbers for prolonged periods with no observable impact (Taronga Conservation Society Australia, 2014). All 20 woodhens and 10 currawongs that were in the trial were successfully released at their individual capture sites after the trial and monitored.

2.1.5 Project Status

The Project is broken into logical phases as shown in Figure 1 below. The Project is currently in Phase 2. Further detail on each phase is provided in Table 1.

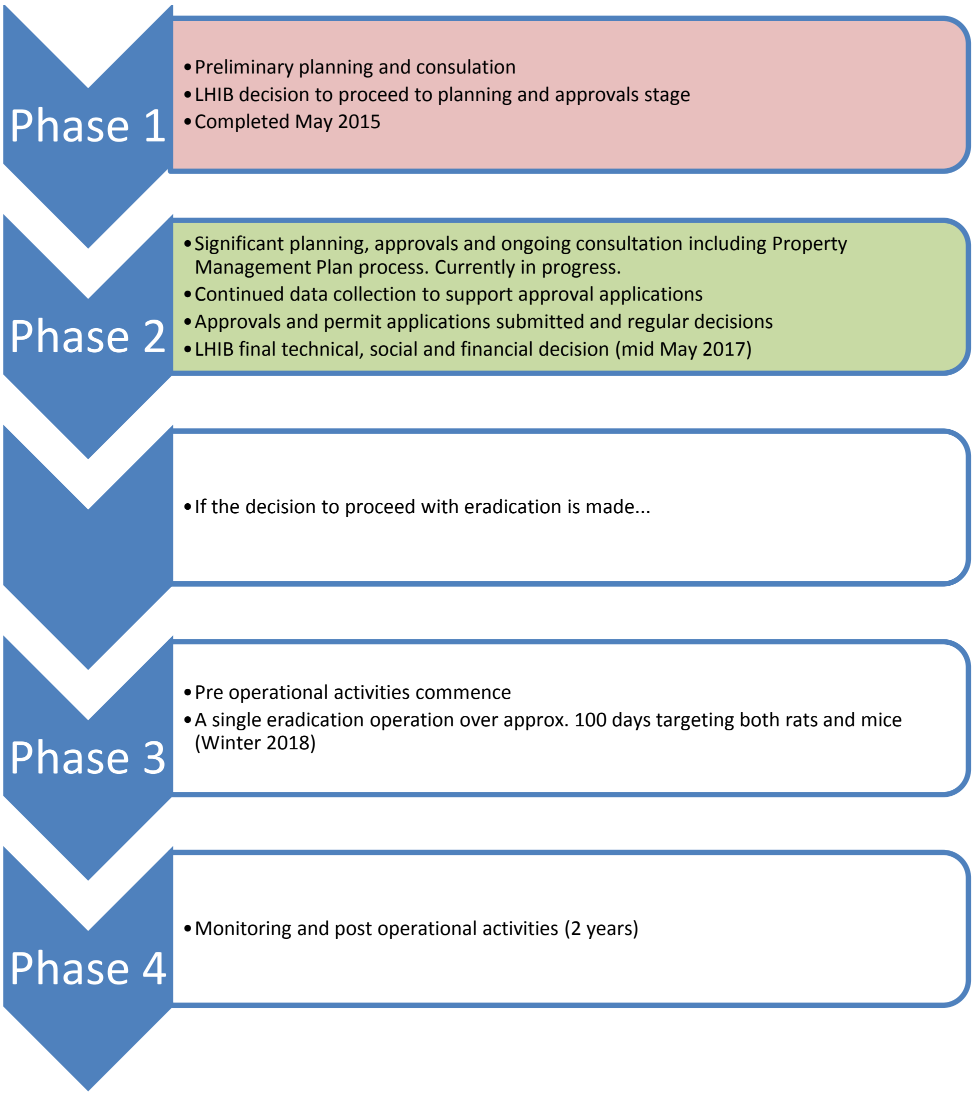


Figure 1 Project Phases Summary

Table 1 Project Phases

Project Phase	Keys Tasks	Proposed Timing
Phase 1 - Preliminary Planning and consultation	Feasibility studies in 2001 and further cost benefit and risk assessment in 2004	Complete
	2006 - 2008 non-toxic trials including non-target uptake and initial community consultation	
	2009 Draft Eradication Plan drafted and presented to community	
	Ongoing and divided community response	
	Project funded in 2012 ($9M over four years)	
	Steering Committee set up consisting of funders (State and Federal) LHIB and technical advisor	
	Community liaison group formed in 2013 to attempt to resolve issues	
	2014 LHIB decision to put project on hold to further consult with community. Process for resolution developed (see below)	
	May 2015 community referendum on expanded control vs. eradicate. Result was 48% (98 respondents) chose expanded control and 52% (106 respondents) chose to proceed with eradication.	
	LHIB decision to proceed to Planning and Approvals Stage	
Phase 2 - Planning and Approvals	Ongoing community extension process and Community Working group (CWG) consultation	Nov 2015- May 2017
	Development of Property Management Plans Livestock Valuations and Tenders	Nov 2015- May 2017
	Prepare and submit approval submissions to various regulatory bodies including APVMA, EPBC CASA, and NSW EPA.	Jan 2016- May 2017
	Human Health Assessment Review	Apr 2016 – Feb 2017
	Mice resistance toxicity trials to be undertaken to define lethal dose rates and efficacy	Mar – Apr 2016
	Recruitment and Training procedures	Sep 2016
	Contractor and Supplier Early Engagement and Tendering EOI	Dec 2016 - May 2017
	Final technical, Social and Financial Feasibility assessments to be undertaken	Feb 2017- May 2017
	Proceed to Final Go / No Go Decision by the LHIB (see below)	May 2017
Phase 3 – Implementation	Finalise PMPs and ongoing community consultation	May 2017- Jun 2018
	Aviary construction for captive management species	June 2017- Oct 2017
	Finalise supply contracts order baits, shipping, customs checks and quarantine checks.	May 2017 -June 2018
	Helicopter logistics, fuel delivery storage facility	Feb-June 2018
	Completion of livestock removal and poultry	May 2017- June 2018
	Recruitment undertaken. Advertising selection relocation training and preparation	Feb-May 2018
	Capture of woodhens an currawong	May – Jun 2018

	Undertake baiting campaign Bait Drop 1 Aerial, hand broadcasting and bait stations, community notification ongoing consultation, Meteorology information, Bait station placement and monitoring. Undertake dead rodent's collection through settlement areas. Bait Drop 2 Bait station monitoring and hand broadcasting. Collection of dead rodents continuing. Monitor bait breakdown. Ongoing community consultation and media updates Bait Break down monitoring Release of currawongs and woodhens	Jun 2018 Jul 2018 Jun – Nov 2018 Aug – Nov 2018
Phase 4 – Monitoring and Evaluation	Continuing monitoring for rodent presence including detector dog arrival and implementation. Continuing community information updates. Biodiversity Benefits monitoring	Sep 2017- Oct 2019

The final decision by the LHIB to proceed with the eradication or not (end of Phase 2) will be informed by the technical, social and financial feasibility. This will include the status of approvals, level of community support and recommendations from the Independent Human Health Risk Assessment as per the agreed process for resolution that was an outcome of ongoing community consultation in 2015.

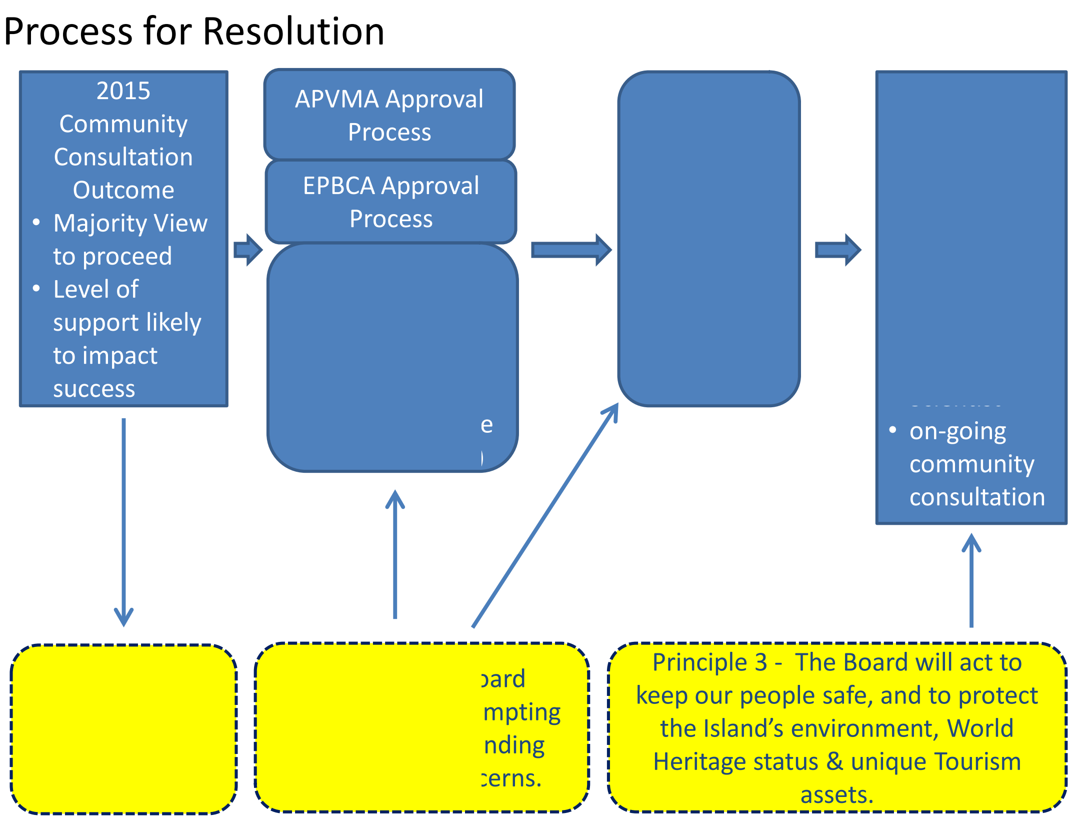


Figure 2 Process for Resolution

2.2 Description of Proposal, Subject Site and Study Area

2.2.1 Description of Proposal

The following operational elements of the proposed REP are described below.

- Removal of livestock
- Captive management of at risk species
- Bait application methods, product storage and disposal and spill response
- Environmental monitoring
- Masked owl eradication
- Rodent detection monitoring
- Improved Biosecurity
- Ongoing biodiversity benefits monitoring

2.2.1.1 Removal of Livestock

Having livestock present during the eradication poses a substantial risk to the success of the operation. Consequently, the proposal is to as far as possible de-stock the island prior to the eradication. Stock feed provides an ideal harbour and food source for rodents. If rodents have access to this feed or any spillage they may not take baits. There is also a risk that livestock may consume baits reducing coverage of bait and availability to rodents.

De-stocking of beef cattle in the 12 months prior to the eradication will be done largely through orderly culling and butchering. Cost of replacement stock and associated costs of returning stock to the island will be met by the LHIB through agreement with livestock owners. Replacement breeding stock will then be brought to the island when the breakdown of bait in paddocks is complete. Most stock-owners on the island have indicated their willingness to cooperate in this process, subject to satisfactory compensatory arrangements being put in place. Breeding stock will be gradually replaced, beginning 100 days after the eradication.

With the proposed mitigation measures in place there is little likelihood of Brodifacoum entering the human food chain via milk from the dairy herd. As such, it will be safe for the dairy herd (approximately 14 animals) to remain on the island throughout the operation, if requested by the owners. Animals will be confined to a small paddock and will receive supplementary feed during the period that bait is present (approximately 100 days). Baiting within the holding paddock will use cattle-proof bait stations

Similar arrangements will be made for remaining goats (approximately three) and horses (approximately three) confined during the risk period. All confined livestock will be fed with fresh-cut grass from unused paddocks, alleviating the need to store food which may provide an alternative food source for rodents. If required, grass will be raked before being cut to remove any bait pellets.

Poultry will be exposed to the risk of primary poisoning from baits spread around the settlement area. More significantly, the presence of poultry poses a major risk to the success of the operation as the presence of large amounts of feed grain has the potential to distract rodents from consuming the bait. As many chickens as possible will be removed from the island or culled at least one month prior to the eradication. Once all bait has disintegrated and no longer poses a threat, disease-free day-old chicks will be brought to the island to replace those birds removed. Residents will be compensated for lost poultry and egg production resulting from the eradication programme.

2.2.1.2 Captive Management

The LHI Woodhen (*Hypotaenidia sylvestris*) and LHI Currawong (*Strepera graculina crissalis*), both of which are listed as Vulnerable under the EPBC Act, are at risk of being poisoned, the former from eating baits and poisoned rodents, the latter from preying on poisoned rodents during the rodent eradication.

In order to protect these two bird species, it is proposed that concurrently with the rodent baiting, a large proportion of the population of the woodhens and currawongs will be taken into captivity on LHI.

The period of captivity will start from approximately two months before baiting commences until baits and rodent carcasses have broken down (or for a total period of up to nine months). The time that baits are available is estimated to be 100 days although the rate of bait breakdown will be monitored to ensure birds are not released at a time which may put them at risk. Up to approximately 85% of the island’s woodhen population will be taken into captivity. For the currawong, the proportion will be about 50-60%. This will also ensure genetic diversity is maintained.

Significant experience has been gained in managing woodhen populations in captivity on LHI. During a recovery program for the species (1981-1983), protocols for capturing and housing woodhens were established (Gillespie, 1993). The highly successful captive breeding and release program resulted in the release of 82 birds bred from just three breeding pairs originally captured (NPWS, 2002). Prior to the commencement of the program it was estimated that only 37 individuals remained in the wild.

In preparation for the LHI REP, a captive management pilot study that was conducted in 2013 for woodhen and currawongs on LHI (Taronga Conservation Society Australia, 2014) has also added significant knowledge on the captive management of the two species. The pilot study showed that woodhens and currawongs could be held in large groups for prolonged periods with no observable impact. All 20 woodhens and 10 currawongs were successfully released at their individual capture sites. The trial report is included inAppendix C – Captive Management Package.

	
Figure 3 Woodhens in 2013 Captive Trial	**Figure 4 Currawongs in 2013 Captive Trial**
	
Figure 5 Woodhen Aviary in 2013 Captive Trial	**Figure 6 Currawong aviaries in 2013 Captive Trial**

Bird capture

Only experienced staff will be involved in the capture of both species. These include rangers on LHI who are involved in the capture of woodhen for banding as part of the annual monitoring of the population and Office of Environment and Heritage (OEH) scientific officers (with assistance from the LHIB rangers) that have been catching and banding currawongs since 2005 to determine their population status and movements. Hand-nets will be used to capture woodhen, and clap-traps will be used for currawongs. Upon capture, birds will be placed into cloth bags or ventilated cardboard boxes (one bird per bag or box) and taken to the holding facility where they will be checked by a veterinarian. A veterinarian with bird experience will be on site during all capture and release operations. A scientific licence issued by the NSW OEH under Section 132C of the National Parks and Wildlife Act 1974 is required to capture woodhen and currawongs on Lord Howe Island. LHIB staff have the relevant licence for capturing LHI Woodhen and OEH staff involved in the project have the same licence for the capture of LHPC.

Birds will be collected from across the island including Mt Gower which will be accessed by helicopter to minimise stress to the birds. The Woodhen Survey Manual (Harden, 1999) provides details around how to capture woodhens.

Captive Housing Design and Location

The design plans for the holding pens used for each species during the 2013 trial were prepared by an experienced team of aviculturists from Taronga Zoo considering knowledge gained from previous facilities built to house these birds (both at Taronga Zoo and on LHI) as well as advice from New Zealand where the Weka, a species similar to the woodhen, had been kept in captivity during rodent-eradication operations undertaken in that country. These, together with recommendations from the pilot study will be used to inform the detailed design of the larger facility needed during the REP. Woodhens will be held in enclosed paddocks 14 m by 14 m (see Figure 7), holding approximately 20 birds each. For the currawongs, aviaries 1.5m wide x 3m high x 6m long aviaries, will be constructed, holding 2 birds per aviary (see Figure 8). Indicative plans from the 2013 pilot study are shown below.

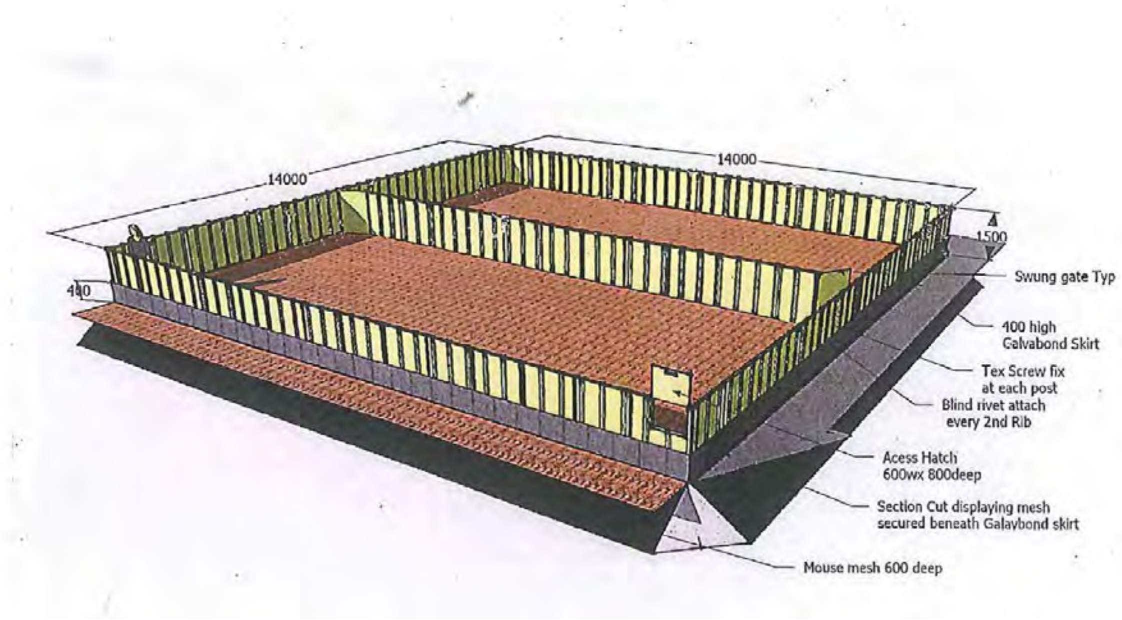


Figure 7 Indicative Woodhen Aviary

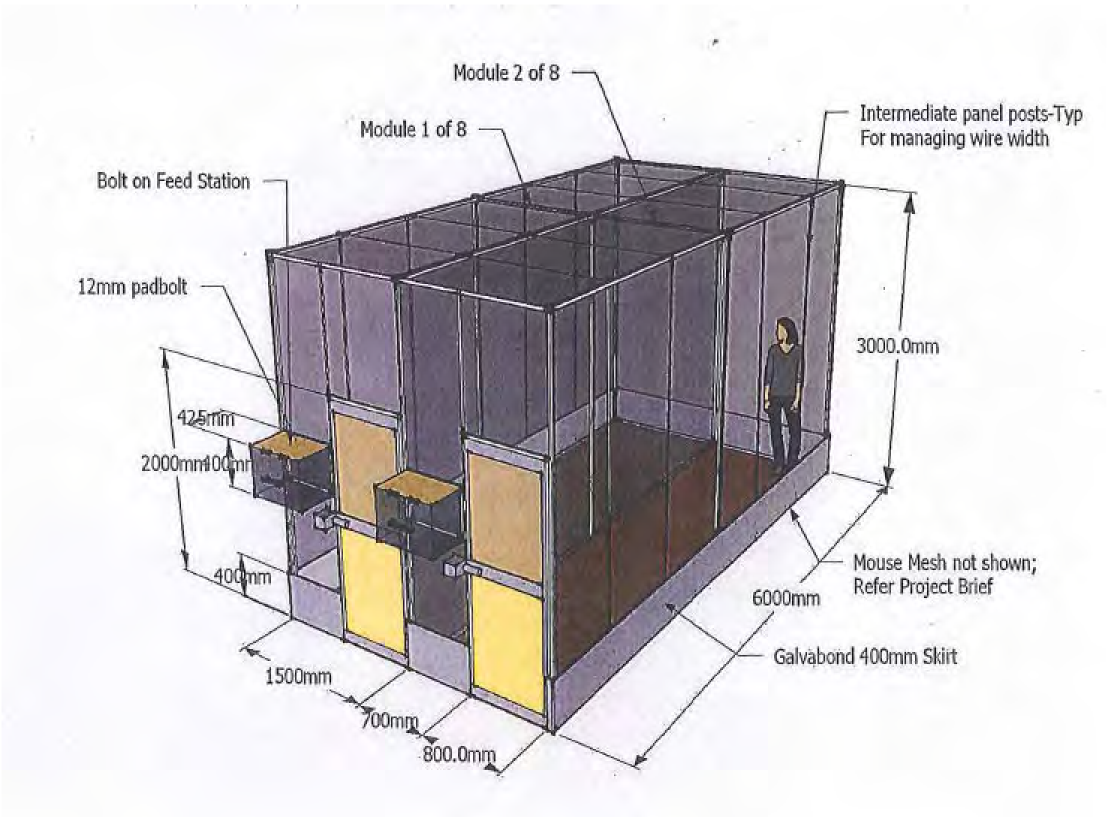


Figure 8 Indicative Currawong Aviary

The required number of aviaries will be accommodated for by reuse of the 2013 aviaries that are still in place at the Nursery site and through modifying existing greenhouses at the Nursery site used in 2013. The existing footprint of the 2013 aviaries and greenhouses should prove sufficient space (see Figure 9). In the unlikely event that additional space is required, expansion may occur on previously cleared and grassed land at the nursery site. No additional vegetation clearing would occur.

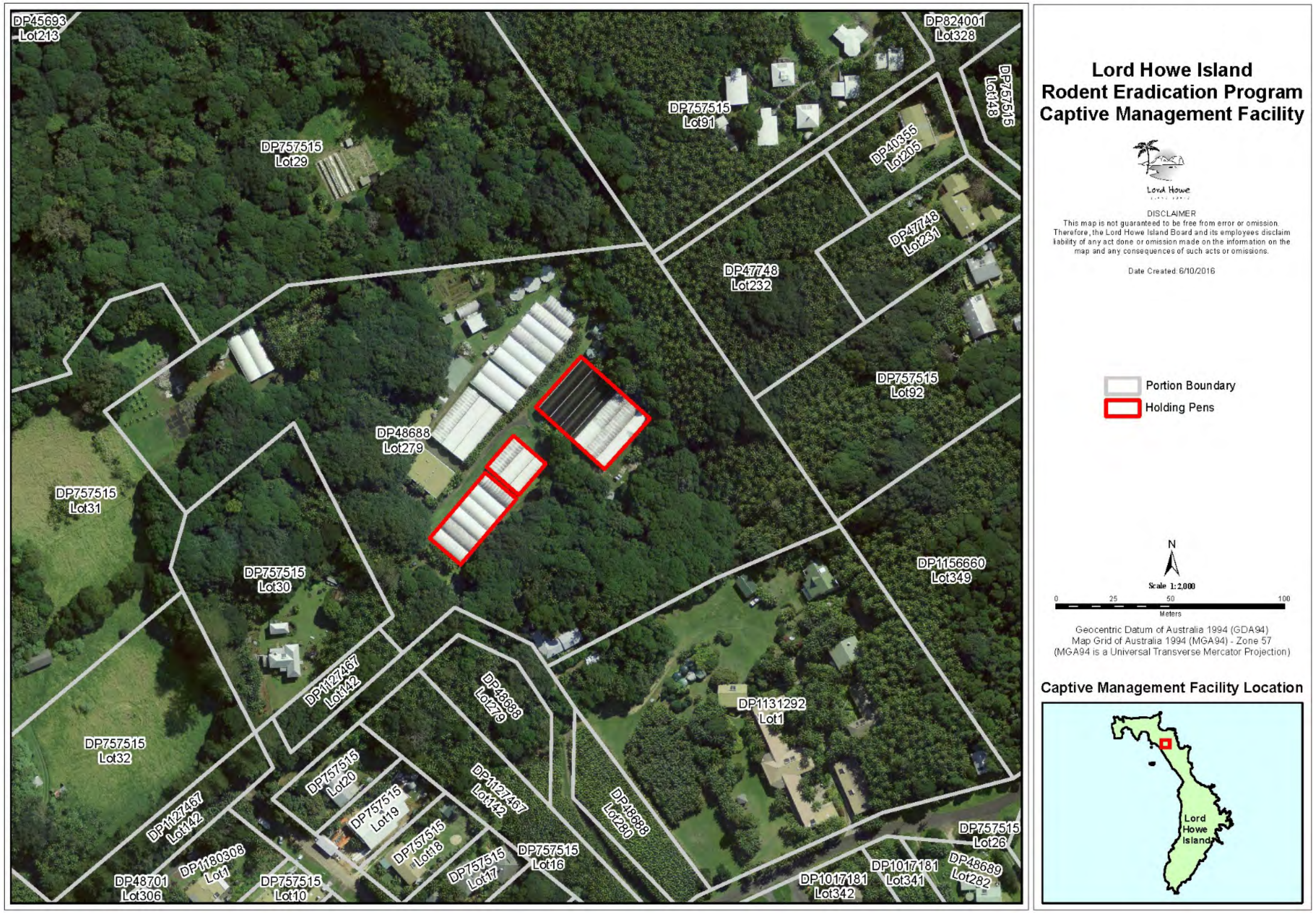


Figure 9 Captive Management Facility Location

Guiding principles used in designing and determining the location of aviaries have included

- Locating the aviaries away from areas frequented by people;
- Providing adequate shade and protection from inclement weather and avian predators;
- Ensuring the birds feel secure by the provision, if need be, of screens between pens containing antagonistic con-specifics;
- Providing cover within pens in which the birds can shelter;
- Ensuring the pens can be effectively cleaned;
- Ensuring drainage is adequate;
- Ensuring internal structures are without sharp surfaces and pointed edges;
- Ensuring that rodents cannot gain access to the aviaries.

A Construction Management Plan for construction of the aviaries was developed in 2013 and will be updated to consider the expansion required for the REP. The 2013 Construction Management Plan is attached as part of Appendix C – Captive Management Package.

Captive Husbandry and Disease Management

At the commencement of the captive period each bird will be examined by a veterinarian from Taronga Zoo who is experienced in avian medicine. The initial health status of individual birds will be determined by detailed physical examination. Measurements such as body weight, an assessment of endoparasitic burden, and faecal examination for intestinal parasites will be taken. While in captivity on LHI, the birds will be under the care and authority of Taronga Zoo. A team of aviculturists will be employed to manage the holding facility for the period that the birds are held.

During the captive period the birds' behaviour and food intake will be monitored daily by experienced keepers and body weight will be monitored regularly. Parasite loads will be monitored by faecal examination.

At the end of the captive period each bird will undergo another physical examination by a veterinarian to ensure that it is fit for release.

Previous health assessments conducted on the Lord Howe Woodhen and other avian species on the island have not identified infectious diseases causing illness (Curran, 2007). During the 2013 husbandry trial, 20 Woodhen and 10 Currawong underwent detailed physical examination to assess their health on arrival into care and on release. Birds were continuously monitored for signs of disease and for endoparasite loads. Low levels of coccidia were identified in the Woodhen. This parasite has potential to cause disease in other ground dwelling birds, if allowed to build to high levels, but was successfully controlled at very low levels through precautionary treatment. No signs of disease were noted in any Woodhen during the trial. Intermittent upper respiratory noise was heard in two Currawong. No disease cause was identified and all the birds were considered healthy at the time of release. No intestinal parasites of concern were identified in the currawong

The most likely disease or injury scenarios that may arise in the captive trial period include trauma due to con-specific aggression, parasitism especially coccidiosis, and outbreak of stress induced disease due to opportunistic environmental organisms such as salmonellosis and aspergillosis.

Facilities will be available for isolation of sick birds. Basic veterinary diagnostic investigation of any ill birds will be undertaken on the island while samples for more detailed diagnostic testing including histopathology and more complex haematology and serum biochemistry will be sent to Taronga Zoo for processing

The capture or housing of birds can result in the injury or death to individuals. Measures taken to reduce the likelihood of injury or death to birds in the program are:

- Experienced staff will be involved in the capture of both species
- A bird-specialist veterinarian will be on site during capture and release operations
- Experienced aviculturists from Taronga Zoo have designed the holding facilities to be sited on LHI
- Experienced aviculturists from Taronga Zoo will manage and care for birds through their period in temporary captivity
- Advice on captive management has been sought from, and will continue to be refined with, specialist aviculturists. Central to this process has been the examination of the successful captive-breeding programme for woodhen undertaken on LHI in the 1980s, the 2013 pilot study, as well as captive trials undertaken in New Zealand with Weka (a species similar to the Woodhen)
- Exclusion of rodents from the facility

- If the holding facilities are found to be inadequate after birds have been taken, attempts will be made to rectify any problems. As a last resort, should the welfare of the birds be at serious risk, the birds can be released back into the wild until deficiencies in the procedure are rectified.

Notwithstanding these precautions, a very small number of birds are likely to die in captivity due to natural mortality (e.g., due to old age) because birds captured for the trial will reflect the age structure and general health of birds on LHI.

Mainland Populations

In discussions with Taronga Zoo (and other zoos), the REP Steering Committee, LHIB Manager Environment /World Heritage and the OEH Science Manager, the risks and benefits of mainland insurance populations for woodhens and currawongs as part of the REP have been extensively considered.

In addition to captive management on LHI during the REP, options considered for insurance populations, addressing the risks for both species included:

- temporary mainland populations for the relevant holding periods of the two species during implementation of the REP
- permanent mainland populations starting during implementation of the REP
- maintaining all birds on Lord Howe Island for the relevant holding periods of the two species, during implementation of the REP with appropriate contingency measures to address potential risks such as disease, fire and natural weather events.

Off island captive management of Currawongs was considered unnecessary given it is considered very unlikely that all free ranging currawong would succumb to secondary poisoning (see section 5.2.3).

Options considered for wooden are summarized below in Table 2. Risk assessment of the events requiring mitigation for an on island only captive population is provided in Table 3.

Following an assessment of the risks, proposed mitigation strategies and emergency procedures and anticipated likelihood of these events occurring, the REP Steering Committee agreed that the option to maintain on island populations only was the preferred approach.

Whilst an off island population provides better risk management, we feel the risks posed by having only an island captive population of both species can be sufficiently managed and are acceptable through development of comprehensive captive management plans including a contingency plan to remove a portion of the on island population to safety on island (or even to the mainland) at very short notice if required.

Table 2 Woodhen Insurance Population Options Summary

	Benefits	**Constraints**	**Recommendation**
Permanent Mainland Population (Breeding)	Provides short term (REP) and long term insurance population for conservation of the species	Requires significant investment, planning, infrastructure, establishment of partnerships, consultation on display and potential exhibits, ownership, husbandry training, development of long term management plans and breeding programs Will permanently remove approximately 10-15% of the population from the wild and requires ongoing supply of woodhen from LHI to maintain genetic robustness of captive population	Whilst this option is considered the best option for long term conservation of the species, it is considered well beyond the scope and resources of the REP. The LHIB to continue to pursue this option separate to the REP.
Temporary Mainland Populations	Provides short term insurance population for the REP Birds can be returned to LHI on completion of the REP (provided disease risks are manageable)	Does not provide long term insurance population for conservation of the species Still requires substantial investment, planning, infrastructure, establishment husbandry training	Requires significant increase in planning and investment than an on island only option without similar increase in mitigation of risks
On Island Population (with contingency plan)	Provides acceptable mitigation of identified risks during the REP Birds can be released to wild on completion of the REP Investment and planning more commensurate with REP project size and scale	Does not provide long term insurance population for conservation of the species Provides a lower level of protection than the other options	Recommended as preferred option for the REP

Table 3 Risk Assessment of On Island Only Woodhen Population Option

Event	Event Comments	Consequence	Likelihood	Unmitigated Risk	Proposed Mitigation	Mitigated Likelihood	Residual Risk
Disease	No known disease in the LHI woodhen from previous testing	All these events could potentially result in loss of entire captive management population on LHI in a worst case scenario leading to possible extinction of a species and are therefore considered as Major consequence	Unlikely	Medium	Disease management procedures Trained staff form Taronga Zoo	Rare	Medium
Fire	Only 3 bushfire events in 20 years Bushfires considered unlikely in LHIB EMP Settlement area considered medium fire risk but rainforest with low vulnerability and low fuel load surrounding the facility Winter highest rainfall period		Possible	High	LHIB emergency procedures Rural Fire Service situated within 2 minutes of aviaries Fire fighting equipment on site Safe house contingency	Unlikely	Medium
Cyclone	No known cyclone events on LHI during winter period. Unlikely during winter.		Unlikely	Medium	Weather monitoring LHIB emergency procedures Safe house contingency	Rare	Medium
Severe Storm	Winter is highest wind period.		Likely	High	Maintenance pruning around facility Weather monitoring LHIB emergency procedures Safe house contingency	Unlikely	Medium
Tsunami	Unknown for LHI given surrounding deep water. Considered unlikely. Captive management facility is >10m above sea level and is considered safe		Unlikely	Medium	Weather monitoring LHIB emergency procedures Safe house contingency	Rare	Medium

Risk Assessment Matrix					
Likelihood Rating	Consequence Rating				
	Severe	Major	Moderate	Minor	Negligible
Almost Certain	Very High	Very High	High	Medium	Low
Likely	Very High	High	Medium	Medium	Low
Possible	High	High	Medium	Medium	Low
Unlikely	High	Medium	Medium	Low	Low
Rare	High	Medium	Low	Low	Low

2.2.1.3 Bait Application

The method chosen for the LHI REP is to eradicate rats and mice by distribution of the toxin Brodifacoum at a concentration of 20 ppm in the cereal based product Pestoff 20R. Justification for this methodology, toxin and bait is provided in Section 2.9.

Baiting Protocol

The bait will be distributed at a nominal dose rate of 20 kg (12kg first application + 8kg second application of bait (or 0.4 g of poison) per hectare on average over the island. At this rate, a maximum of 42 tonnes of bait (containing 840 g of Brodifacoum) will be required to cover the total island group surface area of 2,100 ha. Bait will be distributed by a combination of aerial and hand broadcast and through the use of bait stations/trays.

Area to be baited

Rats and mice occur throughout LHI, including the settlement. LHI is the only island in the LHIG that is known to contain rodents. However, ship rats are able to swim over 500 m and both rats and mice are difficult to detect at low densities. It is therefore possible that either species may occur on offshore islands and islets close to the main island or may invade those islands prior to the implementation of the operation. To minimise the risks of operational failure, the main island and all nearby islands and islets, other than Balls Pyramid and its associated islets, will be baited. The 23 km distance between Balls Pyramid and the main island renders the chances of invasion by rodents very low.

Number of bait drops

The proposal is for aerial and hand baiting to be carried out twice only, the applications separated by about 14-21 days (depending on the weather) although the number of applications in and around dwellings may be more as it is dependent on the rate of removal by rodents of distributed baits. This will maximise the exposure of rodents to the bait. The proposed application rate for the first bait drop is 12 kg of bait per hectare, and 8 kg per hectare for the second drop. These application rates relate to the actual surface area of the islands. Most rodents will be killed by bait from the first bait drop. However, it is beneficial to carry out a second bait drop to eliminate the likelihood of any gaps in the distribution of baits, ensure bait is available long enough to ensure that all individuals receive a lethal dose and to target:

- individuals that may have been denied access to bait distributed in the first application (by more dominant individuals that will now be dead), and
- any surviving young that have recently emerged from the nest.

Timing

The operation is programmed to take place in winter 2018 (June-August), when the availability of natural food for rodents is low, rodent breeding is greatly reduced or absent and the rodent populations are likely to be at their seasonal lowest. This is also a period when most non-target seabirds are absent from the LHIG. Bait drops will be timed to avoid periods of predicted heavy rainfall (as this may prematurely dissolve the bait) and cannot take place in high winds or in the presence of low cloud. Therefore weather will influence the actual timing of the two bait drops. Weather forecasts of rainfall and wind speeds will be obtained from the Bureau of Meteorology station on LHI from June onwards. A forecast of less than 15 knots and four fine days (three fine nights) without significant rainfall (less than 6 mm daily) is preferred for each drop but the decision to apply bait will be taken by the operations manager at the time when all relevant factors are known.

Given the possibly limited operational window, approval is sought for at least a two year period to account for unforeseen delays beyond winter 2018, however the operation would only occur once during that period.

Aerial baiting

Aerial baiting will be conducted throughout the LHI PPP and other areas of the main island excluding the settlement area and identified buffer zones. In all areas baited aerially, 10 mm baits (approximately 2 g each) will be broadcast at a density of 12 kg/ha (one bait every two square metres) for the first drop and 8kg/ha for the second drop on average over the island.

The bait will be dispersed using a purpose built spreader bucket (see Figure 10) slung below a helicopter. A rotating disc typically throws the bait 360º to 35 m (note outlier pellets may be thrown to 45 m); enabling a swathe of up to 70 m to be baited in a single pass.

Overlapping (50%) each swathe will ensure that there are no gaps in the distribution of baits (see Figure 11). Application rates out of the bucket are calculated to account for the 50% overlap (i.e. for the first drop 6 kg/ha on each swathe with 50% overlap will be applied to achieve a 12kg/ha application rate on the ground). Each bait drop will take approximately two days to complete dependant on weather.

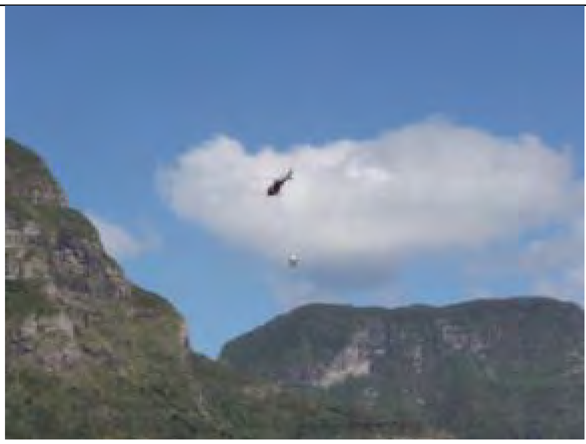


Figure 10 Custom built spreader bucket being prepared and in use on LHI during 2007 trials.

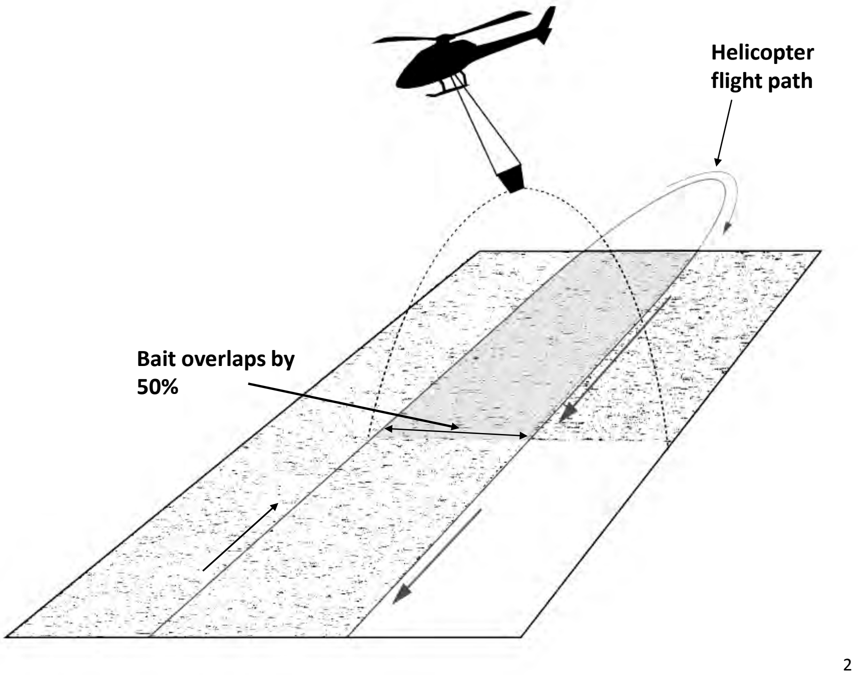


Figure 11 Aerial Application Method

In order to achieve the required baiting density on the cliffs and steep slopes (particularly around Mt Gower and Mt Lidgbird) several horizontal flight lines will be flown at approximately 50 m vertical spacing along these areas to ensure adequate bait coverage. Baiting around the coast line will occur above the mean high water mark to minimise bait entry into the marine environment. A deflector arm can be attached to the spreader bucket to restrict the arc of the swathe to 180º and will be used particularly when baiting the edge of buffer zones and to minimise bait entry into the marine environment when baiting coastal areas including cliffs. The sowing rate, bait direction and swathe width can all be controlled within set limits and will be adjusted as required for specific requirements for different types of flight lines (inland, coastal or buffer zone). Other aerial dispersal options include the idling or turning off of the spinning motor on the spreader bucket which will result in bait trickling vertically below the helicopter for narrow areas if required. The combination of techniques will enable all terrains on the LHIG to be effectively baited. The exact methodology of distributing bait aerially on LHI will be finalised in consultation with the helicopter contractors.

Buffer zones for aerial application to individual properties will be agreed with the relevant occupiers and in accordance with relevant regulations and considering outliers from the bait swath. The LHIB has committed that this would be no closer than 30 m to dwellings, by agreement or if agreement to the contrary is not reached, then the buffer zone will be 150 m. In these buffer zones bait will be applied by hand, or in bait stations. This will be covered in a Property Management Plan for each property. 30 m buffer zones will also be established around containment areas for the dairy herd.

GPS will be used to guide the helicopter along a set of pre-determined flight lines designed to ensure that all areas are adequately baited. Computer-generated plots of the actual path flown will be inspected at predetermined times during and at the completion of the flight to confirm that this has been done. Any identified gaps will be treated. Flight-path height will be set at an altitude that ensures effective and safe baiting. It will be determined in discussion with the baiting operator, and take into account topography, weather conditions, aircraft safety and the need to avoid significant disturbance to roosting birds.

This baiting methodology is similar to (and is based on) established techniques for other island pest eradications undertaken worldwide. In Australia this technique has been used on islands such as Montague (2007) and Broughton (2009) islands in New South Wales and Hermite Island (1996) in Western Australia. It was also used on World Heritage listed Macquarie Island in Tasmania over autumn and winter 2011.

The aerial baiting technique has been trialled on LHI with non-toxic bait and a custom built spreader bucket (DECCa, 2007). The trials have shown aerial baiting to be an effective technique that could be utilised in an operation on Lord Howe Island. The trial report is included in Appendix D – LHI Trials Package. The trial provided an opportunity to establish the correct flight configuration: air speed and settings to produce the required flow rate to achieve the on ground density of bait during operations. Methodologies for loading procedures, and determination of bait usage on flight runs were developed for use in future baiting operations.

Further detailed calibration of the equipment with non-toxic baits (i.e. helicopter, spreader bucket, GPS equipment etc.) will be undertaken immediately prior to the operation as part of an operational readiness check overseen by an international eradication expert most likely from the New Zealand Department of Conservation’s Island Eradication Advisory Group.

Hand broadcasting of bait

Hand broadcasting of bait will be conducted concurrently with aerial baiting. It will be undertaken throughout the settlement area where agreed by residents under individual Property Management Plans and in buffer and exclusion zones (i.e. the lagoon foreshore and Ned’s Beach). In the settlement area, either 10mm (2 g each) or 5.5 mm Pestoff baits (0.6 g each) will be hand-broadcast at a density of 12 kg/ha (one bait every two square metres for the 10mm pellet or one bait every half square metre for the 5.5 mm pellet on average) for the first application of bait and at 8 kg/ha for the second application.

Provisional areas to be hand-baited are subject to completion of individual Property Management Plans and collation into a revised operational plan.

Trained personnel will move through such areas and apply bait at the designated rate. All personnel will carry a GPS unit capable of continuously tracking their path. Computer-generated plots of their paths will be used to check baiting coverage. The aim will be to distribute baits in garden beds and other areas of vegetation around dwellings, rather than broadcast on lawns. These details will be contained in the individual property management plans which will be established between property occupiers and the LHIB.

It is essential that all hand-broadcast bait be out in the open so it is subject to degradation by weathering. No bait will be hand-broadcast directly in or under buildings where it will not be subject to weathering.

Bait stations

Commercially available or specifically designed bait stations (see Figure 12) will be used where aerial or hand broadcasting cannot be undertaken. Bait stations will also be placed within all areas containing livestock (i.e. dairy herd, horses and goats). The bait stations used in livestock areas will be designed specifically to be able to withstand interference and trampling by stock. Where practicable, and with the agreement of householders, small amounts of bait in open containers (‘bait trays') similar to commercial products currently available, will be placed within buildings including kitchens, pantries, pet food storage areas etc. Where possible, bait trays will also be put in accessible roof spaces and under-floor cavities.

Note: there is a potential for currently registered Brodifacoum products to be used in accordance with label conditions by residents in some dwellings. This will be considered on a case by case basis assessing higher palatability of pellets vs. higher dosage, quality control and resident acceptability. However, a major drawback in using commercially available baits is that these baits contain bitrex which is a bitter-tasting compound and is meant to deter children and pets from eating the bait; there is some evidence that some rodents will avoid baits with bitrex.

All bait trays and bait stations will be monitored regularly and bait replenished as necessary for approximately 100 days after the second baiting (this could be longer if surviving rats or mice are detected). Bait uptake will provide an indication of rodent activity, along with other detection techniques such as detector dogs, chew blocks and tracking tunnels. Bait in these locations will not be exposed to weathering, and so any remaining bait will be removed once project staff are confident all rodents have been eradicated from the island.

When using bait stations or trays it is important that they are set close enough together that individual rats and mice encounter at least one station during their nightly movements. Rats are wide-ranging and can be eradicated using a grid spacing of 25 m -50 m. Mice, however, are not as wide-ranging, and require a grid spacing as close as 10 m.

It is expected that the combination of hand broadcasting and setting and arming of bait stations will take approximately 5 days each application (coinciding with the aerial application) dependant on results of the property management plan process and actual staff numbers.

Indicative areas to be treated using the three methods above are shown in Figure 13 and Figure 14.

			
Custom made bait stations (currently in use)		Commercial bait stations	

Figure 12 Bait Station Examples

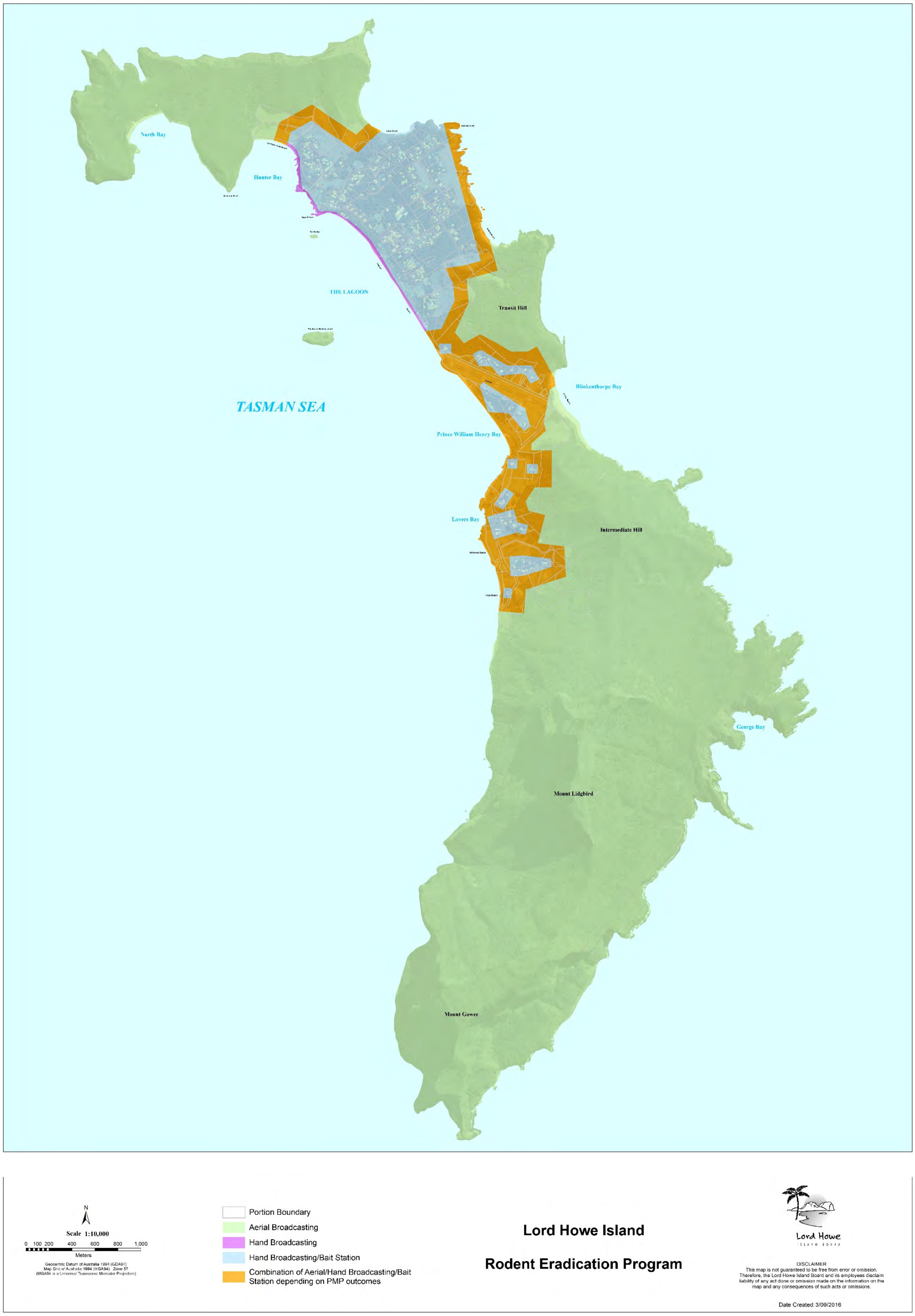


Figure 13 Indicative Treatment Areas by Method

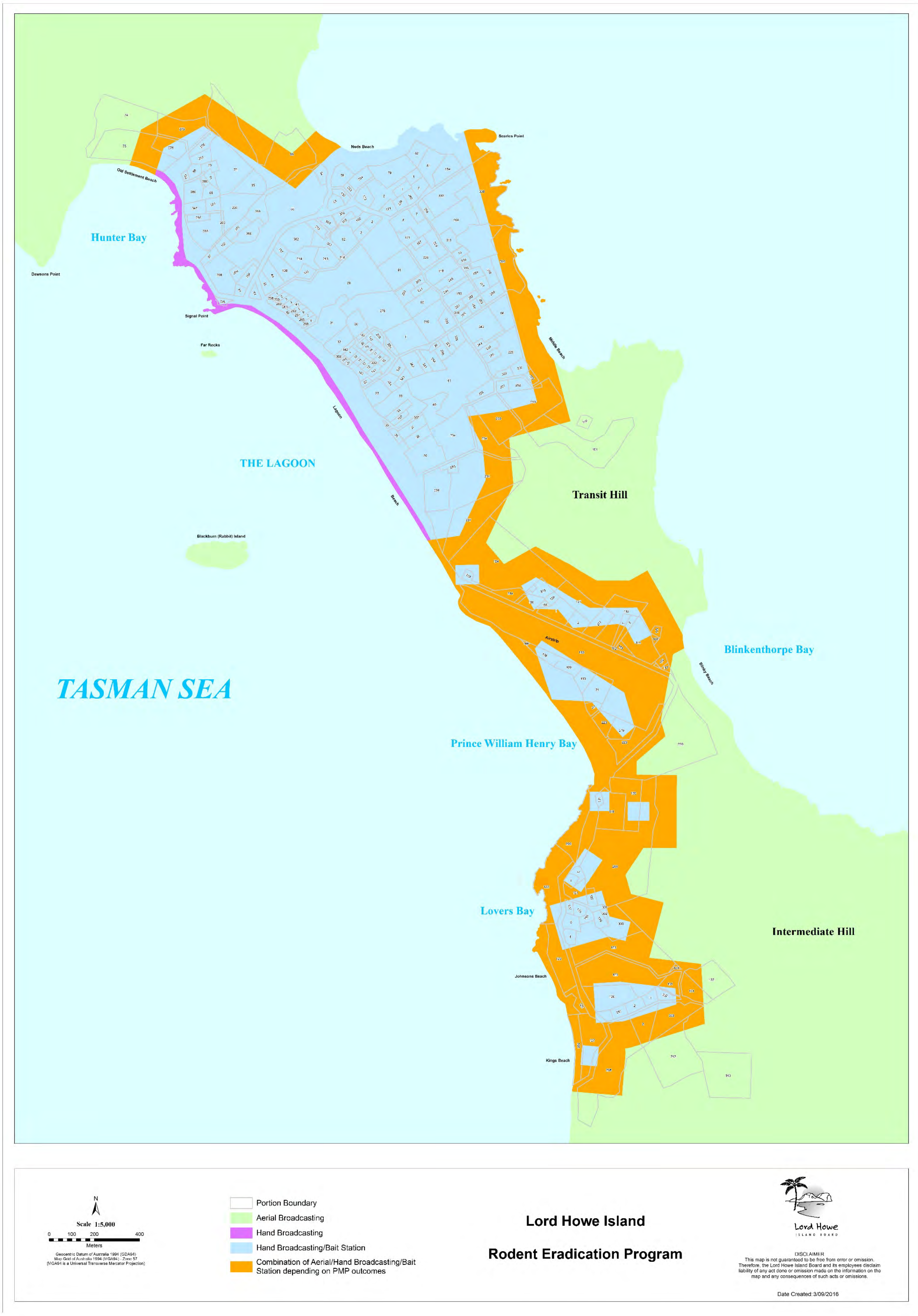


Figure 14 Indicative Treatment Areas by Method - Settlement Area detail

Property Management Plans

The LHIB has been consulting with all property owners and residents on the island to develop individual Property Management Plans (PMPs) as part of the REP. The PMPs include the agreed baiting methods for each lease on the Island, including the settlement area. This can include the desired combination of hand broadcast and bait stations on individual properties and if properties are on the edge of the settlement area, the appropriate buffer distances for aerial distribution.

The PMPs are confidentially discussed and negotiated with the leaseholders / residents individually and consider mitigation of specific risks and areas of concern on individual properties and in accordance with any regulatory approvals or conditions received. The PMPs will only need to be signed once all government approvals have been received and the final decision to proceed with the eradication project has been made by the LHIB. The PMPs will not impact on the tenure of the leases.

Product storage

At the manufacturing plant in New Zealand, the bait will be packaged into 25 kg bags and loaded in approximately 1 tonne weatherproof bait pods for transport by ship to mainland Australia. After customs and quarantine clearance in Australia, the bait will be shipped to LHI. On arrival on LHI, bait will continue to be stored in the weatherproof bait pods in a secured premise most likely at the LHI Airport.

Product Disposal

A limited amount of contingency bait will be purchased as part of the order in case of physical damage including weathering or bait loss so it is anticipated that there will be bait remaining at the end of the operation.

Unused Pestoff 20R is likely to be retained in case it is needed for follow up or incursion response. It may also be transported back to the mainland for sale to other similar projects or for disposal at an appropriately licensed facility. Unusable spillage will be collected and transported to the mainland for disposal. Emptied Pestoff bags may be disposed of in a similar manner as discarded bait pellets or they may be incinerated on LHI in accordance with all legal requirements.

Rodent and non-target carcasses will be collected wherever possible by ground staff during and immediately after the operation, particularly in the settlement area, however due to the large size of the island and rugged and inaccessible terrain this will not be possible across most of the island. It is proposed that carcasses collected will be buried, incinerated on island or transported back to the mainland for disposal at an appropriately licensed facility.

Accidental Release

In the event of a spill, the area will be isolated and all practicable steps taken to manage any harmful effects of the spillage including preventing baits from, as far as practical, entering streams or waterways. Spilled baits will be collected and put into secure containers. Fine material will be swept up and placed into bags for disposal as above.

2.2.1.4 Environmental and Impact Monitoring

An extensive environmental monitoring program will be conducted during and after the REP. This includes

- Monitoring of weather in the lead up to and during the REP.
- Monitoring breakdown of baits after distribution. Bait breakdown will be monitored at random sites using the Craddock Condition Index described below in Section 2.7 at approximately 30 day intervals until complete disintegration.
- Soil monitoring after distribution. Post operational soil samples will be collected to monitor residues of Brodifacoum in the soil. Representative samples will be collected from directly below some toxic bait and at control sites away from bait pellets. Soil samples will be collected approximately 30 days after bait disintegration and approximately every two months (if required, dependant on results). All tests will be conducted at a NATA accredited analytical laboratory.
- Random sampling will be conducted on water bodies (both freshwater and estuary inlets) on the island to monitor Brodifacoum levels after the bait drop. Water samples will be collected within 2 days of each bait drop and approximately weekly (if required, dependant on results). All tests will be conducted at a NATA accredited analytical laboratory. Rain water tanks and groundwater bores will be sampled if requested by residents.
- Monitoring for sick and dead non-target species. All individuals will be treated with Vitamin K where possible. Carcasses of rodents and non-target species will be collected if found, however previous studies have shown that the vast majority of rodents that are poisoned die in burrows underground (Vercauteren et

al.2002). Some analysis of non-target carcasses will be considered where poisoning is considered a likely cause.

- Analysis of milk samples pre and post baiting.

Full details of the monitoring program are provided in the Non-target Species Mitigation Plan in Appendix E – Non-target Impact Management Plan.

2.2.1.5 Masked Owl Eradication

As a result of the proposed rodent eradication, there is also an opportunity to concurrently eradicate the Masked Owl, which was introduced to LHI (along with 5 other Australian and North American owl species) to controls rats in the 1920s and 1930s. The Masked Owl on LHI were until recently believed to be the Tasmanian race *(Tyto novaehollandiae castanops),* however genetic testing has found significant divergence of the LHI population with *T. n. castanops,* suggesting hybridisation with the Mainland race *(Tyto novaehollandiae novaehollandiae) (*Hogan *et al.* 2013). This hybridisation and loss of genetic integrity would exclude translocation of the LHI Masked Owl to Tasmania or NSW.

A recent study (Milledge, 2010) has shown that rodents currently form the Masked Owl's main prey on the Island, supplemented by occasional predation on other native birds. During the rodent eradication it is expected that most owls are likely to succumb to secondary Brodifacoum poisoning by ingestion of poisoned rodents. To avoid any remaining owls switching to a diet of solely native species in the absence of rodents, it is proposed to eradicate remaining owls via hunting or trapping before, during and after the baiting proposal.

Details of the various components of the Masked Owl eradication are provided below.

Pre- and Post-REP Population Estimates

Pre-REP surveys will be performed to estimate the current distribution and size of the owl population and to provide a measure of the number of owls, general location of roost sites and key areas that will be required to be targeted in the subsequent shooting programme. Simultaneous point triangulation surveys (point surveys) will follow the methods performed previously by Milledge (2010). Briefly, locations of point surveys will be selected to cover the slopes of the southern mountains and the northern hills of the island. The aim of the point surveys will be to provide a measure of owl density in two important areas of habitat. Measures of owl density will be then be extrapolated to the remainder of the island to inform an overall estimate of population size. The survey method will comprise a 45 minute listening period from dusk (with an agreed start time prior to the survey) followed by playback of a recorded sequence of owl calls and then a 5 minute listening period. The playback sequence will then be repeated, followed by a further 5 min period of listening. Prior to the REP, the simultaneous point surveys will be performed every three months until baiting occurs, with the first survey to be performed as soon as is practicable. Surveys will then continue to be performed once every three months for two years in line with the post-eradication rodent monitoring.

Acoustic Monitoring

Remote acoustic monitoring devices will be used to constantly monitor owl calls in remote areas of the island. The deployment and recovery of three units in selected locations throughout 2017 can inform both the population monitoring and eradication effort. Acoustic monitoring devices would be rotated throughout the island on a monthly basis (for recovery of recordings and refreshing of power source). The recovery of information from the recordings can either be through intensive replaying or the application of call-recognition software.

Timing and Personnel

A total of sixteen people will be required to perform point surveys at eight locations across the island. Each team of two will have at least one person who is familiar with the triangulation survey method, call playback technique and the calls of the Masked Owl. Volunteers from within the Lord Howe community will be sought to perform these surveys where possible but people from off the island may also be involved.

Trapping with goshawk-type traps using live rats as bait will not be possible once the REP commences, as using live rats cannot be risked due to the possibility of their escape. However live trapping may need to be employed as an alternative to shooting post-REP, for example where a particular owl has become too wary to be lured in by call playback or where an owl has been detected in an area of terrain too difficult to allow shooting. In these cases alternative live baits such as guinea pigs or young chickens may be considered.

Masked Owl Eradication Methods

Secondary Poisoning and Trapping Programme

There is the potential for a number of owls to succumb to secondary poisoning during the REP as a result of preying on rodents that have consumed Brodifacoum. However, it cannot be presumed that all owls will die in this manner; poisoned rodents may be unavailable in some areas, and because rodenticides are currently used on Lord Howe Island to control rats and mice, prolonged exposure to poisons may have allowed the owls to evolve some tolerance. Milledge (2010) had only limited success trapping owls using drop-nets (Dho-Gaza net). Therefore, trials will be performed prior to the eradication programme to explore the suitability of 'goshawk-type traps', which will need to be set after dark and closed prior to dawn to avoid the capture of non-target species such as currawongs. All owls caught during this trial will be destroyed.

Timing and personnel

Trapping of owls for removal (if shown to be an effective method) will continue from three months before and for up to three months after the REP or longer if necessary until all owls not eliminated by shooting have been removed. Owls will be trapped with goshawk-type traps in two teams of two people.

Trapping with goshawk-type traps using live rats as bait will not be possible once the REP commences, as using live rats cannot be risked due to the possibility of their escape. However live trapping may need to be employed as an alternative to shooting post-REP, for example where a particular owl has become too wary to be lured in by call playback or where an owl has been detected in an area of terrain too difficult to allow shooting. In these cases alternative live baits such as guinea pigs or young chickens may be used.

Shooting programme

The proposed method of removing owls that are not eliminated through secondary poisoning and trapping is through a systematic shooting programme. Because it is inevitable that owls will begin preying on native fauna once rats and mice are removed, it is intended that the shooting programme begins as soon as possible after the REP begins without compromising the trapping programme.

Locations across the island will be chosen to provide clear vantage points and suitable overhead perches to enable the shooting of owls. Call playback will be used at these stations to attract owls, at which time they will be shot by experienced, qualified shooters who will be engaged to perform the shooting component. All shooters will be appropriately licensed in accordance with any New South Wales and Lord Howe Island Board requirements. The shooting programme (locations and expected number of owls to be targeted) will be informed by the pre-REP point surveys and acoustic monitoring results.

The shooting programme will cover all accessible habitat across the island. However, the first priority should be to target areas that will be difficult for shooters to access on foot. It is proposed that the helicopter(s) used for spreading bait be used to transport shooters to these inaccessible areas either, during the period between the first and second bait drops, or immediately after the second bait drop. It should be noted that the rodent eradication should be prioritised for helicopter use. When being transported to remote areas by helicopter during the day, shooters will carry adequate equipment to enable them to stay overnight as it will be unlikely that they can be picked up that night and inclement weather or other factors may also delay the return of the helicopter.

Timing and personnel

The shooting schedule will be informed by the population surveys and acoustic monitoring and it is proposed that two teams comprising two persons will perform shooting operations. Shooting in remote areas will begin as soon as is practicable after the first bait drop. The duration and timing of these forays will be dictated by weather and helicopter availability. Shooting forays in areas accessible by foot will also begin soon after the first bait drop once owls have had an opportunity to consume poisoned rodents. These forays will be performed at a frequency of three hours per night three nights per week. Shooting forays may need to continue at this frequency for six months after the REP and should include the period when owls are most responsive to calls (winter and spring, Milledge 2010)). After six months it should be possible to make an assessment of the necessity to continue at the same frequency or reduce either the number of shooting parties or the number of forays. The shooting schedule will be flexible throughout, however, to allow for breaks if, for example, owls become unresponsive to call-play back; previous culling programme found that, following a break, owls responded better to calls.

Firearms

Two firearms with different capabilities will be used in the shooting programme; likely a 12-guage shotgun for close range and a .17 HMR rifle for longer range shots. Longer-range capabilities will be required for occasions when owls do not closely approach the call play-back station. All necessary licensing and shooting operations will be overseen by the LHIB Firearms Officer.

Translocation

As indicated above, genetic analysis has found that the ancestry of Lord Howe Island Masked Owls indicates a mixture of Tasmanian and mainland Australian Masked Owl individuals (Hogan *et al.* 2013). These owls are thus unsuitable for translocation into wild populations elsewhere in the species' range. Nevertheless, the owls are valued by some members of the Lord Howe Island community and the opportunity to transport some individuals to zoos or wildlife parks to maintain captive populations may be explored. Taronga and Melbourne zoos have been approached but these organisations are not able to accept live owls. However, other organisations, such as smaller zoos could be approached to investigate the potential for some owls to be relocated.

A more detailed plan for the eradication of Masked Owls and supporting studies is attached to this PER (in Appendix F – Masked Owl Package).

2.2.1.6 Rodent Detection Monitoring

Following an eradication attempt it is necessary to confirm the success of the operation and to prevent reinvasion. The level of confidence in determining whether an eradication was successful or not, and detecting new invasions is dependent on the type and density of detection devices, duration of deployment, along with the density of rodents present.

Traditional approaches (particularly for aerial eradications) for declaring success have been to wait until at least two rodent breeding seasons (i.e. two years) have passed before undertaking monitoring (Russell and Broome al, 2016). This period allows rodent densities to build up to detectable levels in the event that the operation failed. If no surviving rodents are found after at least two breeding seasons (roughly two years), then the eradication is declared a success. This traditional approach has potential downfalls in that it does not facilitate rapid response to early detection of survivors, and thus obligates repeating the eradication from scratch. An alternative “Rapid Eradication Assessment” approach is to monitor the island at some fixed time soon after the eradication and quantitatively estimate, whether the eradication was successful or not through a spatial-survey model (Samaniego-Herrera et al., 2013). This approach facilitates the early detection and removal of localised survivors in comparison to a complete repeat of the eradication operation. Additionally, if confidence in eradication success is determined earlier, restoration plans can be implemented before the traditional two year mark (Russell and Broome al, 2016).

The differences in scale and topography on LHI for areas treated by aerial application compared to the areas treated by ground based methods (i.e. hand broadcast or bait stations), present an opportunity to implement a combination of the above methods to maximise any chances to remedy a possible failure and increase confidence in eradication success. Therefore rodent detection monitoring will be undertaken in different areas at different scales and intensities on LHI. Monitoring in the following phases is described in more detail below.

- Initial follow up monitoring
- Monitoring to declare eradication success
- Ongoing monitoring for detection of reinvasion from rodents

A range of tools are available for trying to detect rodents at low density however they all have their limitations so in order to maximise the chances of detecting any survivors it is desirable to use a mixture of techniques. Details of these tools are provided further below.

On site trials need to be undertaken to test the local effectiveness and suitability of the various proposed techniques for Lord Howe, particularly the interaction of non-target species with the devices but also the effectiveness of the devices with detecting the target species i.e. rats and mice preferably at low density. Full details of the suite of tools to be used on LHI are yet to be finalised, as is the development of a detailed rodent monitoring plan.

Initial Follow up Monitoring

Due to the scale and topography of most of the areas on LHI that are to be treated by aerial broadcast, it is not realistic to try and detect with a sufficient degree of confidence any rodents surviving the eradication in those areas immediately after eradication. A failure in areas treated aerially means that there has been some failure in planning or implementation, and the ability to undertake any meaningful immediate response if survivors were detected in those areas is limited. Therefore very limited monitoring will be undertaken immediately after the eradication (restricted to some easily accessible areas) in areas treated aerially. This will be best achieved after several breeding seasons have passed allowing potentially surviving rodents to build up to detectable numbers.

However, the area around the settlement does offer an opportunity to undertake a high standard of rodent monitoring and to respond promptly to any survivors detected. This is due to the logistical feasibility of the area i.e. size, topography and access. Importantly, this area warrants the extra attention as it has the highest likelihood of failure given it will be treated by a combination of ground methods.

Russell *et al.* (2016) have tested a statistical model developed for the Rapid Eradication Assessment approach by Samaniego-Herrera *et al.* (2013) for assessing the probability of detecting surviving rodents and their offspring, using a grid of detection devices to predict eradication success. They found that spacing of detection devices and number of monitoring nights provided the best predictors for eradication success.

Preliminary modelling for LHI undertaken by Samaniego-Herrera and McClelland (2016) using the Rapid Eradication Assessment approach has suggested that a detection device network grid spacing of 30 m x 30m in the settlement area immediately after eradication would produce a median Confidence Interval of 100% (lower CI 99.1% and upper CI 100%) of detection when monitored for at least 30 nights.

Based on the modelling, the settlement area and other easily accessible areas of LHI will be monitored intensively for the presence of rodents throughout the 100-day period of the baiting operation (at least 30 days commencing 3-4 weeks after the second bait drop). Focus will be applied to areas that may have had restricted bait stations, and where techniques have overlapped (bait station and hand broadcast or hand broadcast and aerial). Detection of surviving rodents will be assessed by a combination of detection tools described below. All detection devices will be checked frequently – at least every second day and preferably daily, so that a targeted response can rapidly be undertaken, i.e. to maximise the likelihood of any rodents that is detected being in the same area so that it can be targeted with the preferred technique –traps or toxicants. Residents will also be asked to report any evidence of rodent activity to the project team. In addition, trained detector dogs and handlers will be deployed throughout the settlement area approximately 3-4 weeks after the eradication to search for signs of and locate any surviving rodents.

This approach will give a high level of confidence that eradication success has been achieved for the settlement area.

Declaring Eradication Success

During the period immediately following the eradication and in the lead up to declaring eradication success, the monitoring network implemented above will be adjusted in the following ways.

- The network within the settlement area will most likely be maintained but checked at reduced frequency potentially weekly or fortnightly.
- The network will be expanded to include accessible areas of the island. Additional modelling will be undertaken to confirm network spacing and trap nights required.
- The permanent rodent detector / biosecurity dog based on the island will sporadically undertake targeted searches of high risk areas.
- The declaration will be preceded with a thorough search using an additional contract team of rodent detector dogs and handlers to search all accessible areas of the island for rodents.

This methodology will give a high level of confidence to allow declaration of eradication success which will be declared after two years of monitoring with no rodent activity.

Ongoing Rodent Detection Monitoring

The eradication investment will be protected through ongoing rodent detection monitoring on the island aimed at detecting any possible reintroductions. This will form part of the island's permanent rodent detection and prevention system initiated as an integral part of the island's Biosecurity program which will be upgraded in parallel with the REP. The monitoring network developed for the initial follow-up monitoring and declaration of success will be modified to allow targeted monitoring of high risk reinvasion points. It will include:

- A grid network of detection tools at high risk reinvasion points such as the wharf and airport and potential areas for initial recolonisation. This will be checked at a frequency commensurate with arrivals (i.e. daily at the airport and fortnightly at the wharf coinciding with cargo vessel arrivals)
- The permanent rodent detector / biosecurity dog based on the island will routinely screen all incoming cargo and luggage
- The permanent rodent detector / biosecurity dog based on the island will sporadically undertake targeted searches of high risk and random areas

This methodology will allow a high level of confidence that any reinvasion would be detected. Genetic testing on LHI rodents has been undertaken. In the event that rodents are detected post REP, the genetic samples will allow determination of whether the eradication failed or the detection was a reinvasion.

Detection Response

In the unlikely event that rodents are detected, remedial action will be considered to eliminate them.

In the event that possible sign is detected, trail cameras with a variety of baits will be deployed in the area to try and confirm if a rodent is present. At the same time an array of other detection devices chew cards, wax block, tracking tunnels, bait stations and traps will be deployed in the vicinity and any rodent dogs available will be focused on that area. Any response will need to be carefully planned and implemented as previous experience has shown that if not done properly there is a risk of not locating the animal or even scaring it away from the known area.

Due to the wide number of situations that could involve a rodent being detected /confirmed e.g. unconfirmed sign, single confirmed individual, multiple individuals, animals around in buildings etc., it is not realistic to develop comprehensive response scenarios. Instead a Technical Advisory Group (TAG) will be set up who will be on immediate standby to provide consensus advice on how to respond to any specific situation. The TAG will consist of selected experts in eradication techniques, rodent detection and rodent behaviour.

Additional detection and response devices will be held on island to facilitate a rapid response if one is required.

A second eradication attempt using aerial techniques is not part of this proposal.

Detection Tools

Bait stations

There will be a network of bait stations present around much the settlement as part of the eradication. However any rodents surviving the initial eradication operation have for some reason avoided eating bait to which is likely to mean they haven't entered a bait station either because they have avoided the stations (neophobia) or they haven't had a station within their territory. The only way to use bait stations to detect rodents would be to put additional stations in any possible gaps in coverage i.e. reduce the spacing between stations. It is more effective simply to make sure that the initial coverage is adequate.

While the stations can, depending on the design, be used for the deployment of other devices e.g. tracking tunnels or to protect wax blocks this would assume that the rodents are not avoiding the stations themselves possibly due to inter or intra species competition. Unless other devices are placed in the stations the only likely rodent activity that will be recorded in the bait stations will be bait being eaten i.e. tooth marks. If there is still bait take continuing at any bait stations then the response is effectively part of the eradication, i.e. keeping the stations topped up.

Rodent Detection Dogs

Trained rodent dogs are a highly effective tool for locating rodents. They have the benefits over all other tools that they actively seek out the rodent rather than requiring the rodent to come to them. Also the rodent and dog do not need to be in the same place at the same time as the dog will, within limits, detect where the rodent has been. Detector dogs can also cover an area once to get a result whereas all other techniques need to be set up and then ongoing checking.

Detector dogs on LHI will be used in the following ways:

- A team of contract specialist rodent detector dogs and handlers will be deployed to actively search accessible areas (particularly the settlement area) to provide immediate detection capability for any surviving rodents in these areas. This will be undertaken within 3-4 weeks of the second bait drop. The exact number of dogs and handlers will be determined in consultation with the selected tenderer for this service.
- An ongoing rodent detection and general biosecurity dog (and handler) will be trained and permanently based on the island prior to implementation of the REP. This dog will provide a rodent detection capability at the border (airport and wharf) as well as generalised biosecurity capability.
- A team of contract specialist rodent detector dogs and handlers will be deployed to actively search all accessible areas (particularly the settlement area) to provide evidence for the declaration of eradication success. This will be undertaken approximately 2 years after the eradication. The exact number of dogs and handlers will be determined in consultation with the selected tenderer for this service.
- If the dogs indicate the current or recent presence of any rodents other techniques will be used to try and confirm it and to refine and hopefully kill the individual(s).

Minimum training, accreditation and ongoing certification requirements for both dogs and handlers will be developed prior to implementation of the REP. This will include

- Ability to identify target scent and avoidance of non-target species and scent
- High level obedience and control
- Good temperament around people and other dogs
- Initial and ongoing assessment and certification of dog and handler

Rodent Detection Dog Gadget on Ulva Island Photo: detectorgadget.blogspot.com	Rodent Detection Dog Cody on Macquarie Island Photo: Meg McKeown	Dog trainer Steve Austin with Rabbit Detection Dogs Gus and Ash Photo:K9 Wildlife Conservation

Figure 15 Rodent Detection Dog Examples

Trail Cameras

Trail cameras / remote cameras come in a variety of specifications e.g. natural light / infrared, stills or movie and are widely used to detect various species of wildlife around the world. Trail cameras have been shown to be very effective for confirming the presence of rodents but are of limited use for the LHI operation due to the cost ($300 + per camera), the time required to set up and maintain them i.e. to check all photos, and the limited range of the cameras without having any initial direction on where to set them up. As such cameras are best used when there is a preferred location e.g. a major food source, a high risk area e.g. the waste management facility or where the presence of a rodent is suspected in an area but unable to be confirmed.

Chew blocks / Wax tags

Chew blocks/wax tags are peanut butter flavoured wax blocks with a smooth surface. When an animal bites one it leaves incisor tooth marks which can usually be identified to species (mouse/rat). Chew blocks are cheap to purchase or can be made on site and are easy to deploy and check. However while they have proved very useful for locating rats and have been widely used for mice, potential issues have been raised with identifying mouse chew sign which warrant further investigation. Their low cost and ease of use means that they have potential to be a very useful detection tool in the Lord Howe situation.

Chew blocks can be bought commercially from Pest Control Services in New Zealand (NB only peanut butter flavoured tags should be used for rodents) or they can be made by project staff . Blocks should be placed 4 cm above the ground to facilitate access by mice.

There can be issues with non-target interference which need to be checked for the site, however with the absence of other mammal species on Lord Howe this is considered to be a very low concern .

Chew cards are pieces of corflute cardboard with peanut butter pressed into the holes. The standard design is a 9 x 18 cm card made of 3 mm white plastic corflute. When the rodent attempts to get to the peanut butter it leaves distinctive chew marks on the corflute which can be identified as rat or mouse. Chew cards are cheap, effective for both target species although somewhat less for mice than rats. Depending on the specifics of the devices used it can also include an ink card to try and get footprints.

Mice and rats have similar bite marks that are mainly distinguished on size. They leave pairs of incisor marks, nearly straight lined on top and more curved underneath. Incisor pairs are about 1 mm across for mice (less than half the width of the corflute channels) and about 2 mm across for rats (more than half the width of a corflute channel). Look for individual bites clear of continuous chewing along card edges. Rats frequently chew large chunks out of the cards leaving a relative cleanly cut edge. Mice usually chew small amounts, sometimes making just small scattered nicks along the edge, or chew short channels between card partitions on just one surface. Continuous mouse chewing along the card edge also tends to be less cleanly cut than for rats, with a short chewed flange attached to the remaining card with numerous light tooth impressions beyond that, as opposed to cleanly cut edges frequently made by rats.

Figure 16 Chew Block

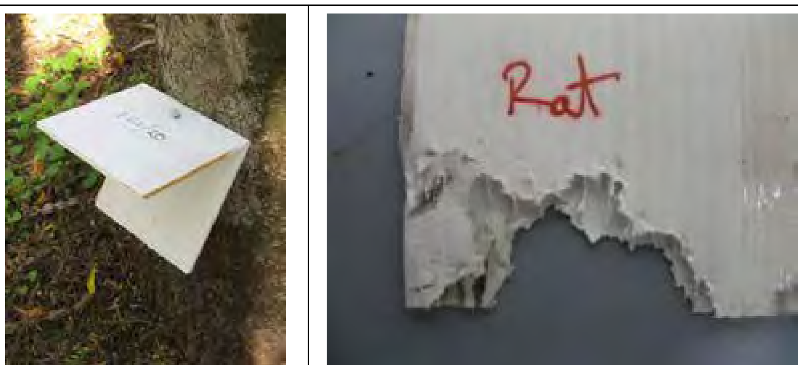


Figure 17 Examples of Chew Cards and Evidence of Rodent Damage

Traps

Traps have the major advantages over the other technique of both killing the survivor and providing a body which can then be examined for species, age, sex and breeding status i.e. a female that has bred is of far more concern than a lone male. However they have several disadvantages:

- They are labour intensive, both to set up and to monitor – NB every trap has to be set with care as each one needs to be considered as THE trap that will catch the rodent.
- They are much more expensive to purchase.
- They are generally species specific i.e. rat versus mouse, so you need to effectively set pairs of traps.
- There is a non-target risk with kill traps, particularly with rat traps i.e. they need to be set under covers to reduce the risk.

Traps are divided between kill traps – most commonly snap traps, and live or cage traps which come in a variety of designs.

	
Figure 18 Example Snap Trap	**Figure 19 Example Live Traps**

Live traps- the only advantage of using live traps on Lord Howe is that they largely eliminate the non-target risk as any non-targets which are caught can be released. However this requires at least daily checks for animal welfare reasons. The benefit of reduced non-target risk has to be balanced against the greater cost of the trap and the possible risk of neophobia i.e. rodents avoiding a new object especially one where they have to enter a box and the intensive servicing required. Also many live traps are more reliable for rats than mice i.e. the larger body size facilities the traps operation.

Kill traps, the most common and simplest kill traps are snap traps which are lightweight and relatively cheap. There are concerns that some rats may escape from snap traps and where feasible other designs e.g. the DOC 150 and 200 series are the preferred option in most situations. However most of the concerns relate to large Norway Rats (*Rattus norvegicus*) so are not a significant issue for LHI. The DOC series traps need to be placed in a purpose built wooden box mean they are not feasible for this task.

There are multiple variations of the snap trap and care should be taken to select the most suitable one – the Victor treadle trap with a yellow plastic treadle is the preferred option as unlike most other traps the rodent only needs to inspect the bait to set it off whereas for most snap traps the animal needs to actively chew on the bait. The double spring on the rat trap also gives greater killing power.

When used inside, as long as there is no risk to children, the traps can be set without a cover, however it is important to use a cover when setting kill traps outside to minimise the risk to non-targets. The cover can be made from a range of materials including corflute, plastic sheet, sheet metal or wood. Woodhen, currawong and banded rail are particularly likely to interfere with traps in order to access the bait so that even if they are not caught they will make the trap non-functional until it is reset. Also it is likely that once any of these birds learns that the traps are a food source they will target them.

Bait for the traps is highly variable but peanut butter with fish oil and rolled oats to bind it is the standard bait.

There is currently a self-resetting trap available (Good nature A24) however while these have major benefits when targeting multiple individuals as they don't need to be reset. These will be investigated for suitability on LHI.

Tracking tunnels

Tracking tunnels come in a variety of designs from semi-permanent wooden structures to lightweight plastic. Rodents are known for entering tunnels but the tracking tunnels are usually baited/lured to act as an added attractant. Inside the tunnel is a plain card with an ink source- either inked card or an ink tray set up so that any animal that walks through it will leave footprints on the card which can then be identified to species. To reduce the risk of neophobia the tunnels, minus tracking cards should be put in place a couple of weeks prior to the planned activation period.

There is a likelihood of currawong, rail and any woodhen interfering with the tunnels to access the bait after they have been released from captivity. The design of the tunnel should be set to reduce non-target interference while still allowing easy access to rodents, this is important as making the entrance small enough to prevent entry by non-targets may effectively deter the target species.

The cost of using tracking tunnels is in a large part dependent on the servicing regime as they can be left for several days between checks if required, however this reduces the likelihood of being able to mount an effective response to any detection as the individual may have moved prior to detection.

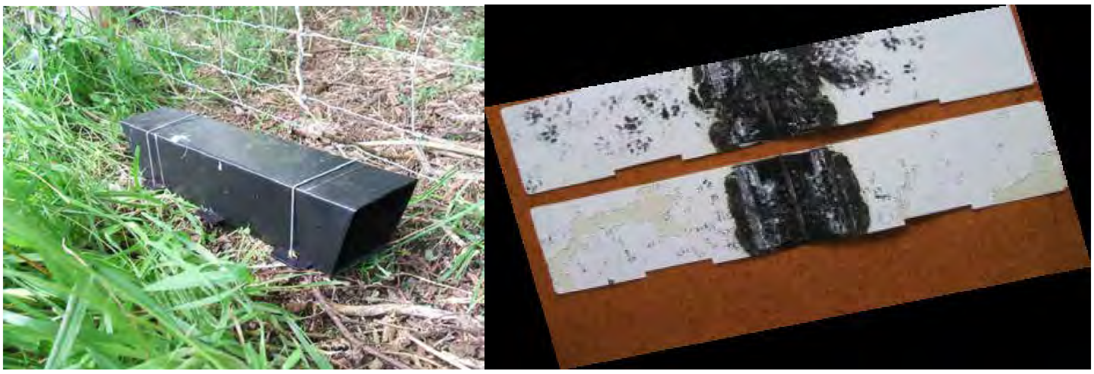


Figure 20 Example Tracking Tunnel and Foot Print Evidence

Implementation

Trials

On site trials need to be undertaken to test the local effectiveness and suitability of the various proposed techniques for LHI, particularly the interaction of non-target species with the devices but also the effectiveness of the devices with detecting the target species i.e. rats and mice preferably at low density. The latter is particularly an issue with mice which are generally more difficult to detect but are also more likely to be an issue for the eradication i.e. have a higher likelihood of failure to eradicate with the initial techniques.

It is possible that birds especially currawongs and woodhens will interfere with the devices (noting that it is likely that all Woodhen from the settlement area will be in captivity). It is also useful to see what if any invertebrate activity may confuse the results. Some insect marks are easily confused with the small marks made by mice.

A trial protocol will be developed separately which, along with the level of resources available for the monitoring and logistical constraints e.g. access to sites, will be used to develop the final monitoring plan.

Trial results will determine the final configuration of the monitoring network.

Timing

Timing of when the monitoring commences is important so as to not waste resources detecting and then targeting walking dead i.e. animals that will die from the delayed action of the toxicant, but there is a need to detect animals as early as possible to facilitate a fast and targeted response. It is proposed to commence the monitoring approximately 4 weeks after the first baiting operation as this is likely to have given all animals which have eaten the bait time to have died. It also means that the monitoring can be tied in with the eradication work e.g. checking of monitoring devices can be linked to the ongoing servicing of bait stations.

To reduce the risk of neophobia reducing the value of any detection tools, any tools which are suitable e.g. tracking tunnels or traps will be deployed well in advance of when they will need to be activated.

Training and Data recording

It is important that the location of all detection devices is accurately recorded and detailed records of all checks and any changes to the plan recorded. Failure to do so can lead to major issues with interpreting results later in the programme. All personnel involved in implementing the plan will be properly trained in deploying the devices and in identifying rodent sign – not just on the devices but also any incidental sign they may encounter.

2.2.1.7 Improved Biosecurity

To improve Biosecurity on the island more generally and to protect the rodent eradication investment, the LHIB is updating the Island's Biosecurity system concurrently with the proposed REP although upgrades will occur regardless of whether the REP goes ahead. In 2015 a consultant was engaged to review and update the LHI Biosecurity Strategy. Recommendations from the updated Strategy (AECOM, 2015) include:

- reducing risk at the Port Macquarie wharf

- increasing education and awareness for residents and visitors pre arrival to LHI
- Increasing inspection regimes for all pathways
- pursuing legislative declaration of LHI as a Special Biosecurity Zone under the Biosecurity Act 2015
- increasing residents' awareness of biosecurity risks of plants, animals and diseases both before and after import
- being prepared to react quickly to new incursions through early detection and rapid response
- continuing with on ongoing management and eradication programs
- ensuring biosecurity is adequately resourced with realistic cost and resource estimates

Specifically in relation to rodents and in addition to the ongoing rodent detection measures described in Section 2.2.1.6, the following measures will be applied:

- Employment of a dedicated on island biosecurity officer who will have primary responsibility for the ongoing rodent detection network. This role may be combined with the rodent / biosecurity detector dog handler
- Upgrades to the shipping contract to increase emphasis on rodent prevention including requirements to:
    - have in place a Biosecurity Management Plan
    - maintain rodent baiting at the point of mainland departure
    - maintain rodent baiting and De-ratting certificates on the cargo vessel
    - report biosecurity risk cargo and incidents prior to arrival.

2.2.1.8 Biodiversity Benefits Monitoring

A Biodiversity Benefits monitoring program associated with the REP has been established to assess and document the biodiversity benefits of removing rats and mice from LHI. The program is predominantly run through the NSW OEH – Science Division. The program provides a measure of the return on investment and also allows an evaluation of status of species prior to and following the eradication so any impacts of the eradication of rodents on key non-target species can be tracked during their recovery in the absence of rodents. Over time, results from the various monitoring components can be integrated to identify and explore changes to ecosystem processes.

Monitoring has and will continue to be undertaken to collect baseline data to determine the short-, medium- and long-term trends and changes in the distribution and abundance of key species and taxa following the removal of exotic rodents from LHI. Monitoring reports to date are provided in Appendix G – Biodiversity Benefits Monitoring Package.

Currently the biodiversity benefits monitoring program has developed a Plan of Action until the point of implementation of the REP. Additional monitoring in the short medium and long term post eradication will be developed if the final decision to proceed with the eradication is made. To fully assess the long-term biodiversity benefits of eradication, monitoring will need to continue for at least three years after the eradication and preferably up to 10.

Monitoring previously undertaken and monitoring planned but not yet implemented as part of the program is described below.

LH Pied Currawong

Population size of the LH Pied Currawong *Strepera graculina crissalis* (LHPC) has been estimated previously using trapping, banding and mark-recapture analysis (Carlile and Priddel 2007). Full monitoring will recommence in Spring-Summer of 2016. Techniques are well established. With OEH consultation, birds can be attracted to designated locations across the island with food, and any unbanded birds caught, banded and released in early spring. A second round of surveys can then take place. Birds individually marked with coloured leg bands can be observed and the band combinations recorded. Population abundance can then be determined by mark-recapture analysis, and the size of the population tracked over time. Data will then be available to compare the survival of (i) the population prior to rodent eradication, (ii) birds left in the wild during the period of risk (i.e., during and in the period immediately following the baiting operation), and (iii) birds held captive during the period of risk.

Prior to the end of 2016-17 year and with an expectant commencement of Phase 3 of the rodent eradication program (baiting) it will be necessary to bring into captivity a proportion of the LHPC population. The capture process will target breeding pairs close to the settlement and from Mount Gower to cover the range of birds from the island during an intensive 3-week program including helicopter transport (from Mount Gower) in conjunction with Woodhen activities.

Land birds

Land birds are highly visible to the community and some species may suffer short-term declines as a result of the baiting. Consequently it is important to have robust baseline data for this faunal group. Surveys of the distribution and abundance of land birds were undertaken annually in spring of 2013, 2014 and 2016. This sampling will be replicated in 2017. Replicated sampling will be undertaken at randomly selected points from a grid covering all readily accessible parts of the island (i.e., excluding the southern mountains). At each sampling point, standard 10-minute counts of bird abundance will be recorded. In addition, a series of transects along roads will be counted to gather data on those birds that tend to inhabit more open areas and are not well represented in the sample points. Methodology has been scientifically validated using preliminary data and is detailed in the 2013 census report (Fullagar *et al.* 2014). This monitoring program will be undertaken by volunteers from the Canberra Ornithologists Group with the assistance of Ian Hutton and any other interested members of the local community. Data from the BirdLife Australia transects established by the LHIB will also be analysed, although because of the non-systematic nature of these data, they are unlikely to demonstrate changes or trends in the short term.

Seabirds

Monitoring the impact of rodents on seabirds needs to focus on the loss of eggs and chicks, as these are the life stages most vulnerable to rat predation. The time of egg laying, hatching and fledging varies among the species of vulnerable seabirds present on LHI. Consequently, monitoring several species requires numerous trips. Thus, during this project (2015-16 and 2016-17 focus has been on two species only—the Little Shearwater P*uffinus assimilis* and Black-winged Petrel *Pterodroma nigripennis*.

Initial research in 2014-15 indicated that these small burrowing seabirds are vulnerable to rat predation of nestlings (Carlile, *et al.* 2015). For both species, the distribution and abundance of nests or burrows within a delineated sub-colony will be monitored using surveillance cameras from just after egg laying to the fledgling of any young. This will allow the determination of hatching success (the proportion of eggs that hatch), fledging success (the proportion of chicks that fledge) and breeding success (the proportion of eggs that produce fledglings). Where such information is available, breeding success in the presence of rodents will be compared with that on rodent-free islands. Monitoring of Little Shearwaters began in July 2016 with the installation of 28 surveillance cameras on active burrows. A further 35 active burrows are being monitored to measure breeding success. A large part of the colony has also been assessed for burrow occupancy and density which will allow any changes in these parameters to be assessed post-eradication.

Reptiles

There are two native reptile species on LHI, the LHI Gecko *Christinus guentheri* and the LHI Skink *Oligosoma lichenigera.* Both species are likely to increase considerably in distribution, and abundance following the removal of rodents. Average body size may also increase as the survival of larger animals improves. The gecko was recently surveyed (Bray *et al.* 2013), providing some coarse baseline data from which to assess changes in distribution and abundance after the eradication, particularly if, as expected, the animal were to expand across basalt soils. The skink was monitored during the 2014-15 season (Wheeler and Madani 2015). This monitoring made several recommendations for a post- rodent environment and sufficient information was collected from which to monitor changes in their populations.

Land snails

Baseline data of the distribution and abundance of the LH Placostylus *Placostylus bivaricosus* were collected in 2006-07 (Hutton 2007) and 2010 (Hutton and Hiscox 2010) where permanent survey plots were established in representative habitats, focussing on those areas where snails had been recorded previously.

Surveys of the LH Placostylus are best conducted after rain, so are problematic to plan, and consequently are best done in collaboration with residents on the island. Existing plots will be resurveyed to detect snails foraging on the surface at night in 2016-17. Similar species are more active on wet, warm nights, between 0200 and 0300 hours (Brescia *et al.* 2008), so surveys are best done late on summer nights after rain. All animals will be measured and marked. 'Dead' shells will also be counted. Population number and body size (as determined by shell size of both live and dead animals) can then be compared before and after the eradication.

Other invertebrates

It is expected that the biomass of invertebrates on the island will increase sharply after the eradication of rodents. General abundance of ground-dwelling and tree-dwelling invertebrates will immediately benefit from the removal of a major predator. To capture this gross change in the biota several monitoring programs have been established. In June 2016, 20 invertebrate monitoring sites were established across the island. Sites have been positioned on both major soil types (calcarenite and basalt) and a number of sampling techniques have been utilised, including collection of leaf litter and the installation of artificial habitat designed to mimic ground cover, exfoliating bark, and tree crevices. Material collected will be sorted to Order and weighted over four 3-month periods prior to the eradication. The repeating of this sampling post eradication will, along with flora monitoring of seedling survival, give the most immediate response of the biota to a rodent-free environment.

Big and Little mountain palms

Rats severely reduce seedling recruitment of the Little Mountain Palm *Lepidorrhachis mooreana* and Big Mountain Palm *Hedyscepe canterburyana auld* (Auld *et al.* 2010). This was repeated in 2014-15 and confirmed the earlier results (Auld *et al.* 2015). Fruiting and seedling establishment in both these species has been measured over a number of years, with almost no seedling establishment evident where there is no rat baiting occurring. Further studies are need to confirm the initial results from the slopes of Mt Gower, where baiting is minimal. Monitoring of these species using established plots, once rats are removed from LHI, is likely to demonstrate a marked change in seedling recruitment. This work will be undertaken by Dr Tony Auld (OEH).

Fruiting plants

From monitoring carried out in 2014-15 there was evidence that rats were consuming fruits or seeds in all 16 species examined (Auld *et al.* 2015). In summary, seed or fruit losses were apparent in all study species, at least at some sites. Losses were very high for six study species (H*owea forsteriana, Olea paniculata, Baloghia inophylla, Jasminium simplicifolium, Smilax australis* and *Geitonoplesium cymosum*); potentially very high but variable for one species (Ochrosia elliptica); moderate for three species (*Syzygium fullagarii, Chionanthus quadristamineus, Dietes robinsoniana*) (the actual losses may be higher as the trials only ran for a short period); generally low in 4 species (*Sarcomelicope simplicifolia, Psychotria carronis, Dysoxylon pachyphyllum, Coprosma putida)* (but the actual losses may be higher where the trials only ran for a short period); and low-moderate in two species (*Sophora howinsula, Drypetes deplanchei*).

Further work on examining the impact of fruit losses on the ecology of the study species would assist interpretation of these data. Given that losses are occurring in all tested species, sampling will be extended to additional species as many other species are also likely to be impacted by rats. This work will be undertaken by Dr Tony Auld (OEH).

Woodhen

Annual surveys of woodhen conducted by the LHIB will continue in November / December each year. Data from these surveys can be analysed to track the population and identify changes in population abundance as a result of the eradication program.

Prior to the end of 2016-17 year and with an expectant commencement of Phase 3 of the rodent eradication program (baiting) it will be necessary to bring into captivity the entire woodhen population from surveyed areas in an intensive 3-week program. This process will require both LHIB employees familiar with trapping techniques and the breeding areas frequented by woodhen as well as OEH and Taronga Zoo staff. Ideally the Mt Lidgbird population should be targeted but logistical constraints may not make this possible.

The monitoring reports undertaken to date are provided in Appendix G – Biodiversity Benefits Monitoring Package.

2.2.2 Definition of SIS Study Area

Lord Howe Island (LHI) is located 780 kilometres north-east of Sydney (See Figure 21). It covers 1455 ha, is 12 km long, 1.0–2.8 km wide and formed in the shape of a crescent, with a coral reef enclosing a lagoon on the western side (see Figure 22, Figure 23 and Figure 24). Mount Gower (875 m), Mount Lidgbird (777 m) and Intermediate Hill (250 m) form the southern two-thirds of the island; the northern end of the island is fringed by sea cliffs of about 200 m in height (See Figure 22, Figure 23 and Figure 24). A settlement of approximately 350 inhabitants is located in the northern section of LHI and covers about 15% of the island. Approximately 75% of LHI plus all outlying islands, islets and rocks are protected under the Permanent Park Preserve (PPP), which has similar status to that of a national park. The LHIG has been placed on the Register of the National Estate and was listed as a World Heritage Area in 1982. It is also located within the Lord Howe Island Marine Park (NSW) out to 3 nautical miles (under NSW jurisdiction) and the new Lord Howe Commonwealth Marine Reserve (under Commonwealth authority), a further area of 110 000 km^2). Coordinates for the project area boundary are provided below.

Table 4: Project Area Coordinates

Location point	Latitude			Longitude		
	degrees	minutes	seconds	degrees	minutes	seconds
1	-31	28	53	159	4	23
2	-31	31	31	159	0	38
3	-31	36	18	159	4	8
4	-31	33	47	159	8	3

The 2 dimensional area of LHI is 1,455 ha. The 3 dimensional area when considering the rugged topography is approximately 2,100 ha.

The Proposed REP will occur over the entire LHIG, excluding Balls Pyramid which therefore is defined as the study area.

Potential impacts to the Lord Howe Island Marine Park (NSW) under the NSW *Marine Estate Management Act 2014* and threatened species listed under the NSW *Fisheries Act* 1994 have been addressed in a separate application to the NSW Department of Primary Industries.

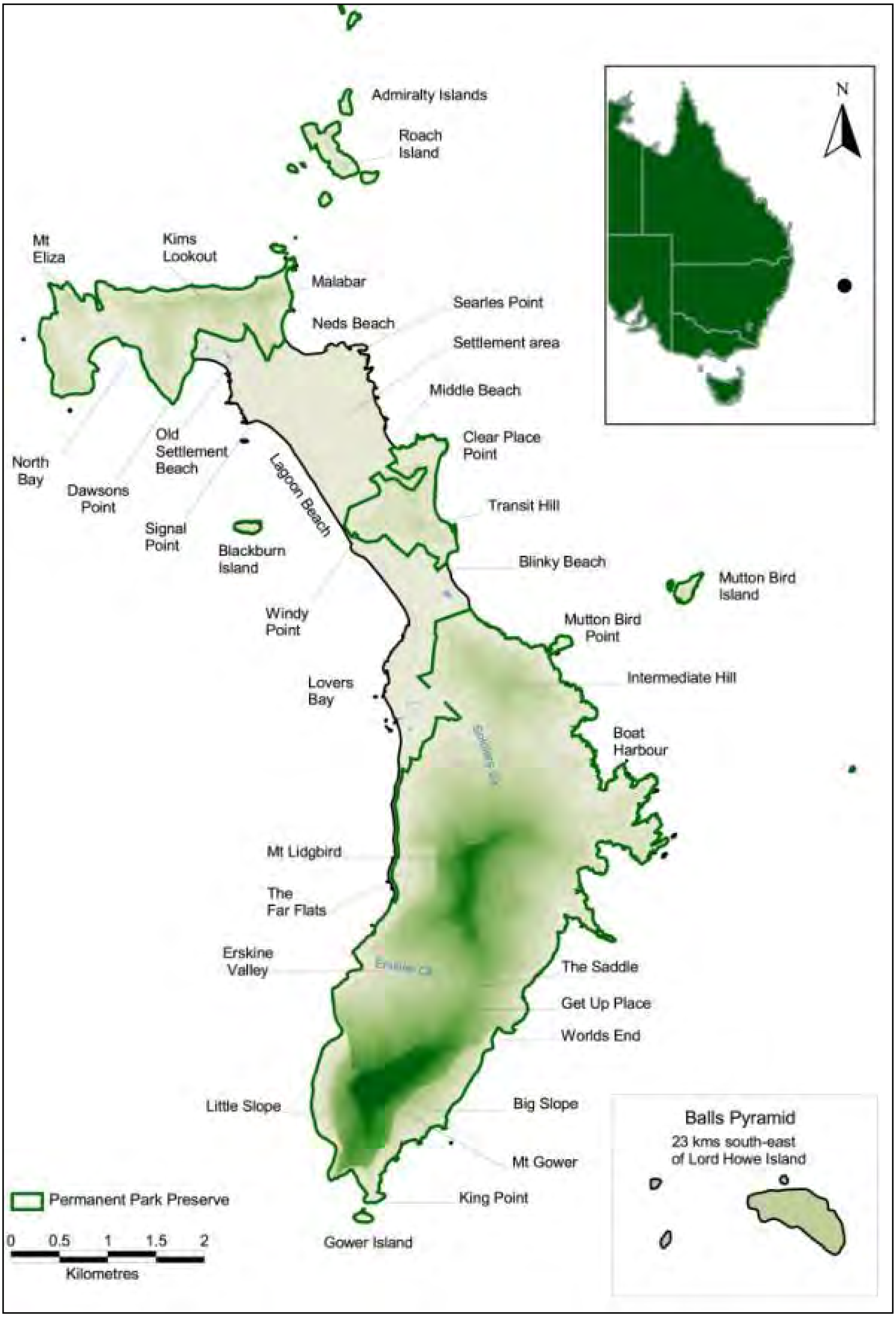


Figure 21 Lord Howe Island Locality (DECC, 2007)

Figure 22 Lord Howe Island overview (DECC, 2007).

Figure 23 Lord Howe Island as seen from the North

(Image courtesy Dave Kelly)

Figure 24 Lord Howe Island as seen from the South

(Image courtesy Ian Hutton)

2.2.3 Description of Study Area

The LHIG supports a diverse terrestrial flora and fauna with a high degree of endemic species and communities. Many biogeographical relationships are discernible, with components of the terrestrial flora and fauna exhibiting affinities with eastern Australia, New Zealand, Norfolk Island and New Caledonia (DECC, 2007). The biodiversity of the island has been well studied over a long period of time. A summary of relevant studies is found in section 4.

2.2.3.1 Flora

There are currently believed to be approximately 240 native species of vascular plants in the LHIG (DECC, 2007). While the vegetation has affinities with the flora of northern New South Wales, southern Queensland, New Zealand, Norfolk Island and New Caledonia, there is a high level of endemism (113 species (47%)). The high degree of endemism is illustrated not only at the species level, but also at the generic level, where there are five endemic vascular plant genera including three endemic palms (DECC, 2007).

Approximately 270 species of vascular flora have naturalised (introduced species that are reproducing in the wild) on the LHIG since settlement.

The non-vascular flora of terrestrial and freshwater habitats (bryophytes, lichens and freshwater algae) is less well known, but is also considered to be diverse with many endemic species. For example, 105 species of mosses are known, 21 (20%) of which are endemic.

2.2.3.2 Fauna

Birds

Similar to other oceanic islands, the terrestrial fauna of the LHIG is dominated by birds. The LHIG forms one of the major seabird breeding sites in the Tasman Sea and is thought to be home to the most diverse and largest number of seabirds in Australia (DECC, 2010). Many of these species are believed to have important breeding populations on the LHIG; they are the only major breeding locality for the Providence Petrel, and contain one of the world's largest breeding concentrations of Red-tailed Tropicbird.

182 species have been recorded from the LHIG of which 20 are resident land birds, 14 are breeding seabirds, 17 are regular visitors and 120 are vagrants (DECC, 2010). 34 species have been recorded as regularly breeding on the islands. Many of the breeding seabirds found on the islands are listed migratory species.

The LHIG is the only known breeding locality in the Australasian region for the grey ternlet and Kermadec petrel, and is the southernmost breeding locality in the world for the masked booby, the sooty tern and common noddy.

Endemic land birds on the islands include the Lord Howe Woodhen, Lord Howe golden whistler and Lord Howe currawong. Nine land birds are believed extinct, five of which have been at least partially attributed to the presence of rats.

Mammals

The only known native mammal on the LHIG is the large forest bat (*Vespadelus darlingtonii*) (DECC, 2010). The Lord Howe Long-eared Bat (*Nyctophilus howensis*) is thought to be extinct (DECC, 2007).

Reptiles

There are two native reptiles, the LHI skink and LHI gecko (DECC, 2010). Both are now severely reduced in their range and abundance on the main island due to predation by rats; however both are present on Blackburn Island, the Admiralty group, Mutton Bird Island and Balls Pyramid. Until recently it was believed that both species also occurred on Norfolk Island, although recent genetic work indicates they are separate species.

Invertebrates

The LHIG has a very complex and biogeographically interesting invertebrate fauna, characterised by relatively high species richness (>1600 species recorded) and high endemism (DECC, 2010). This includes 157 land and freshwater snails, 464 beetles, 27 ants, 183 spiders, 21 earthworms, 137 butterflies and moths and 71 springtails. The rate of discovery of new species remains high, indicating that numerous endemic species are yet to be discovered (DECC, 2007).

Of particular note are the Lord Howe Island phasmid, which was previously thought to be extinct, the wood-feeding cockroach, and the darkling beetle which are no longer found on the main island, but are restricted to outlying, rodent-free islands (DECC, 2007).

There are more than 50 endemic species of land snails found in the island group. One large species, *Epiglypta howinsulae*, has already become extinct and another large species, the Lord Howe placostylus (*Placostylus bivaricosus*), is endangered with one of its subspecies presumed extinct (DECC, 2010). A new species of

Phasmid *Davidrentzia validus* was discovered in 1988, with only 12 records of the species been detected since then. The species is considered at risk from predation by rodents.

It is believed that numerous invertebrate extinctions have occurred including one endemic ant and ten endemic beetles (DECC, 2007).

Freshwater Fishes

Three species of freshwater fish (two eels and a galaxias) occur on the LHIG (DECC, 2007).

2.2.3.3 Hydrology

A small number of ephemeral streams are found on LHI. It is anticipated that a small amount of pellets may fall into these streams as part of the aerial distribution where they will sink and disintegrate rapidly. The Brodifacoum from these pellets will settle and bind strongly to sediments.

LHI has very limited groundwater which is predominantly used by a small number of accommodation providers to supplement rainwater for toilet flushing, washing, gardens. Some properties occasionally use bore water for drinking and stock watering. Several of the properties have desalination plants for treatment of groundwater before use.

The low-moderate application rate of Brodifacoum (0.4 g/ ha) for the LHI REP and one off eradication means that any environmental contamination would be of a sufficiently low magnitude as to not present a significant risk. Any potential impacts are likely to be very localised and temporary in nature.

2.2.3.4 Soil and Vegetation

The LHIG is a volcanic remnant characterised by volcanic basalt outcrops and sedimentary calcarenite (mostly coral fragment) formations in the low slopes and low lying areas. Soil profiles are limited across the island.

Soil on the island is unlikely to be impacted by the proposal. Fate of the bait and the toxin in soil is described in Section 5.2.1. The pellet will degrade in approximately 100 days. Manner of use of Brodifacoum baits and physical and chemical properties of Brodifacoum suggests little accumulation of Brodifacoum in soil, with concentrations of Brodifacoum in soil predicted to be negligible/low and occurring only sporadically according to bait treatment timings. Brodifacoum is strongly bound to soil particles, and radio-labelled Brodifacoum was found to be effectively immobile (i.e. not leached) in four soil types (World Health Organisation 1995). It is broken down by soil micro-organisms to its base components, carbon dioxide and water, the half-life being 12-25 weeks (Soil Degradation for 50% of the compound (DT_{50}) – typical 84 days: Field – 157 days; Shirer 1992). Any potential impacts are likely to be very localised and temporary in nature. The rodent eradication project will lead to an overall reduction in rodenticide use in the long term.

2.2.3.5 Gradient

The LHIG is a sea mount chain. The lagoon, which is approximately 6 kilometres by 1.5 kilometres at its widest point, has an average depth of just 2–3 metres, although its deeper holes can be up to 10 metres deep. The lagoon fringing reef is pierced by four principal passages: Erscotts Passage, South Passage and Erscotts Blind Passage to the south; and North Passage, the latter constituting the main entrance and being 4–6 metres deep (Allen *et al.*1976). On the seaward edge of the lagoon, the shoreline drops off steeply to depths of 15–20 metres and then gradually slopes to deeper water (Allen *et al.*1976). Around other parts of the island, the shorelines are steep, with rocky cliffs extending to the water's edge adjacent to water depths of 10–20 metres (MPA, 2010).

2.2.3.6 Current State of the Environment

The LHIG is a World Heritage property and is often considered pristine. The LHIG however has not escaped significant impacts due to human activity and introduced species. Current and historical key threats (DECC, 2007) include:

- habitat clearing and modification particularly for accommodation and farmland in the settlement area
- vegetation windshear and associated canopy dieback
- trampling, browsing and grazing from introduced cattle and horses and historically goats
- weed invasion from 270 plant species that have become naturalised including 68 declared noxious weeds
- predation by rodents
- predation and competition from other introduced animals including:

- 18 land bird species and five sea bird species that have established populations on the LHIG since human settlement
- Cats, goats and pigs that have now been eradicated
- African Big-headed Ant *Pheidole megacephala*. Number on the island have been significantly reduced and an eradication program is well commenced (expected eradication 2018)
- Approximately 100 other species of introduced invertebrates
- Bleating Tree Frog *Litoria dentata* and Grass Skink *Lampropholis delicate*

Other threats include sea bird ingestion of plastic, by catch from fishing, traffic impacts to shearwaters and woodhens, *Phytopthora* infestation, habitat fragmentation and climate change.

Threats are managed under the LHI Biodiversity Management Plan (DECC, 2007) and through significant investment in conservation from the LHIB and numerous funding partners.

A 2014 World Heritage property outlook assessment undertaken by the IUCN considered that overall management of the LHIG World Heritage property was "Good", the highest rating (IUCN, 2016). It stated:

"Good management is in place and provided resourcing and commitment to addressing the key threats to World Heritage values are sustained the values should remain preserved. The outstanding scenic values are likely to remain in good condition and subject to funding and effective program implementation the significant natural habitat; rare plants and threatened wildlife are likely to persist in their current or an improved condition"

The assessment recognised the threat to the LHIG World Heritage values from rodents as a "High Threat" and recommended implementation of the rodent REP to address the threat (IUCN, 2016).

2.2.3.7 Indigenous Heritage Values

No indigenous groups or indigenous heritage values are found on the LHIG.

2.2.3.8 Other Important or Unique Values of the Environment

Approximately 75% of LHI plus all outlying islands, islets and rocks above the high water mark are protected under the Permanent Park Preserve (PPP), which has similar status to that of a national park. The PPP area is managed by the LHIB.

2.2.3.9 Climate

The LHIG is considered to have a sub-tropical climate moderated by oceanic air currents and mild sea temperatures. Winters are wet and cool whilst summers have less rainfall and are mild or warm. A summary of key climate statistics during the proposed operational period is shown below (BOM, 2016).

Table 5 Lord Howe Island Climate

Key Climate Statistics	Jun	Jul	Aug	Sep
Mean maximum temperature (°C)	19.9	18.9	19.0	20.0
Mean minimum temperature (°C)	14.9	13.9	13.5	14.5
Mean rainfall (mm)	171.2	144.0	108.8	114.0
Mean number of days of rain ≥ 1 mm	17.2	17.8	15.0	11.9
Mean 9am relative humidity (%)	66	67	65	68
Mean 9am wind speed (km/h)	21.9	21.8	21.5	21.0
Mean 3pm relative humidity (%)	66	66	64	68
Mean 3pm wind speed (km/h)	22.5	23.9	23.0	22.4

2.3 Relevant Plans and Maps

A plan of the project area including land tenure is found in Figure 25 below.

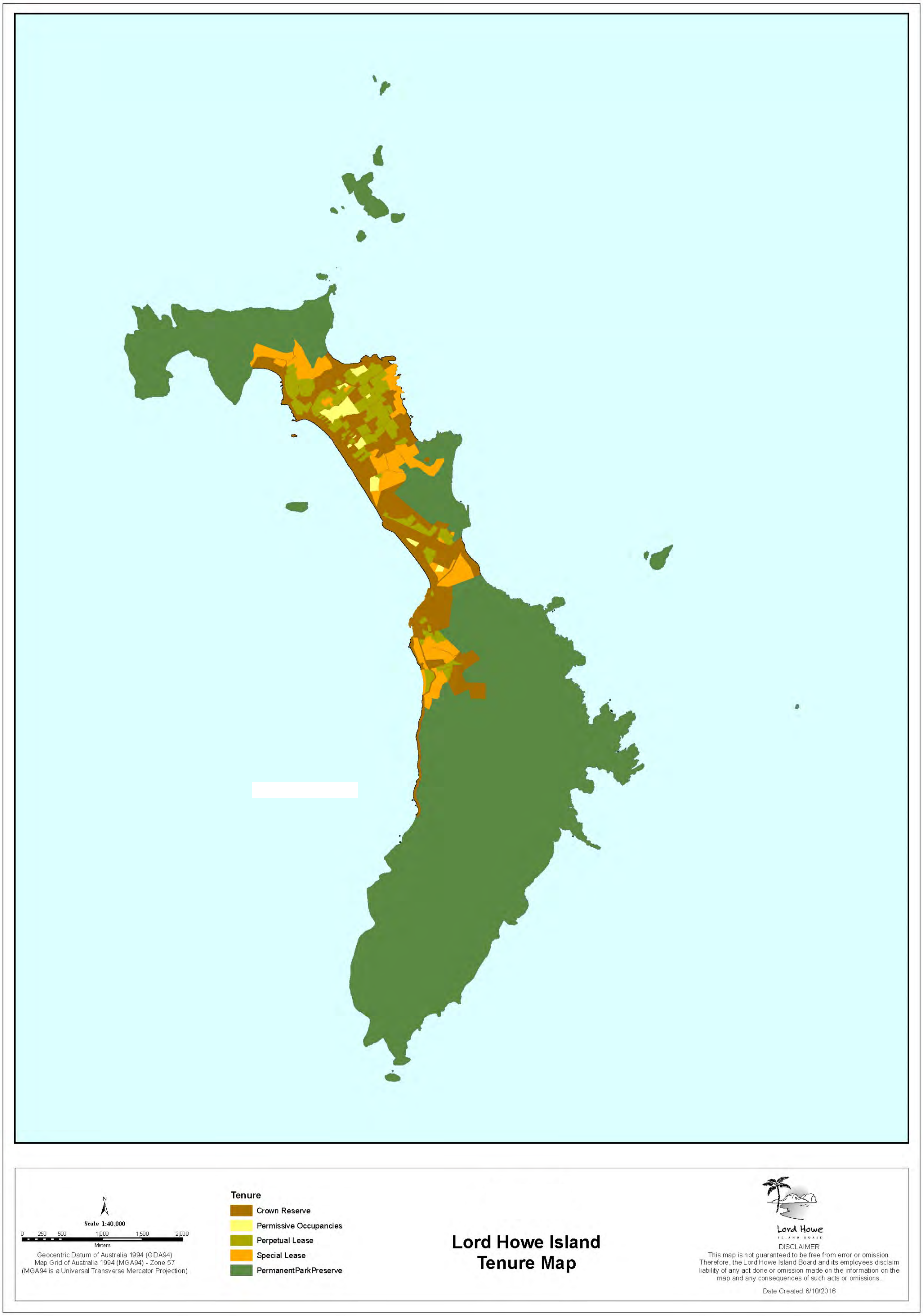


Figure 25 LHI Tenure Map

2.4 Land Tenure Information

2.4.1 Local Government Area

The LHIG is part of the State of New South Wales and, for legal purposes, is regarded as an unincorporated area administered by the LHIB, a statutory authority established under the provisions of the *Lord Howe Island Act, 1953* (the Act). The LHIB is directly responsible to the NSW Minister for the Environment and comprises four Islanders elected by the local community and three members appointed by the Minister. It is charged with the care, control and management of the Island's natural values and the affairs and trade of the Island. It is also responsible for the care, improvement and welfare of the Island and residents.

The LHIB carries out all local government functions on behalf of approximately 350 Island residents. It controls all land tenure on the island and administers all residential and other leases in accordance with the Act. The LHIB manages the Island PPP and the protection and conservation of the Island's fauna and flora.

The LHIB also undertakes the role of the relevant Local Government Authority and Consent Authority under the NSW *Environment Planning and Assessment Act, 1979*. Relevant Contact is Dave Kelly, Manager Environment and Community Development P.O. Box 5, LHI, 2898. Telephone 02 6563 2066.

2.4.2 Land Tenure

The LHIG consists of the following lease types:

- The Permanent Park Preserve
- Crown Land
- Permissive Occupancy
- Perpetual Leases
- Special Leases

Lease Boundaries are shown on Figure 25.

2.4.3 Land Use

A settlement of approximately 350 inhabitants occurs in the northern section of LHI and covers about 15% of the island; approximately 400 hectares. The settlement area is used predominantly for residential, pastoral/agricultural and commercial uses.

Ocean waters from the high water mark to three nautical miles offshore are protected under the NSW Lord Howe Island Marine Park (approximately 47,000 hectares) and are the responsibility of the New South Wales Marine Park Authority.

Tourism is the most significant industry and major source of income on the Island and is heavily focused around the world heritage values of both the marine and terrestrial environments. Key tourism activities include:

- Marine activities in the Marine Parks such as beach and reef walking, swimming, snorkelling, scuba diving, fish feeding, surfing, underwater photography, windsurfing, sea-kayaking, fishing, sightseeing cruises and eco tours, and other water sports and beach activities
- Terrestrial activities such as hiking, bird watching, golf, walking, bike riding, sightseeing and eco tours, lawn bowls.

Export of the Lord Howe Kentia Palm and to a lesser extent, three other palm species endemic to LHI, has been a major industry since the late 1800s. The species is now one of the most popular decorative palms in the world. Seed is collected from natural forest and plantations and then germinated in soil-less media and sealed from the atmosphere to prevent contamination. After testing, they are picked, washed (bare-rooted), sanitised and certified then packed and sealed into insulated containers for export. The industry has suffered a decline on LHI as a result of increased global competition from foreign plantations and to a lesser extent, rodent impacts. The Kentia Palm Nursery formerly managed by the LHIB was bought by a private consortium in 2014 who are re-establishing the industry. The nursery currently exports 400,000 seedlings year.

2.5 Vegetation

2.5.1 Vegetation Communities

Over thirty vegetation communities have been described from the LHIG and many of these are endemic or have highly restricted distributions. Eighteen of these communities are considered to be of particular conservation concern (DECC, 2007).

The dominant vegetation on the island is Closed Forest, the major sub-formations of which—Rainforest, Megaphyllous Broad Sclerophyll Forest (mainly palms) and Gnarled Mossy Forest—cover 54%, 19% and 2% of the island respectively. A full description of the vegetation was compiled by John Pickard of the National Herbarium of NSW, Royal Botanic Gardens, and published in the journal *Cunninghamia* in 1983 (Volume 1, pages133-265) (Pickard, 1983). The methods he used involved transects, the examination of aerial photographs and subsequent ground truthing. He discounted the structural classification of Specht for that of F.R. Fosberg (1967, A classification of vegetation for general purposes. In *Guide to the Checklist for IBP Areas*, G.F. Peterken, editor; pp. 55-120; IPB Handbook 4). Pickard describes the physiography, community structure and floristics, and history of disturbance for each plant association. Although published in 1983, little has changed in the intervening years because the island was declared a World-Heritage site in 1982. A summary is included in the LHI Biodiversity Management Plan (DECC, 2007) which is included as Appendix H – LHI Biodiversity Management Plan.

2.5.2 Remnant native vegetation

Most of the island (87%) is considered remnant vegetation (DECC, 2007). Closed forest is the most extensive remnant vegetation, covering over half of the main island and extending from the lowlands to the mountain tops. The remaining natural vegetation cover consists of scrubs, herbfields, grasslands and the vegetation of exposed cliff and littoral terrains. Thirty four vegetation communities are defined for the LHIG (DECC, 2007) and many of these are endemic or have highly restricted distributions. Eighteen of these communities are considered to be of particular conservation concern (DECC, 2007) due to threatening processes that are causing, or likely to cause their decline including impacts from introduced rodents.

The proposal is unlikely to impact on remnant vegetation. In contrast, if the proposal proceeds and rodents are eradicated, significant improvement is expected for remnant vegetation communities.

2.6 Consequences of Not Proceeding with the Project

Introduced rats and mice are currently having a significant impact on the biodiversity, World Heritage and socio-economic values of LHI (DECC, 2007). The LHIB currently implements a rodent control program (covering approximately 10% of the island) aimed at reducing rodent impacts but even with this in place, neither the rat or mouse population is being reduced to a level that reduces landscape scale ecological impacts. Even with the current control program in place rodent population estimates from the entire island range from 63,000 to 150,000 rats and 140, 000- 210,000 mice (30 -74 rats per hectare and 67-100 mice per hectare (DECC, 2007a and 2008)).

Failure to proceed with the REP will result in continuing adverse consequences to these values through:

- Ongoing impacts to biodiversity including population declines and potential extinctions as a result of rodent predation and competition.
- Continuation of the current (or expanded) rodent control program (and the continuous presence of poison baits in the environment) essentially in perpetuity. This presents ongoing risks of poisoning for non-target species and high probability that rodents will develop a resistance to poison.
- Potential further degradation of World Heritage values (including endemic and threatened species) and the potential for the LHIG to be inscribed on the “World Heritage in Danger List”.
- Ongoing socio-economic impacts associated with rodents.

A one off, planned eradication will eliminate these risks. Further detail is provided in the following sections.

2.6.1 Failure to Mitigate Rodent Impacts to Biodiversity

Globally the introduction and spread of invasive species is a leading cause of biodiversity loss. Invasive species are particularly destructive to island species and ecosystems. Nearly two-thirds of recent extinctions (Jones *et al.* 2016) and 75% of all recorded terrestrial vertebrate extinctions occurred on islands and most were caused fully or in part by invasive species (McCreless *et al.* 2016). Currently, 40% of species threatened with global extinction are from islands. Eradication of invasive mammals has recently been modelled as having the potential to prevent up to 75% of extinctions of threatened species on islands (ibid).

Exotic rodents, particularly ship rats and perhaps mice, have been a key (and often the critical) cause of extinction, extirpation (local population loss) and decline of many native species, adverse changes to island ecosystems, as well as economic damage to island peoples' livelihoods and potentially to their health (DEWHA, 2009). Ship rats alone are responsible for the severe decline or extinction of at least 60 vertebrate species (Towns *et al.* 2006), and currently endanger more than 70 species of seabird worldwide (Jones *et al.* 2008). They suppress plants and are associated with the declines or extinctions of flightless invertebrates, ground-dwelling reptiles, land birds and burrowing seabirds (Towns *et al.* 2006). Mice have also been shown to impact on plants, invertebrates and birds (Angel *et al.* 2009).

On LHI, rodents are implicated in the extinction of at least five endemic birds and at least 13 invertebrates (DEWHA, 2009). They are also recognised in the LHI Biodiversity Management Plan (DECC, 2007) as a threat to at least 13 other bird species, 2 reptiles, 51 plant species, 12 vegetation communities and numerous threatened invertebrates on the island (ibid) including TSC listed species shown below in Table 6 . Further detail on rodent impacts on LHI is provided in Section 2.8.

Table 6 TSC Act Listed Species Currently Impacted by Rodents on the LHIG (from DECC, 2007 and Carlile et al. 2016)

CE = Critically Endangered, E = Endangered, V = Vulnerable

	Common name	**Scientific Name**	**Endemic**	**TSC Act**
Birds	Black-winged petrel	*Pterodroma nigripennis*	-	V
	Flesh-footed shearwater	*Ardenna carneipes*	-	V
	Grey ternlet	*Procelsterna cerulea*	-	V
	Kermadec petrel	*Pterodroma neglecta*	-	V
	Little shearwater	*Puffinus assimilis*	-	V
	Lord Howe woodhen	*Hypotaenidia sylvestris*	Yes	V
	Masked booby	*Sula dactylatra*	-	V
	Providence petrel	*Pterodroma solandri*	-	V
	White-bellied storm petrel	*Fregetta grallaria*	-	V
Reptiles	Lord Howe Island gecko	*Christinus guentheri*	-	V
	Lord Howe Island skink	*Oligosoma lichenigera*	-	V
Invertebrates	Lord Howe Island phasmid	*Dryococelus australis*	Yes	CE
	Lord Howe placostylus	*Placostylus bivaricosus*	Yes	E
	Whitelegge's land snail	*Pseudocharopa whiteleggei*	Yes	CE
	Masters' charopid land snail	*Mystivagor mastersi*	Yes	CE
	Mt Lidgbird charopid land snail	*Pseudocharopa lidgbirdi*	Yes	CE
	Magnificent Helicarionid land snail	*Gudeoconcha sophiae magnifica*	Yes	CE
	LHI Earthworm	*Pericryptodrilus nanus*	Yes	E
	LHI Wood feeding Cockroach	*Panesthia lata*	Yes	E
Plants	Little mountain palm	*Lepidorrhachis mooreana*	Yes	CE
	Phillip Island Wheat Grass	*Elymus multiflorus var. kingianus*	-	CE

Impacts of rodents on some species on LHI and subsequent consequences if the REP did not proceed are demonstrated in both *Key Threatening Process* and *Threatened Species listings* under the *EPBC* Act and TSC Act.

Predation by exotic rats on Australian offshore islands is listed a Key Threatening Process under the *EPBC* Act (DEWHA, 2009). The eligibility criteria for a process to be listed as a key threatening process under the EPBC Act are:

a) it could cause a native species or an ecological community to become eligible for listing in any category, other than conservation dependent; or

b) it could cause a listed threatened species or a listed threatened ecological community to become eligible to be listed in another category representing a higher degree of endangerment; or

c) it adversely affects 2 or more listed threatened species (other than conservation dependent species) or 2 or more listed threatened ecological communities.

Exotic rodents on islands were considered by the commonwealth Threatened Species Scientific Committee (TSSC, 2006) in their eligibility assessment to meet all three of the above criteria. Specific examples provided by the TSSC in their assessment included the following LHI species:

- Criterion A: The LHI Wood-Feeding Cockroach (*Panesthia lata).* The TSSC concluded that predation by exotic rats could cause this species to become eligible for listing as threatened under the EPBC Act.
- Criterion B: Lord Howe Flax Snail (*Placostylus bivaricosus)*. The TSSC concluded that predation by rodents could cause the species to become eligible for listing in another category representing a higher degree of endangerment (critically endangered).
- Criterion C: Lord Howe Flax Snail (*Placostylus bivaricosus);* Lord Howe Island Gecko (*Christinus guentheri)* and Lord Howe Island Phasmid (*Dryococelus australis).* The TSSC concluded that rodents are currently or could adversely affect these species.

In NSW, *Predation by the Ship rat on Lord Howe Island* is listed as a key threatening process. Eligibility criteria include for listing as Key Threatening Process are:

- it adversely affects threatened species, populations or ecological communities
- it could cause species, populations or ecological communities that are not threatened to become threatened.

In their final determination in 2000 the NSW Scientific Committee was of the opinion that Predation by the Ship Rat, Rattus rattus on Lord Howe Island adversely affects two threatened species and could cause species or populations that are not threatened to become threatened.

The EPBC Act *Guidelines for Assessing the Conservation Status of Native Species* (TSSC, 2014) and NSW *Threatened Species Conservation Regulation 2010* provide guidance on eligibility criteria for listing of threatened species including probability of extinction. Both eligibility criteria are closely aligned to the International Union for Conservation of Nature (IUCN) Red List Categories and Criteria (IUCN, 2012) which is used to maintain the Red List of Threatened Species (also known as the IUCN Red List), the world's most comprehensive inventory of the global conservation status of biological species.

Rodents are listed as a key threat to many of the TSC Act listed threatened species on LHI. Continued predation and competition from rodents as a result of not proceeding with the REP could lead to further population declines and increased risk of extinction. Current and potential threatened species listings under various TSC / IUCN categories below in Table 7, highlight the risk of further population declines and potential extinctions if the REP did not proceed. Many more species that could experience population declines are listed in Appendix 3 of the LHI BMP (DECC, 2007).

Table 7 Potential Population Declines of LHI Species

TSC Act / EPBC/ IUCN Category	**Definition and Probability of Extinction**	**Current and potential LHI species listings**
Critically Endangered	Is considered to be facing an extremely high risk of extinction in the wild. Probability of extinction in the wild is at least 50% within 10 years or three generations, whichever is the longer (up to a maximum of 60 years).	Currently listed: • Whitelegge's land snail (*Pseudocharopa whiteleggei*) • Masters' charopid land snail (*Mystivagor mastersi)* • Mt Lidgbird charopid land snail (*Pseudocharopa ligdbirdi)* • Magnificent Helicarionid land snail (*Gudeoconcha sophiae magnifica)* • Little Mountain Palm (*Lepidorrhachis mooreana*) • Phillip Island Wheat Grass (*Elymus multiflorus var.*

		Kingianus) • *Calystegia affinis* Potential Listing: • Lord Howe Placostylus (*Placostylus bivaricosus*). Currently listed as Endangered • *Chionochloa howensis* (not listed) • *Passiflora herbertiana* ssp. *insulae-howe*i (not listed) • Gnarled mossy cloud forest (Threatened Ecological Community, not listed)
Endangered	Is considered to be facing a very high risk of extinction in the wild. Probability of extinction in the wild is at least 20% within 20 years or five generations, whichever is the longer (up to a maximum of 100 years).	Currently listed: • Lord Howe Placostylus (*Placostylus bivaricosus*) • *Xylosma parvifolia* • *Geniostoma huttonii* • Rock Shield Fern (*Polystichum moorei)* Potential Listing: • LHI Gecko (*Christinus guentheri*) Currently listed as Vulnerable • LHI Skink (*Oligosoma lichenigera*) Currently listed as Vulnerable • *Cosprosma inopinata* (not listed) • Wood-Feeding Cockroach (*Panesthia lata)*
Vulnerable	Is considered to be facing a high risk of extinction in the wild. Probability of extinction in the wild is at least 10% within 100 years.	Currently listed: • Kermadec petrel (*Pterodroma neglecta*) • White-bellied storm petrel (*Fregetta grallaria*) • Lord Howe woodhen (*Hypotaenidia sylvestris*) • LHI Gecko (*Christinus guentheri*) • LHI Skink (*Oligosoma lichenigera*)

In addition to biodiversity losses, failure to proceed with the REP will negate the potential for the reintroduction of extirpated species confined to offshore islands (i.e. the Wood-Feeding Cockroach, Phasmid, Kermadec petrel, and White-bellied storm petrel), reintroduction of ecological equivalent extinct species and recovery of threatened species to enable restoration of ecological processes. None of these conservation actions would be possible with the ongoing presence of rodents on LHI. Failure to proceed with eradication will negate the restoration of these essential ecological functions.

Therefore it is highly likely that failure to proceed with the REP will allow continued negative impacts of rodents on biodiversity on LHI through:

- An increased risk that several species could experience population declines and become eligible for listing under any category under the TSC Act.
- An increased risk that several TSC Act listed threatened species could experience population declines and become eligible to be listed in another category representing a higher degree of endangerment
- An increased extinction probability for several species.

These impacts have a high probability of being avoided if the REP proceeds as evidenced on Macquarie Island. Since eradication of rabbits, rats and mice in 2011, eight species of birds have an improved conservation outlook (Birdlife Australia, 2016).

2.6.2 Failure to Mitigate Impacts of Ongoing use of Poison

Failure to proceed with the REP will mean continuation of the current (or an expanded) rodent control program (and the continuous presence of poison baits in the environment) essentially in perpetuity. The LHIB undertakes a rodent control program however many residents also carry out their own rodent baiting (sometimes in contravention to rodenticide label requirements). This control program only covers about 10% of the island. In order to mitigate biodiversity, world heritage and socio-economic impacts, it is likely that if the eradication did not proceed, an expanded control program would need to be implemented to protect ecological assets. Consequences of ongoing use of poison for rodent control on LHI include:

- Ongoing and continual exposure to poison for non-target species. For example in 2011, eight out of ten deceased woodhens examined for cause of death tested positive to Brodifacoum residue likely as a result of community rodent baiting. Numerous other woodhens have been observed exhibiting symptoms of Brodifacoum poisoning and many have recovered after being administered vitamin K antidote (Bower, H. *pers comms*, 2016). Ongoing exposure also increases the risk to non target species of bioaccumulation through consumption of poisoned invertebrates.
- Significant potential for rodents on LHI to develop bait shyness or resistance to poison. Mice have already developed a resistance to warfarin on Lord Howe Island (Billings, 2000). The suite of second-generation anticoagulants, which includes Brodifacoum, is the only tool currently available for effectively eradicating rodents from islands. Resistance to these poisons, if it develops, will make eradication impossible and will greatly restrict control, meaning impacts to biodiversity will be greatly magnified.
- Ongoing potential exposure to poison for humans particularly small children and pets.

A one off, planned eradication will eliminate these risks.

2.6.3 Failure to Mitigate Rodent Impacts to World Heritage Values

As a signatory to the “Convention Concerning the Protection of the World Cultural and Natural Heritage”, Australia has agreed to:

- “identify, protect, conserve, and present World Heritage properties”; and to
- “undertake 'appropriate legal, scientific, technical, administrative and financial measures necessary for the identification, protection, conservation, presentation and rehabilitation of this heritage”

A 2014 World Heritage property outlook assessment undertaken by the IUCN considered the threat to the LHIG World Heritage values from rodents as a “High Threat” and recommended implementation of the rodent REP to address the threat (IUCN, 2016).

Failure to mitigate the threat of rodents on the LHIG could potentially result in the further degradation of World Heritage values (including endemic and threatened species) and the potential for the LHIG to be inscribed on the “World Heritage in Danger List”. The World Heritage Committee has previously inscribed other World Heritage properties to the “In Danger List” as a result of invasive species impacts (UNESCO, 2009). Examples include Djoudj National Bird Sanctuary (Senegal) listed in 2000, Galápagos Islands (Ecuador) in 2007 and Río Plátano National Park (Honduras) 1996.

Inscription to the “World Heritage in Danger List” would have severe reputational consequences for Australia. As the World Heritage values contribute immensely to the island’s economy and the wellbeing of its residents any degradation of the World Heritage values would also have a severe impact on the Island’s economy.

2.6.4 Failure to Mitigate Socio-Economic Impacts of Rodents

Rodents on LHI have the following socio-economic impacts:

- Impacts on community amenity though hygiene issues and spoiling of food stuffs including locally grown fruit and vegetables.
- Impacts to the tourism industry through negative interactions with rodents or rodent control program
- Impacts to the Kentia Palm industry through predation of seeds and seedlings
- Ongoing costs of rodent control. The LHIB currently spends $85,000 per annum on its rodent control program. Many residents also implement their own rodent control at their own cost (estimated to be $4,800 per annum).
- Ongoing potential for rodent borne diseases.

Failure to proceed with the REP will ensure the continuation of socio economic impacts from rodents on LHI and failure to reap the $141M in biodiversity and tourism benefits expected from the REP Gillespie Economics, 2016).

2.7 Potential Impacts of the Project

- The proposed REP has the potential for the following environmental impacts:
- Pollution of air, soil or water
- Bioaccumulation of poison in the environment
- Mortality of non-target species due to primary poisoning from consumption of bait pellets. This is considered on an individual species level in sections below.
- Mortality of non-target species due to secondary poisoning from consumption of poisoned rodents, fish or invertebrates. This is considered on an individual species level in sections below.
- Bird strikes and collisions from helicopter activity. This is considered on an individual species level in sections below.
- Disturbance from helicopter activity. This is considered on an individual species level in sections below.
- Potential impacts as a result of handling and captive management during the captive management program. This is considered for woodhen and currawong below.
- long term changes to ecological relationships affecting threatened species following the eradication of rats and mice
- Cumulative impacts with other projects or threats.

2.7.1 Fate of the Bait and Toxin in the Environment

The Pestoff 20R bait pellets are made from compressed finely ground cereal, and are designed to break down following absorption of moisture from soil or precipitation. Baits swell, crack and then crumble over time and the rate of pellet breakdown is influenced by temperature, rainfall and invertebrate activity.

The Pestoff 20R pellets will disintegrate very rapidly, when immersed in water, with the actual rate dependant on turbulence, flow, wave and current action.

Brodifacoum itself is highly insoluble in water (World Health Organisation 1995). It is slightly soluble in water at pH 9.2 or above but solubility reduces exponentially with decreasing pH. It has an estimated solubility of <10 parts per million in fresh water at pH 7 and 20^{O} C (U.S. EPA 1998). For comparison, table salt has a solubility of 1,200,000 mg/L under similar conditions.

Note: Solubility is the determining factor for the pesticide pathway beyond the bait in soil or water. For insoluble pesticides, fate in water (and therefore plants) is insignificant because negligible amounts of poison are dissolved.

During a laboratory study the stability of radio-labelled Brodifacoum in sterile buffered water showed that the half-life of Brodifacoum at pH 7 and 9 was much longer than 30 days. A precise calculation of the half-life was not possible because the degradation seen after one day did not continue (World Health Organisation 1995).

In laboratory studies using radioactive-labelled Brodifacoum, less than 2% of Brodifacoum added to any of four soil types tested, leached more than 2 cm (WHO, 1995) suggesting it is effectively immobile.

Brodifacoum in water will settle and bind to sediments and break down slowly. This is discussed in the soil and sediments sections below.

2.7.1.1 Fate in the Air

Brodifacoum is a solid and does not readily volatise or enter the atmosphere (Toxikos, 2010).

The baits are small, solid and specifically designed for aerial application and to minimise dust. Torr and Agnew (2007) found approximately 130 - 150 g fine material (<2mm size) in a 25 kg bag of Pestoff 20R bait as delivered. They also determined the amount of fines produced by mechanical abrasion during aerial dispersion from a number of different style hoppers to be approximately 50 – 330 g per bag. Therefore the maximum amount of fine particles (<2mm) from aerial application is assumed to be 150g as delivered in bags plus 330g produced during dispersion = 480 g (rounded up to 500 g). This equates to approximately 2% of the total bait content.

At the LHI REP proposed application rate of 12 kg/ha bait (first drop) and concentration of 20 mg/kg Brodifacoum (20 ppm) this equates to 240 mg/ha of Brodifacoum. If 2% of this 240 g/ha is fines (<2mm) this equates to 4.8 mg/ha (4.8 g/10000m^2) Brodifacoum dust. At a drop height of 50m this equates to 0.0000096 mg/m^3 or 0.0000096 ug/L Brodifacoum dust in the air column. Fine Particles in the air column are expected to settle on the ground reasonably quickly.

The occupational exposure limit applied to protect workers from the effects of Brodifacoum during manufacture of rodent bait is 0.002 ug/L or (2 µg/m^3) (Syngenta 2006 cited in Toxikos 2010). Thus the maximum estimate of Brodifacoum in inhalable particulates in air during aerial broadcasting is many orders of magnitudes lower than the concentration used to protect workers so is therefore considered to present negligible risk to the environment. No air pollution is expected.

A study of dust dispersion from aerial application by spreader buckets of similar bait pellets (albeit with a different toxin) over three separate application sites was undertaken by Wright *et al* in 2002. The study sampled for downwind dust deposition at 200m intervals up to 1km of the treatment areas and showed that whilst some dust drift could occur, concentrations outside the treatment area were significantly lower than with in the treatment area. Toxikos (2010), considered potential human exposure to dust during the LHI REP treatment area assuming no wind dispersion (a worst case scenario) and found that risks to humans were negligible.

2.7.1.2 Fate in Soil

The Pestoff 20R bait pellets are made from compressed cereal, and are designed to break down following absorption of moisture from soil or rain. Baits swell, crack and then crumble over time and the rate of pellet breakdown is influenced by temperature, rainfall and microbial and invertebrate activity. Mould and fungi can appear rapidly as breakdown proceeds; once this has happened baits are less likely to be eaten by non-target species.

Baits not exposed to weathering remain toxic for a long period and any bait not exposed to weathering (i.e. in bait stations or in dwellings) will be collected approximately 100 days after the second treatment.

A condition index for assessing bait breakdown has been developed (Craddock, 2004). The index uses a 1-6 scale, based on the following conditions and illustrated in Figure 26:

- Condition 1: Fresh Pellets/Pellets not discernible from fresh bait.
- Condition 2: Soft pellets. <50% of pellet matrix is or has been soft or moist. Bait is still recognisable as a distinct cylindrical pellet; however cylinder may have lost its smooth sides. <50% of bait may have mould. Bait has lost little or no volume.
- Condition 3: Mushy Pellet. >50% of bait matrix is or has been soft or moist. <50% of pellet has lost its distinct cylindrical shape. >50% of bait may have mould. Bait may have lost some volume.
- Condition 4: Pile of Mush. 100% of bait matrix is or has been soft or moist. Pellet has lost distinct cylindrical shape and resembles a pile of mush with some of the grain particles in the bait matrix showing distinct separation from the main pile. >50% of bait may have mould. Bait has lost some volume.
- Condition 5: Disintegrating Pile of Mush: 100% of bait matrix is or has been soft or moist. Pellet has completely lost distinct cylindrical shape and resembles a pile of mush with >50% of the grain particles in the bait matrix showing distinct separation from each other and the main pile. >50% of bait may have mould. Bait has definitely lost a significant amount of volume.
- Condition 6: Bait Gone: Bait is gone or is recognisable as only a few separated particles of grain or wax flakes.

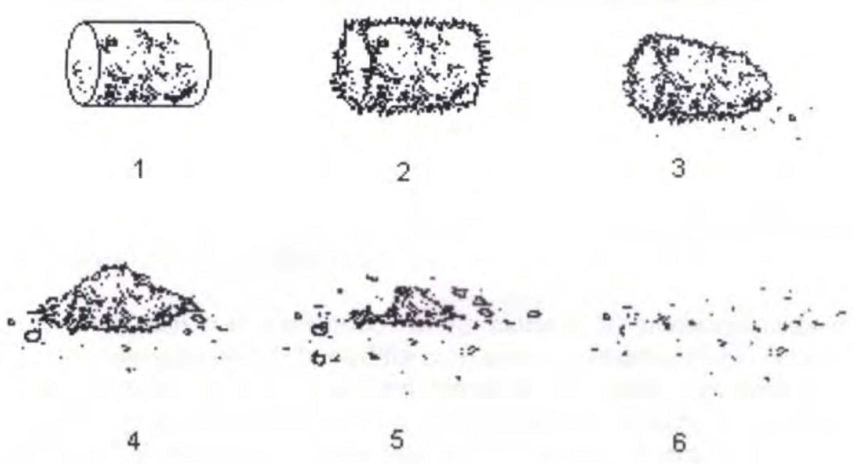


Figure 26 Illustration of typical bait condition (reproduced from Craddock, 2004)

Craddock (2004) monitored bait breakdown of 10mm pellets in a variety of habitats at Tawharanui Regional Park, north of Auckland in winter of 2003 as shown in Figure 27 below. All pellets had reached condition index score of 5.5 to 6 by 120 days.

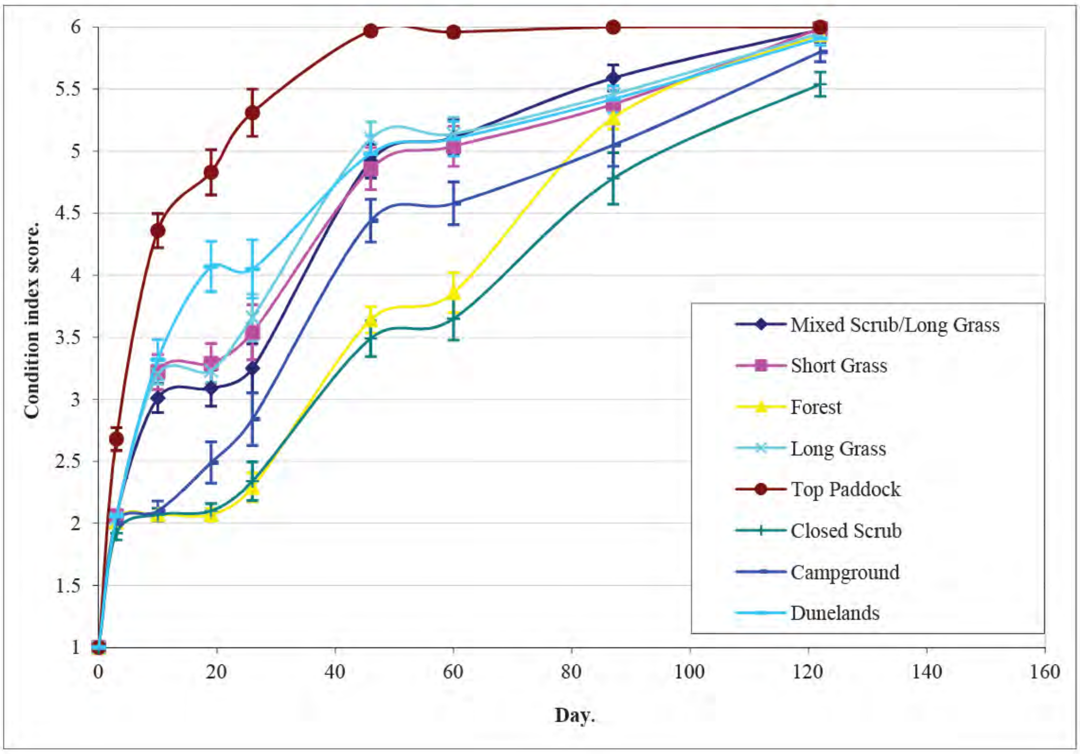


Figure 27 Bait Breakdown times of 10mm pellets (sourced from Craddock 2004)

A non-toxic bait trial using Pestoff 20R conducted on Lord Howe Island in August of 2007 examined bait breakdown and longevities in the environment (DECC, 2007a). Baits were covered with 6 mm wire mesh to prevent access by rodents or non-target species to trial baits. Cages containing 5.5 mm and 10 mm baits were placed at three locations: an open site with zero canopy cover, a medium cover site with a broken canopy and a full canopy cover site to monitor bait longevity. 100 baits were placed in each cage and samples removed at approximately weekly intervals and photographed to assess the status of the baits. Bait condition was assessed according to the Craddock (2004) condition scale described above. Results showed that both 5.5 mm and 10mm baits in all three habitats were in advanced stages of decomposition (at least Condition 4) after 55 days and 164.2 mm of rainfall. Further monitoring showed that all baits had completely disappeared after approximately 100 days.

Results of similar breakdown studies of Pestoff 20R in the environment on other temperate islands in New Zealand are shown below (Broome *et al.* 2016):

- Trials on Great Mercury island in New Zealand found that bait at 10 out of 12 bait sites monitored were completely broken down in five weeks. Baits monitored on sand dunes lasted 3 months;
- Bait monitored at Rangitoto and Motutapu Islands had disappeared completely from pasture in less than 1 month, from coastal broadleaf forest within two months and on bare lava field in ten months post baiting ;
- Baits on the Ipipiri Islands in the Bay of Islands were in the final stages of breakdown when monitored from pasture 28 days, from sand 91 days, from manuka scrub 147 days and from bare rock 203 days post baiting.

A New Zealand withholding period trial for sheep (Day, 2004), found Pestoff 20R baits degraded rapidly after placement in pasture and were severely degraded or completely gone by Day 60. Baits continued to contain some Brodifacoum for as long as they were present in the pasture, but all baits had completely disappeared by Day 90.

Although the cereal pellet disintegrates and disappears within 100 days or so, the poison takes longer to break down. Environmental factors such as temperature, rainfall, leaf litter, and presence or types of micro-organisms will determine breakdown times.

Manner of use of Brodifacoum baits and physical and chemical properties of Brodifacoum suggests little accumulation of Brodifacoum in soil, with concentrations of Brodifacoum in soil predicted to be negligible/low and occurring only sporadically according to bait treatment timings. Brodifacoum is strongly bound to soil particles, and radio-labelled Brodifacoum was found to be effectively immobile (i.e. not leached) in four soil types (World Health Organisation 1995). It is broken down by soil micro-organisms to its base components, carbon dioxide and water, the half-life being 12-25 weeks (Soil Degradation for 50% of the compound (DT_{50}) – typical 84 days: Field – 157 days; Shirer 1992).

Soil residue monitoring has been undertaken from various trials and eradication operations following the use of cereal-based Brodifacoum baits particularly in New Zealand. Soil residues have rarely been found in random sampling but have been detected from soil taken from near or under disintegrating baits. Operational monitoring reported to date suggests soil residues have fallen below detectable levels after two to six months. Results from field testing or monitoring of similar projects are shown below.

During the Little Barrier Island operation in 2004, soil samples were collected from directly under decaying Pestoff® 20R baits or where they had lain. Samples were taken 56 and 153 days after the aerial bait drop. Those in grassland areas had Brodifacoum residues of 0.2 μg/g (micrograms of poison per gram of soil) after 56 days, and 0.03 μg/g on day 153. In forested areas the figures were 0.9 μg/g on day 56 and 0.07 μg/g on day 153. These data indicate a rapid decline in Brodifacoum content in soil, with around a 90% reduction in poison levels between days 56 and 153 (Fisher *et al.* 2011).

Brodifacoum soil residues were also tested in a baiting trial conducted at Tawharanui Regional Park, Auckland. Soil samples were collected from directly beneath disintegrating baits at 56, 84, 112 and 153 days after first exposure to the elements. These samples produced residues of between 0.02 and 0.2 μg/g, with all positive samples occurring within the first 84 days; that is, no Brodifacoum was detectable in the soil immediately below baits after 84 days. The residues remained below the method detection limit (<MDL) from 110 days after the pellets were placed on the ground (Craddock, 2004).

Soil was sampled after aerial application of 10mm Pestoff 20R baits containing 20ppm Brodifacoum to the Ipipiri Islands in the Bay of Islands in June 2009. This project applied two applications of bait 20 days apart to give a combined total average application rate of 26 kg/ha. Samples were taken within 20cm of baits in three habitat types (pasture, bare rock, manuka forest). Soil samples taken 28 days following aerial application of baits contained Brodifacoum residues of 0.0016 mg/kg. Samples taken 58 days post baiting contained Brodifacoum residues of 0.002 mg/kg. Soil samples taken near baits laid in manuka scrub contained (very low) residues up to 147 days after baiting (Vestena and Walker 2010).

Analysis of bait and soil samples from Kapiti Island following an aerial application (14 kg/ha), showed only 10–30% of original levels of Brodifacoum in samples taken 3 months after the operation (Empson in Brown *et al.* 2006).

No residues of Brodifacoum were detected in soil samples taken from Lady Alice Island before, and then 2, 12, 34 and 210 days after an aerial poisoning operation using Talon □20P cereal pellets
1994 (Ogilvie *et al.* 1997).

Morgan and Wright (1996a) reported no Brodifacoum residues were detected in eight topsoil samples taken one month following the aerial application of Talon □ 20P cereal pelle
islands in October 1992.

An accidental release of 700kg of Pestoff 20R bait into a 30ha freshwater lake in Fiordland was monitored for a month. No residual Brodifacoum was detected in samples of sediment (*n*=16) (Fisher *et al.* 2012).

The manner of use of Brodifacoum baits and physical and chemical properties of Brodifacoum suggests little accumulation of Brodifacoum in soil. Concentrations of Brodifacoum in soil are predicted to be negligible/low and occurring only sporadically according to bait treatment timings. Brodifacoum would not be expected to leach in soil and no mobile degradation products are produced. Brodifacoum strongly binds to soil particles and is slowly broken down by microbial activity with a half-life of 12-25 weeks (Shirer 1992).

The low-moderate application rate of Brodifacoum for the LHI REP (0.4g / ha) and one off eradication means that any soil contamination and bioaccumulation would be of a sufficiently low magnitude as to not present a significant risk.

Breakdown of baits and Brodifacoum levels in soil will be monitored after the LHI REP.

Bait breakdown will be monitored at established monitoring and random sites using the Craddock Condition Index described above at approximately 30 day intervals until complete disintegration.

Post operational soil samples will be collected to monitor residues of Brodifacoum in the soil. Representative samples will be collected from directly below some toxic bait and at control sites away from bait pellets. Soil samples will be collected approximately 30 days after bait disintegration and approximately every two months (if required, dependant on results). All tests will be conducted at a NATA accredited analytical laboratory.

2.7.1.3 Fate in Fresh Water

The Pestoff 20R pellets will disintegrate very rapidly when immersed in water, dependant on turbulence, flow, wave and current action. The presence and type of sediment layers in a waterway will also affect the degradation of Brodifacoum in aquatic environments as will temperature, pH, volume, or presence or types of micro-organisms.

Brodifacoum is practically insoluble in water (WHO 1995), and leaching from soil into water is unlikely to occur. Erosion of soil might lead to Brodifacoum entering water bodies, where it is likely to be strongly bound to organic material and settle out in sediments (Eason and Wickstrom 2001). Brodifacoum degrades slowly in natural waterways. Where baits have been sown directly into waterways during other baiting operations worldwide, Brodifacoum residues have rarely been detected in water samples.

Due to the low solubility of Brodifacoum, detection of residues in fresh water after aerial and hand distribution of Pestoff 20R baits is extremely rare, despite at least 324 samples analysed over 11 operations (Broome *et al.* 2016).

The only residues of Brodifacoum which have been detected in water bodies following pest control operations in New Zealand come from a single sample of stream water collected 24 hours after bait application and within 20cm of baits in the stream bed. This sample measured 0.083ppm and was one of 12 samples taken within a week of aerial application of 10mm Pestoff 20R baits containing 20ppm Brodifacoum to the Ipipiri Islands in the Bay of Islands in June 2009. Three of the four stream water samples taken within 24 hours of bait application had no measurable residues (MDL 0.02ppb) (Vestena and Walker 2010). 25 Samples of drinking water taken from 13 tanks (covered or disconnected from roofs during the operation) and one bore over a two month period showed no Brodifacoum residues (MDL 0.02ppb) (Vestena and Walker 2010).

Pestoff 20R baits containing 20ppm Brodifacoum were applied in three aerial applications on Rangitoto and Motutapu Islands during the winter of 2009. In total about 38 kg/ha was applied to the islands over the three drops. Roof water collection systems were disconnected before baits were applied and roofs cleared of any baits afterwards. Four drinking water samples were taken about two months following the last bait application and tested for Brodifacoum residues. None were found (MDL 0.00002 mg/l) (Fisher *et al.* 2011).

During the 2004 Hauturu rat eradication, 8 water samples were taken directly downstream from Pestoff 20R baits lying in stream beds within 24 hours of the aerial drop. Brodifacoum was not detected in any of the samples taken (Griffiths, 2004). Samples tested from bore water on the island did not detect any Brodifacoum.

Two fenced ‘cells’ on Maungatautari (35 ha and 65 ha) each received two bait drops of Pestoff 20R Brodifacoum cereal bait in September and October 2004. 15 kg/ha was applied on the first drop and 8 kg/ha in the second. The area (c.8 ha) immediately around the inside of both cell fences was hand spread. A total 217 stream water samples were taken from 4 streams flowing out of the poison area. In each stream, samples were taken at the fence boundary and again 800 metres downstream. Time intervals post each drop for taking samples were 1hr, 2hrs, 3hrs, 6hrs, 9hrs, 12 hrs, 24hrs, 48hrs, 72hrs, 2 weeks, 3 months. No sample analysed detected Brodifacoum. The minimum detection level for these samples was 0.00002 mg/l (Fisher *et al.*2011.).

None of the seven water samples taken after bait application contained detectable residues of Brodifacoum (MDL 0.07ug/l) during the 2011 Macquarie island Eradication Project (Broome *et al.* 2016).

An accidental release of a box containing 700kg of Pestoff 20R bait by a helicopter flying over a 30ha freshwater lake in Fiordland was monitored for a month. No residual Brodifacoum was detected in samples of lake water (*n*=27) (Fisher *et al.* 2012).

In an isolated case, testing of liver and gut contents from two eels found dead in a Southland (NZ) waterway (Tomoporakau Creek, Branxholme) in May 2012, measured 0.095 ppm Brodifacoum in the gut contents of one eel (noting that other anticoagulants were not tested for). This suggests that the eel had recently ingested food containing Brodifacoum, probably through scavenging the carcass of a poisoned possum. There was a bait station approximately 100 metres from the location where a possum and eels (*n*=13) were found dead in the water (Fisher, 2013).

Laboratory studies using radioactive-labelled isotopes have shown that it is effectively immobile (i.e. not leached) in the soil (WHO 1995). It is strongly bound to soil particles; therefore contamination of ground water is not expected to occur.

Drinking water on LHI is primarily sourced from rain water tanks in the settlement area on LHI. Aerial application of baits will not occur in the settlement area and buffer zones from roofs and rainwater tanks will be established through individual Property Management Plans. There are a small number of bores on the island and covering of bores will also be discussed with individual owners. A small number of ephemeral streams are found on LHI. It is anticipated that a small amount of pellets may fall into these streams as part of the aerial distribution where they will sink and disintegrate rapidly. The Brodifacoum from these pellets will settle and bind strongly to sediments. The low-moderate application rate of Brodifacoum (0.4 g/ ha) for the LHI REP and one off eradication means that any environmental contamination would be of a sufficiently low magnitude as to not present a significant risk.

Random sampling will be conducted on water bodies on the island to monitor Brodifacoum levels after the bait drop. Water samples will be collected within 2 days of each bait drop and approximately weekly (if required, dependant on results). All tests will be conducted at a NATA accredited analytical laboratory. As a precaution tourists and residents will be advised not to drink from streams until laboratory testing confirms absence of detectable Brodifacoum. Supplementary water for people climbing Mount Gower will be provided during the eradication. Testing of resident's water tanks and groundwater bores will be undertaken if requested on a case by case basis.

2.7.1.4 Fate in the Marine Environment

Bait will not be intentionally applied to the marine environment however when Brodifacoum pellets are applied aerially to islands in attempts to eradicate rodents, all terrestrial habitats which may harbour rodents must receive bait. In achieving this it is often the case that a small quantity of bait enters the marine environment near the shore. On LHI it will be impossible to collect these baits.

Howald *et al.* (2005) investigated how much bait entered the water when applied aerially to steep cliffs. The bait was applied with a spreader bucket and deflector arm at the rate of 15 kg/ha. SCUBA divers were used to count bait pellets on the sea floor and to observe the behaviour of marine organisms that encountered the baits. Boat- and island-based observers reported that no bait was directly spread into the ocean but a small amount of bait was seen to enter the water as a result of bouncing off the cliff faces (ibid). The divers counted a mean of 72 baits (range: 69-75) over 500 metres, at a 1-4 m depth on the ocean floor. No fish or other animals were observed feeding on the baits. This would equate to less than 0.5% of baits out of the approximate 15,000 baits applied over that area.

Empson and Miskelly (1999) investigated the fate of pellet baits, which fell into the sea as part of the Kapiti Island rat eradication. Non-toxic baits were dropped into the sea about 30 m offshore to a depth of 10 m and monitored by a diver. The bait disintegrated within 15 minutes. On the assumption that accidental discharges were likely to occur only in the coastal fringe, Empson and Miskelly (1999) concluded that it was unlikely that baits would withstand wave action and remain intact for more than a few minutes.

During the LHI REP it is expected that similar rapid disintegration of pellets will occur where pellets fall into the open ocean exposed parts of the coastline. With less wave action in the lagoon, pellet breakdown may take slightly longer in this environment. Bait entry into the lagoon will be minimised by hand baiting along the lagoon foreshore and through the use of the deflector arm on the spreader bucket. Trickle bucket option will also be used in areas where a thin line of bait application between 5-10m is required. This will be undertaken by removing the spinner from the bait bucket and allowing bait to be distributed via the selected aperture on the bucket.

Monitoring undertaken for similar projects has shown that of a total of 38 seawater samples analysed following three operations, none of the samples showed detectable Brodifacoum (Broome *et al.* 2016).

None of 12 seawater samples taken (within 20 cm of where baits had fallen) during the Ipipiri rodent eradication project in 2009 showed measurable residues of Brodifacoum (MDL 0.02ppb) (Vestena and Walker 2010).

None of 18 seawater samples taken from near Rat Island in Alaska following aerial application of baits showed measurable residues of Brodifacoum (MDL 0.02ppb) (Buckelew *et al.* 2009).

Sampling of the marine environment following application of Brodifacoum cereal baits at 15 kg/ha on Anacapa Island in California during 2001 and 2002 found no detectable residues in 8 seawater samples taken following baiting (Howald *et al.*2010). Four of these samples were taken within 24 hours of baiting and the remainder 1 month after.

In 2001 a truck crashed into the sea at Kaikoura spilling 18 tonne of Pestoff 20R (20 mg/kg Brodifacoum) cereal pellets into the water. Measurable concentrations of Brodifacoum were detected in seawater samples from the immediate location of the spill within 36 hours but after 9 days the concentrations were below the level of detection (0.02 µg/L). (Primus *et al.* (2005).

The low-moderate application rate of Brodifacoum (0.4 g/ ha) for the LHI REP, low solubility, high dilution factor in the marine environment and one off eradication mean that any sea water contamination would be of a sufficiently low magnitude as to not present a significant risk to marine life or humans through any activity (including swimming or snorkelling).

Additionally significant mitigation through the use of the deflector arm on the spreader buckets, hand baiting within the Lagoon foreshore area and only baiting above the high water mark will minimise bait entry into the water. No seawater samples will be analysed for Brodifacoum after the LHI REP.

It is reasonable to expect that breakdown in marine sediments, would occur similar to soil. Operational monitoring of marine sediment samples taken after application of baits in the 2009 Ipipiri eradication project found that one of 12 samples had detectable residues (MDL 0.001ppm). This sample was taken 24hours after bait application. All samples were taken from within 20 cm of baits.

The low-moderate application rate of Brodifacoum (0.4 g/ ha) for the LHI REP, high dilution factor in the marine environment, and one off eradication mean that any contamination of marine sediment would be of a sufficiently low magnitude as to not present a significant risk.

Additionally significant mitigation through the use of deflector buckets, hand baiting within the Lagoon foreshore area and baiting only above the high water mark will minimise bait entry into the water. No marine sediment will be analysed for Brodifacoum after the LHI REP.

2.7.1.5 Fate in Plants

Brodifacoum is strongly bound to soil particles and practically insoluble in water, therefore it is not likely to be transported through soils and into plant tissues. It is not herbicidal.

Sampling of grasses (Poaceae) collected 6 months following application of Brodifacoum cereal baits at 15 kg/ha on Anacapa Island in California during 2001 and 2002 found no detectable residues in the six samples tested (Howald *et al.* 2010).

A literature search failed to find published or verified unpublished data regarding plant uptake or persistence. However it should be noted to no impacts to vegetation have been recorded from over 380 eradication attempts globally.

Cereal forming the bait matrix has been crushed, screened and heat treated so there is no possibility of the cereal in the bait germinating on Lord Howe Island or spreading pathogens.

The proposed REP is unlikely to have a significant impact on vegetation on the island. Conversely the eradication of rodents is likely to have significant benefits to a range of individual plant species and many vegetation communities through increases in the abundance of plants, seeds and seedlings, thereby enhancing the process of forest regeneration.

2.7.2 Bioaccumulation

Brodifacoum has been shown to bio-accumulate in mammals, birds, invertebrates and fish following repeated sub-lethal exposures. The low-moderate application rate of Brodifacoum for the LHI REP (0.4g / ha) and one off eradication means that any bioaccumulation would be of a sufficiently low magnitude as to not present a significant risk. Bioaccumulation potential in invertebrates and fish / aquatic organisms is discussed below.

2.7.2.1 Bioaccumulation in Terrestrial Invertebrates

Brodifacoum is not expected to have significant effects on invertebrates as they have different blood clotting systems to mammals and birds. Trials and operational monitoring conducted during rodent eradications in NZ so far have shown few invertebrate species are at risk of primary poisoning, and deleterious effects on arthropod, annelid, and mollusc populations have been rarely detected (Booth *et al.* 2001; Booth *et al.* 2003; Craddock 2003; Brooke *et al.* 2011; Bowie and Ross 2006). Several studies have demonstrated significant increases in invertebrates numbers following rodent eradication (Booth *et al.*2001, Green 2002, and Green *et al.* 2011).

Observations of baits in the field during non-toxic bait trials conducted on LHI in 2007 showed invertebrate damage occurred within a day of the bait drop. Several species of invertebrates were scanned externally with UV light to determine if they had ingested bait. Slugs and one snail (not Placostylus) fluoresced brightly indicating bait uptake, whilst ants, cockroaches, termites and millipedes did not show any fluorescence even though ants and cockroaches were observed feeding directly on bait (DECC, 2007a).

Similarly bioaccumulation in terrestrial invertebrates has shown to be in low concentrations and short lived in similar eradication operations. Invertebrates appear to metabolise or excrete residues rapidly at first but may retain trace amounts for several weeks.

When large-headed tree weta (*Hemideina crassidens*) were dosed with 15 µg/g Brodifacoum (equivalent to consumption of a 6g Talon® 20P pellet), Brodifacoum persisted in the weta for a maximum of four days (Morgan *et al.* 1996). Booth *et al.* (2001) dosed tree weta at 10ug/g to evaluate the persistence of Brodifacoum over time. Four days after dosing, Brodifacoum residues had declined to below the limit of detection (0.02ug/g).

Brooke *et al.* (2013) studied the persistence of Brodifacoum in cockroaches and woodlice. In the first experiment cockroaches captured on Henderson Island were allowed to feed on Pestoff 20R pellets containing 20ppm for 4 days. Brodifacoum residues declined quickly in the first 24 hours followed by a gradual decline for the remaining 11 days of the experiment. By day 12 mean concentrations were 0.061ug/g. One cockroach collected in a control group before the treatment group were fed baits had a detectable Brodifacoum residue (below MLOQ) presumed to be from exposure to bait laid on the island 2 months previously. In a second experiment using cockroaches and woodlice, samples were tested for up to 42 days after access to Brodifacoum pellets (Pestoff 20R) was removed. Again depletion of Brodifacoum residues was rapid in the first two weeks followed by a long period of slow decline. Seven of 10 animals tested on day 35 contained measurable residues. By day 42 seven of 10 animals contained residues at a mean level of 0.02ug/g (Brooke *et al.*2013). This level is 1000 times less than the concentration of baits they fed on.

Craddock (2003a) fed captive locusts (*Locusta migratoria*) Pestoff possum baits containing 0.02 g/kg Brodifacoum and tested them for residue at 1,2,3,4,5,10 and 15 day intervals. The test group exposed for 72 hours were observed eating bait but only 2 of the 7 samples had detectable residues of Brodifacoum 3 to 4 days after dosing. Another test group exposed for 144 hours had no detectable residues. A bio-tracer experiment found the dye became undetectable 7 days after dosing. Craddock concluded that on average 48 hours of exposure gives a concentration of 0.41 ug/g which drops below the detection limit of 0.06 µg/g after 3 days.

Craddock (2003) sampled live invertebrates captured around bait stations using cereal pellets containing 20ppm Brodifacoum. He found weta, cockroaches and beetles up to 10m from a bait station contaminated with Brodifacoum residues. The highest residue levels (up to 7.47 ug/g) were closer to the bait stations and soon after they were filled with bait. After toxic bait had been removed from bait stations, residue levels in invertebrates took in excess of 4 weeks to return to background levels. Trace levels of Brodifacoum were still detectable up to 10 weeks after bait had been removed.

On Red Mercury Island, invertebrates were collected after the aerial application of Brodifacoum baits, and were analysed for Brodifacoum residue. No such residue was found in 99% of the sample (Morgan *et al.* 1996).

On Lady Alice Island, tree-weta and cockroaches were collected in the days and weeks after aerial baiting and tested for Brodifacoum; none was detected. A cave-weta and beetles found on the baits were also tested. No Brodifacoum was detected in the beetles, but was found in this weta (Ogilvie *et al.* 1997). Similar testing was done after the aerial application of Brodifacoum on Coppermine Island. In this instance no residues were found in the weta or beetles, or in the ants and weevils that were found on the baits, but residues were found in cockroaches (G.R.G. Wright cited in Booth *et al.* 2001). Non-target insects and millipedes in the Seychelles Islands consumed Brodifacoum bait with no apparent adverse effects.

Significant bioaccumulation in terrestrial invertebrates is not expected with the proposed LHI REP given the one off nature of the eradication, the relatively low dose and short timeframe in which bait will be available. Conversely the eradication will permanently remove the use of rodenticides including Brodifacoum on the island from the current control program.

2.7.2.2 Bioaccumulation in Terrestrial Vertebrates

Laboratory studies and field monitoring have shown that Brodifacoum can bio accumulate in terrestrial vertebrates and is very persistent in the livers of most sub-lethally exposed animals, (up to nine months in some cases). However short-term sub-lethal exposure is not expected to have any significant adverse effects. Brodifacoum residues have been detected in tissues of animals during the monitoring of field distribution, but not always associated with mortality or evidence of haemorrhage. Non-target deaths have been documented in eradication programmes. However, most incidences have involved low numbers and the affected species have recovered quickly to pre-eradication population levels, or higher, once invasive rodent species has been removed (Broome *et al.* 2016).

Nine months after 15kg/ha Talon® 20P pellets were aerial sown on Red Mercury Island in 1992 six blackbirds were sampled. The livers of all six birds contained low levels of Brodifacoum (0.004 to 0.2 mg/kg) (Morgan *et al.* 1996)

After rat eradication on Langara Island (British Columbia) bald eagles (*Haliaeetus leucophalus*) were sampled for Brodifacoum residues and prothrombin time evaluation. Three out of the 20 eagles examined had been recently exposed to Brodifacoum, but none were suffering from clinical anticoagulation (Howald *et al.* 1999).

Native birds have been sampled on two occasions following the use of Brodifacoum during pest control operations in New Zealand. In 1995, four months after Brodifacoum was used in bait stations at Mapara Wildlife Management Reserve, King Country, 14 native birds (five tomtits, five whiteheads, one bellbird, one fantail, one Australasian harrier and one morepork) were sampled for Brodifacoum residues. Only the morepork contained residue. Four robins were sampled for Brodifacoum residues in Waipapa, Pureora Forest Park, two months after Brodifacoum was used in bait stations in 1997. None of the birds had Brodifacoum residues (Murphy *et al.* 1998).

One month after being exposed to Pestoff rodent blocks containing 0.02 g/kg Brodifacoum two plague (rainbow) skinks had liver residues of 0.005 and 0.01 µg/g (Wedding 2007).

Two Duvaucel's geckos (*Hoplodactylus duvauceli*) found in traps were tested for Brodifacoum residues. One of the geckos had 0.007 mg/kg residue in its liver. Brodifacoum had been used in the area in bait stations up until two years prior to the gecko being caught (Vertebrate Pest Record Database 11938 cited in Broome *et al.* 2016).

Mourning gecko (*Lepidodactylus lugubris*) and common house gecko (*Hemidactylus frenatus*) samples were collected live following aerial application of Bell Labs 25w bait on Palmyra Atoll. Although showing no clinical signs of poisoning, 14 of the 24 samples were found to contain Brodifacoum residues, indicating that they were exposed (Pitt *et al.* 2012).

Significant bioaccumulation in terrestrial vertebrates is not expected with the proposed LHI REP given the one off nature of the eradication, the relatively low dose and short timeframe in which bait will be available. Conversely the eradication will permanently remove the use of rodenticides including Brodifacoum on the island from the current control program.

2.7.2.3 Bio-accumulation in fish/aquatic organisms

Whilst Brodifacoum can bio-accumulate in fish and aquatic organisms from repeated exposure and may cause long term effects in the aquatic environment (Tomlin, 2009), there is limited evidence of marine vertebrates or invertebrates being adversely affected by Brodifacoum poisoning during rodent eradication projects.

Fish potentially killed by Brodifacoum poisoning have been observed on only a very few occasions and a few studies have found residues in live fish shortly after bait application. Where tissue samples have been separated, this contamination has been confined to livers. Further sampling of these sites indicate residues are not long lasting (Broome *et al.* 2016). Results from operational monitoring of similar projects are detailed below.

Following aerial application of baits on Ulva Island near Stewart Island (NZ) in 2011, fish were sampled 10 days after a final bait application (i.e. 43 days after first bait application). No residues were detected in the flesh of blue cod (*Parapercis colias*) (30 individuals combined into 6 samples), trumpeter (*Latris lineata*) (10 individuals combined into 2 samples), spotties (*Notolabrus celidotus*) (18 individuals combined into 4 samples), girdled wrasse (*Notolabrus cinctus*) (1 individual, 1 sample) (MDL 0.001ppm) (Masuda *et al.*2015). However 2 of 6 blue cod liver samples (30 individuals) taken at the same time were found to contain 0.026 and 0.092ppm. A further 20 blue cod (4 samples) were tested 1 month after final bait application (77 days after first bait application) and no residues were found in either flesh or liver (MDL 0.001ppm) (Masuda *et al.*2015). Four months after bait application 20 blue cod (4 samples) were again tested and none showed detectable residues in liver or flesh (Masuda *et al.*2015). In the same operation marine invertebrates were sampled 10 days after final bait application. 85 mussels (*Mytilus edulis*) were collected from 3 sites. These were batched to form 9 mussel samples. Three samples had residues ranging from 0.003ppm to 0.022ppm. Two of 8 limpet *(Cellana ornata*) samples (50 individuals) had detectable residues (0.002 and 0.016ppm). Both pipi samples (20 individuals), all 3 paua (*Haliotis iris*) (15 individuals), all 3 kina (*Evechinus chloroticus*) (15 individuals) samples and one cockle sample (7 individuals) had no detectable residues (MDL 0.001ppm). Five further mussel samples (50 individuals) were tested one month after final bait application and none were found to have detectable residues. However two of the 6 limpet samples (50 individuals) tested at this time had residues very close to the MDL of 0.001 ppm. Further testing of limpets and mussels was done 4 months after final bait application (i.e. 176 days after first bait application) resulting in one of 6 mussel samples (50 individuals) with detectable residue (0.018ppm). All 6 limpet samples (50 individuals) had no detectable residues. Further testing of limpets and mussels was undertaken 8 months after the bait application. Four limpet and 4 mussel samples taken from 2 sites had no detectable residues (MDL 0.001ppm) (Masuda *et al.*2015).

Following aerial application of baits on Shakespeare Open Sanctuary north of Auckland a large marine monitoring programme was undertaken, collecting 206 samples of 33 marine taxa from 4 sites before and after baiting. Among these samples were 2 blue cod, 1 parore (*Girella tricuspidata*), 1 spotty, 1 triple fin (*Forsterygion varium*), 1 moki (*Latridopsis ciliaris*), and 1 snapper (*Chrysophrys auratus*) taken 1 or 8 days after bait application. No detectable residues were found in any of the fish samples (MDL 0.001ppm). Samples were also collected for Pacific oysters (*n*=7), crayfish (*Jasus edwardsii*) (*n*=2), cushion star (*Asterina spp.*) (*n*=2), shrimps (*n*=1), kina (*n*=2), cockles (*Austrovenus stutchburyi*) (n=2), whelks, crab and sea cucumber (*Stichopus spp*). One of the post bait application samples catseye (*Turbo smaragdus*) had detectable residues (0.006ppm).

Interestingly one sample of catseye and one oyster sample taken before any bait was laid had low levels of Brodifacoum (0.009ppm and 0.002ppm respectively). However on re-testing the catseye sample remained below and the oyster sample equal to - the limit of detection (0.001ppm) (Maitland 2012).

Following the aerial application of baits (18 kg/ha over 2 applications) on Taranga (Hen) Island in Northland (NZ) in 2011, 4 samples each containing 3 crayfish were taken from near shore rocks. The selected sample collection sites were also adjacent to where two streams, draining the largest island catchments, entered the marine area. Two samples were collected 25 hours and two samples nine days after bait application. No residues were detected (MDL 0.0005ppm). During the same project 4 samples each containing 3 kina were similarly collected with no detectable residues (Broome *et al.* 2016).

Baits containing 20ppm Brodifacoum were applied in three aerial applications on Rangitoto and Motutapu Islands (NZ) during the winter of 2009. In total about 38 kg/ha was applied to the islands over the three drops. Five dolphins (*Delphinus spp*), a number of pilchards (*Sarditlops neopilchardus*) (tested as one sample) and nine little blue penguins found dead around the Hauraki Gulf at the time of the operation were also tested for residues. Only 3 of the penguins contained detectable residues of Brodifacoum but all of the birds necropsied showed no evidence of anticoagulant poisoning and starvation was considered the most likely cause of death (Fisher *et al.* 2011). Ten pipi and ten mussels collected three weeks following the final drop were tested for Brodifacoum residues. None were found (MDL 0.001 ppm) (Fisher *et al.* 2011).

A field trial was also conducted to examine the fate of Talon® 20P cereal pellets dropped into the sea at Kapiti Island (NZ) and any consumption by fish. Non-toxic baits disintegrated within 15 minutes and spotties, banded wrasse (*Notolabrus fucicola*) and triple fins were observed eating the bait. In subsequent aquarium trials blue cod, spotty and variable triple fin were fasted for 24 hours before being exposed to Brodifacoum cereal pellets for 1 hour. The fish were moved to a clean tank and held for 23-31 days, then killed and analysed. Six of 24 triple fins exposed to bait died although none were observed eating bait and no residue was detected in their livers. Of 30 spotties, six ate toxic bait and one died of Brodifacoum poisoning. Two other spotties which died were not observed eating bait but showed clinical signs of poisoning. It is thought the poison was absorbed through gills or skin. This is unlikely to happen in the sea given wave action and dilution (Empson and Miskelly 1999). There was no evidence of a population decline in spotties as a result of the aerial application of Talon® 7-20 at 9.0 kg/ha followed by 5.1 kg/ha on Kapiti Island, based on surveys conducted before and after the poison drops (Empson and Miskelly 1999).

In 2001 a truck crashed into the sea at Kaikoura (NZ) spilling 18 tonne of Pestoff 20R (20 mg/kg Brodifacoum) cereal pellets into the water. A butterfish (*Odax pullu*) sampled 9 days after the spill had Brodifacoum residues of 0.040 ppm in the liver, and 0.020 in the gut, although muscle tissue was below the MLD (0.020ppm). Residues in a scorpion fish (*Scopaena sp*.), two herring (*Sprattus* spp.) and an unknown species of fish collected between day 14 and 16 were all <0.020 ppm. Samples taken from two seals (*Arctocephalus forsteri*), two black backed gulls (*Larus dominicanus*) and a shag (*Phalacorcorax* spp.) found dead in the area following the spill contained no detectable Brodifacoum levels, and necropsies found no signs of anti-coagulant poisoning (Primus *et al.* 2005). Samples of mussels and paua taken from the immediate location retained measurable residues for up to 31 months. This result was probably confounded by the animals being re- exposed to Brodifacoum bait particles through wave action. Effects of the spill were only measurable within a $100m^2$ area surrounding the crash site (Primus *et al.* 2005)

Two of 5 pipi (*Paphies australis*) samples taken within 72 hours of aerial application of baits containing 20 ppm Brodifacoum to the Ipipiri Islands in the Bay of Islands (NZ) in 2009 were found to have low levels of Brodifacoum. Four mussel (*Perna canaliculus*) samples taken from the site at the same time were clear and nothing was detected in a further 4 pipi and 3 mussel samples taken at 1 and 2 months post bait application (MDL 0.001ppm). Samples in this study were deliberately taken from within 20cm of baits (Vestena and Walker 2010).

On tropical Palmyra Atoll non-toxic baits were dropped into four marine environments to observe the reactions of the marine species present. Baits placed on exposed tidal flats had no interest shown in them by the species present (fiddler crabs, bristle-thighed curlews and Pacific golden plover). In shallow (1m depth) water fish showed no interest in the first pellets entering the water. However on following occasions 3 species did eat baits. In moderate depth (3m) trials, 2 species took baits falling through the water and in deep (10m) water trials, 1 species was seen to mouth baits but consumption could not be confirmed. In total six of 20 species observed showed interest in the baits (Alifano and Wegmann 2010). In the same study crabs were held in captivity and fed Bell Labs 25W pellet baits containing Brodifacoum for 7 days followed by a natural diet. Crab excrement was collected daily and analysed for Brodifacoum content. Results indicated that Brodifacoum levels climbed over the first couple of days but then levelled out and fell to low levels within 3 days of the crabs moving off their bait diet to natural food. However traces (0.25ppm) could still be found 16 days after the pellet diet ended. Crabs did not appear to be affected by the toxin (Alifano and Wegmann 2010).

Nine of ten black spot sergeant fish (*Abudefduf sordidus*) collected live following aerial bait application of Bell Labs 25w bait on Palmyra Atoll were found to contain residues ranging from 0.05 to 0.315 ppm (whole fish). Two applications of bait (80 kg/ha and 75 kg/ha) were applied about 10 days apart. Fish samples were collected shortly after the second application. A number of mullet (*Liza vaigiensis* and *Moolgarda engeli*) and a single puffer fish were found dead after this application and were found to contain residues ranging from 0.058 to 1.16

ppm. Interestingly, over half the residue results from the dead mullet samples were within the range of residues found in the live sergeant fish (Pitt *et al.* 2012). All hermit crab samples collected soon after baiting contained residues with levels ranging from 0.134 to 1.58 ppm less than 5 days after baiting. By the 3rd sampling period (22-25 days post first bait application) one of 5 samples had no detectable residues, and by the 4th sampling period (6 weeks after the last baiting) only one sample had detectable residues (MLD<0.018). Aquatic fiddler crabs were also collected during this study and showed similar results (Pitt *et al.* 2015)

A range of fish species were tested for Brodifacoum contamination following the aerial application of baits (Bell Labs 25W) to Wake Atoll in the mid Pacific in 2012. Forty-two samples from six species collected from 7 sites around the island were tested. Five samples returned results above the MDL of 0.001 ug/g, ranging from 0.002 to 0.005 ppm. Because the fish (papio trevally and blacktail snapper) were tested whole, it is likely that the contamination measured was in the gut of the fish (R. Griffiths pers com. in Broome *et al.* 2016).

Sampling of the marine environment following application of Brodifacoum cereal baits at 15 kg/ha on Anacapa Island in California during 2001 and 2002 found no detectable residues in 26 tide pool sculpins (*Oligocottus maculosus*) which are small fish found in the intertidal zone (Howald *et al.* 2010). Sampling found no detectable residues in marine invertebrate fauna collected 15, 30 and 90 days following bait application (Howald *et al.* 2010). Included in these samples were 6 hermit crabs, 1 limpet, 22 mussels, 42 shore crab (*Pachygrapsus spp*) and 10 sea urchins.

Following aerial application of baits on Kaikoura Island near Great Barrier Island (NZ) in 2008 two samples were taken from a nearby mussel farm and tested for residues. None were found (MDL 0.001ppm) (VPRD 11421, 11422 cited in Broome *et al. 2016*).

Following aerial application of baits on Hauturu (Little Barrier) Island in the Hauraki Gulf (NZ) in 2004, two paua and two scallop (*Pecten novaezelandiae*) samples (each consisting of about 4 animals) were taken from near the island and tested for residues. None were found (MDL 0.001ppm) (Fisher *et al.* 2011).

Following the aerial application of baits on Motuihe Island in the Hauraki Gulf in 1997 two Pacific oyster (*Crassostrea gigas*) and 4 mussel samples were tested for residues. The oysters and 3 of 4 mussels had no residues detected (MDL 0.01ppm). One mussel sample had 0.02 ppm Brodifacoum, perhaps because a toxic bait was deliberately dropped into the rock pool it was living in (Fisher *et al.* 2011).

The low-moderate application rate of Brodifacoum (0.4 g/ ha) for the LHI REP, high dilution factor in the marine environment, and one off eradication means that the risk of bioaccumulation in local marine species would be of a sufficiently low magnitude as to not present a significant risk. The amount of Brodifacoum assimilated into the marine environment will be an extremely small fraction of (many orders of magnitude lower) the concentrations known to be toxic to fish (Empson, 1996).

Additionally significant mitigation through the use of deflector buckets, handing baiting within the Lagoon foreshore area and baiting above the high water mark will minimise bait entry into the water.

2.8 Alternatives Considered

Three alternative scenarios that have been considered are discussed below. These include:

- doing nothing
- continuing the current rodent control program
- eradication of rodents.

2.8.1 Do Nothing Scenario

The devastating impacts of introduced rodents on offshore islands around the world are well documented. The presence of exotic rodents on islands is one of the greatest causes of species extinction in the world (Groombridge 1992). Ship rats alone are responsible for the severe decline or extinction of at least 60 vertebrate species (Towns *et al.* 2006), and currently endanger more than 70 species of seabird worldwide (Jones *et al.* 2008). They suppress plants and are associated with the declines or extinctions of flightless invertebrates, ground-dwelling reptiles, land birds and burrowing seabirds (Towns *et al.* 2006). Mice have also been shown to impact on plants, invertebrates and birds (Angel *et al.* 2009).

Rats and mice prey heavily on birds, bats, reptiles, snails, insects and other invertebrates. The ship rat is known to eat seeds and other plant material, fungi, invertebrates, small vertebrates and eggs (NSW Scientific Committee 2000 in DECC 2007). Rats prey on the eggs and chicks of land birds and seabirds, and can cause major declines in these species (Merton *et al.* 2002). Mice eat the eggs and chicks of small bird species such as storm-petrels, but are also capable of killing chicks of birds as large as albatrosses.

Rats and mice consume vast quantities of seeds, flowers, fruits, foliage, bark and seedlings. This severely reduces seedling recruitment which changes the characteristics of native vegetation communities (Rance 2001; Shaw *et al.* 2005; Brown *et al.* 2006; Athens 2009; Meyer and Butaud 2009; Traveset *et al.* 2009). The impact that rats have on the regeneration of plants on islands is often not fully appreciated. After rats were removed from the Chetwode Islands, New Zealand, there was a twenty-fold increase in seedling numbers and a seven-fold increase in the diversity of plant species (Brown 1997a).

One of the indirect impacts of rats on islands is the loss of nutrients. Rats kill seabirds and this leads to a reduction in the amount of nutrients available from guano, regurgitations and failed eggs. These losses can profoundly affect the health and condition of forest ecosystems (Holdaway *et al.* 2007), as has happened on Norfolk Island after the loss of the Providence petrel (*Pterodroma solandri*).

Mice probably arrived on LHI by the 1860s. Rats arrived in 1918. Rats are implicated in the extinction of five endemic bird taxa (species or subspecies), at least 13 species of endemic invertebrates on LHI including two endemic land snails (Ponder, 1997) – *Epiglypta howinsulae* and a sub-species of *Placostylus bivaricosus* and 11 beetles. While many of these extinctions occurred within only a few years of rats arriving, the detrimental effect of rodents on the island's plants and animals is ongoing. They are also a recognised threat to at least 13 other bird species, 2 reptiles, 51 plant species, 12 vegetation communities, and three species of threatened invertebrates on LHI that are currently threatened because of the presence of exotic rats (DECC, 2007). Another four species of land snails have subsequently been added to this list.

Two seabirds – white-bellied storm-petrel (*Fregetta grallaria*) and Kermadec petrel (*Pterodroma neglecta*) – that once bred on the main island are now restricted to breeding on smaller, rat-free islands within the LHI Group. They were last recorded breeding on the main island by Roy Bell in 1913-1915, just prior to the introduction of rats. The Kermadec petrel nests above ground, where it is highly vulnerable to rat predation. The small size of storm-petrel adults, nestlings and eggs make them especially vulnerable to predation by rats.

The consumption of seeds and invertebrates by rats reduces the amount of food available to the island's seed-eating and insectivorous birds. This competition for food resources is likely to be reducing the abundance of remaining bird populations.

Rats prey heavily on reptiles and have severely reduced the abundance and distribution of the LHI skink (*Oligosoma lichenigera*) and LHI gecko (*Christinus guentheri*) on the main island (Cogger 1971). It is no coincidence that these species are more abundant on the rat-free outer islets (DECC 2007).

Rats are voracious predators of invertebrates. The loss of invertebrates on LHI is particularly significant because invertebrates play an important role in maintaining natural ecological functions, such as nutrient cycling, pollination, pest control and decomposition. Documented impacts to invertebrates include the loss of two endemic land snails (Ponder 1997) – *Epiglypta howinsulae* and a sub-species of *Placostylus bivaricosus* and 11 beetles. These beetles, that were present on LHI prior to the introduction of rats, have not been recorded since. This is despite significant effort including a systematic invertebrate survey by the Australian Museum between 2002 and 2004 (C. Reid unpublished data). Rats are also responsible for the local extirpation of Wood-feeding Cockroach *Panesthia lata* which now only occurs on offshore islands including the Admiralty Group. Rats are also widely believed to be responsible for the elimination of the endangered LHI Phasmid from the main island. The only remaining wild population of phasmid occurs on rat-free Balls Pyramid (Priddel *et al.* 2003).

Rats are believed to have caused the extinction of the bridal flower (*Solanum bauerianum*) and native cucumber (*Sicyos australis*) from LHI (DECC 2007). Rat predation on seeds and seedlings also severely reduces or stops recruitment of the little mountain palm *Lepidorrhachis mooreana*) and big mountain palm (*Hedyscepe canterburyana*) (Moore Jr 1966; Auld *et al.* 2010). It is thought that seed and seedling predation by rats is hindering the regeneration of the palm stand on Little Slope (Pickard 1982), and rodent eradication is considered critical for the long term conservation of both little and big mountain palms (Auld *et al.* 2010).

Rats consume the seeds of many other plant species including: blue plum (*Chionanthus quadristamineus*), green plum (*Atractocarpus stipularis*), pandanus (*Pandanus forsteri*) and tamana (*Elaeodendron curtipendulum*) (Harden personal observations). Rats damage the vegetative parts of a number of plant species, including all four species of palms on the island. Rats commonly chew through the rachis, completely detaching the frond from the tree (Pickard 1983; Harden personal observations). Rats damage the bark on the trunk and limbs of a number of tree species, including Sally wood (*Lagunaria patersonia*), tamana and island apple (*Dysoxylum pachyphyllum*). In severe cases this can result in the death of the tree (Harden personal observations). The impact on vegetation also indirectly affects invertebrates through habitat loss and birds through the removal of food sources.

A monitoring program has been established on LHI to assess and document the biodiversity benefits of removing rats and mice from the LHIG. The program provides a measure of the return on investment and allows an evaluation of current status of species so any impacts of the eradication of rodents on key non-target species can be tracked during their recovery. The most recent results (Carlile, 2015) show:

- seed and fruit losses to rats of all 16 plant species examined, comprising a mixture of plant families, life forms (trees, shrubs, vines) and habitats, with some experiencing very high losses
- recruitment failure as a result of rat predation on seeds and seedlings of the Critically Endangered Small Mountain Palm and associated loss of biotic process and interactions in the Critically Endangered Gnarled Mossy Cloud Forest (ibid)

- Low numbers of reptiles and birds and observed predation by rodents on eggs and suspected removal of nestlings in some species.

While the impacts of house mice on the LHI Group are difficult to positively confirm in the presence of rats and may not be as significant or as well understood as those of ship rats, they are likely to be similar to those demonstrated on other islands (see Newman 1994; Jones *et al.* 2003). For example, evidence on subantarctic Gough Island has identified mice as being responsible for increased mortality of several species of seabird nestlings (Cuthbert and Hilton 2004), including the Tristan albatross (*Diomedea dabbenena*). This albatross is a similar size to the masked booby (*Sula dactylatra*) which is the largest seabird breeding in the LHI Group. New Zealand studies have found that mice prey on reptiles and their eggs and can severely deplete populations (Towns and Broome 2003). Whilst the impacts of mice may be suppressed in the presence of rats (Angel *et al.* 2009), the potential negative impacts of house mice include:

- predation on seeds, competing with native seed-eating fauna for food resources
- severely reducing seedling recruitment which in turn changes vegetation communities
- predation of the eggs and chicks of small bird species, such as storm-petrels and the potential to attack large seabirds
- adverse effects on affected populations of the LHI skink and LHI gecko
- predation on invertebrate fauna which can cause the extinction of some species, as has occurred on Antipodes Island in New Zealand (Marris 2000)
- a detrimental effect on island nutrient recycling systems by reducing the abundance and diversity of soil invertebrates (Smith and Steenkamp 1990).

In summary, continued impacts to matters of NES; 10 bird species, two reptile species, six invertebrate species and two plants species (Table 6) are unacceptable in a do nothing scenario. Consequences of failing to proceed with the REP are detailed in section 2.6.

From the perspective of the human population, rats and mice are major domestic pests. They infest residences, destroy foodstuffs, vegetable gardens and contaminate homes with excrement. They are also a known health risk to humans as they harbour and transmit diseases and parasites.

From an economic perspective, rats cause considerable economic loss to the island's Kentia Palm *Howea forsteriana* industry with predation of seed as high as 30% (Parkes *et al.* 2004) severely reducing seed production (Pickard 1983; Billing 1999).

Tourism, the LHI Group's main industry, is based on the islands' unique biodiversity and World Heritage values. Evidence from LHI and other islands around the world (Towns *et al.* 2006) shows that the ongoing impacts of rodents on native fauna and flora erodes the biodiversity and World Heritage values, and therefore reduces the visitor experience offered by the island – the basis of its tourism industry.

In other locations the impact of invasive rodents on tourism has been acknowledged and is a primary consideration in decisions to eradicate rodents. In the Seychelles, which is a global biodiversity hotspot, the importance of rat eradication to tourism has been recognised (Nevill 2004). Tourism operators on privately owned islands funded eradications with the primary goal of facilitating the reintroduction of endangered bird species thus enhancing their existing tourism operations. Private tourist operators in the Seychelles have continued to embrace the eradication concept. This enthusiasm reflects the realisation that ecotourism is the fastest growing niche market in the tourism industry. Providing near pristine tropical island getaways allows the Seychelles to target the exclusive top-end tourist market.

A survey of island managers where rat eradications have been undertaken showed that ecotourism was the (or one of the) primary motivation(s) behind the activity. Resort owners noted that 'exclusive 5 star tourism and rats don't mix' (Nevill, 2004). Tourism operators in the Seychelles promote the efforts made to rid their islands of rodents, and the benefits of doing so—the subsequent proliferation of fauna and flora and the opportunity to re-introduce species previously lost to predation. North, Frégate, Denis, and Bird Islands all promote the conservation initiatives conducted on their islands, including reporting on eradications. Island restoration facilitated by rodent eradication has resulted in North Island winning numerous travel awards including nomination as the best travel location on earth.

On Ulva Island in New Zealand, an eradication of rodents was undertaken in 1996. The success of the eradication, and subsequent reintroduction of species lost from the island as a consequence of rat predation, has resulted in the island becoming a premier tourist location. Tourist numbers increased from around 10 000 to 30 000 per year in the decade after rat eradication. This boost in tourism resulting from ecosystem recovery sustains 17 new businesses (A. Roberts, Department of Conservation pers. comm.).

2.8.2 Continuing the Rodent Control Scenario

Since ship rats and house mice arrived on LHI, the Lord Howe community has invested considerable resources in trying to keep the populations of both species under control.

Control is quite distinct from eradication. It aims to keep the negative effects within acceptable limits, but its ongoing nature brings with it a constant financial burden. It also brings an increased potential for negative impacts caused by the ongoing presence of poison in the environment.

Since the 1920s numerous methods of control have been tried on LHI including a bounty on rat tails, hunting with dogs, introduction of owls and the use of various poisons including barium chloride, diphacinone, warfarin, and now Brodifacoum and coumatetralyl. The prolonged use of warfarin has led to house mice becoming resistant to this poison.

Over time, the bait that the LHIB has used for rodent control has changed from warfarin to coumatetralyl, largely due to the LHIB being unable to source commercial quantities of warfarin as a consequence of rodents being largely resistant to it on the mainland. The coumatetralyl based bait currently used (in the product Ratex at a concentration of 0.38g/kg) is a first generation anticoagulant that has similar mode of action as warfarin. The LHIB has an Australian Pesticides and Veterinary Medicines Authority (APVMA) Minor Use Permit to apply the bait in stations with 200 gm of bait which is replenished five times per annum (approximately every 10 weeks) in order to reduce resistance build up in rodent populations. The LHIB rodent control baiting contract covers the servicing of 1,400 stations over 30 baiting areas throughout the Island's Settlement Area and in some sections of the Permanent Park Preserve for conservation purposes (approximately 10% of the island).

In addition to the LHIB rodent control contract, coumatetralyl is also supplied by the LHIB to residents who wish to use it on their properties. The main reasons for choosing this rodenticide for control measures is its low impact on non-target species on the Island; and to reduce the likelihood of rats and mice developing a resistance to Brodifacoum in the lead up to the eradication through unregulated resident use of Brodifacoum based products.

In 2015, the LHIB purchased 192 x 15 kg buckets (total of 2880kg) of Ratex grain bait containing coumatetralyl for use in its rodent control program to be used by both LHIB and leaseholders on the Island for rodent control. In the 6 months from January to the beginning of July 2016, the LHIB has used and provided to residents approximately 700 kg of Ratex grain bait for rodent control on Lord Howe Island.

In addition, many Island residents also purchase Brodifacoum based rodenticides such as Talon™ and Tomcat™ (generally at concentrations of 50 mg/kg) to control rats and mice around their properties and inside dwellings. As residents can purchase this locally or directly from the mainland, exact quantities used are unknown but it is estimated to be around 400kg per year over the 54 ha residential area. This equates to approximately 7.4 kg/ha per year of Brodifacoum alone. The LHIB has no control over this.

Anecdotal evidence gained via the Property Management Plan process has shown that a large percentage of residents in the settlement areas use commercially available Brodifacoum based rodenticides in off label situations (i.e. not in accordance with product label conditions) for their individual rodent control programs. This includes the use of Brodifacoum products in the open, away from buildings, in gardens or in combination with other products. Project Staff assisting with baiting through the settlement areas during the LHIB's scheduled baiting program have shown that as many as 1 in 3 residents are using Brodifacoum products such as Talon™ and Tomcat™ (50 ppm Brodifacoum) exclusively or in conjunction with LHIB provided bait, Ratex- coumatetralyl. The main reason given by residents for this supplementary baiting is the perceived view that the bait provided by the LHIB is not as effective at controlling rodents, particularly mice, as the Brodifacoum based commercially available products. This practice of using off label rodenticide has been demonstrated to indiscriminately poison birdlife on the Island as a secondary poison occurrence.

The present control baiting program does not adequately protect the island group's native flora and fauna. Even with the current level of control estimates of rodent numbers on the island range from 63,000 to 150,000 rats and 140, 000- 210,000 mice (30 -74 rats per hectare and 67-100 mice per hectare (DECC, 2007a and 2008)).

Rodents cannot be considered to be in equilibrium with native species on LHI. Based on the following:

- the number of extinctions attributed to rodents on LHI in a relatively short evolutionary timeframe
- the recent listings of new threatened species as a result of population declines attributed to rodent predation (i.e. land snails) and;
- the ongoing impacts to least 13 other bird species, 2 reptiles, 51 plant species, 12 vegetation communities, and seven species of threatened invertebrates on LHI

Continued impacts to listed TSC Act threatened species; 9 bird species, two reptile species, six invertebrate species and two plants species (Table 6) are unacceptable in the current scenario. Consequences of failing to proceed with the REP are detailed in section 2.6.

Widespread control is simply not practical given the large area and rugged terrain. There is also a significant risk that through ongoing control (and the continuous presence of poison baits) the island group's rodent populations will develop bait shyness or a resistance to current rodenticides. Mice have already developed a resistance to warfarin. The suite of second-generation anticoagulants, which includes Brodifacoum, is the only tool currently available for effectively eradicating rodents from islands. Resistance to these poisons, if it develops, will make eradication impossible and will greatly restrict control. 2013 studies show that within benign laboratory conditions, rats succumb to the bait as expected while mice currently take approximately three weeks (Wheeler and Carlile 2103). Ongoing use of poison in the environment also presents a major risk to non-target species including humans, pets and livestock through continued exposure. Ongoing exposure also increases the risk to non target species of bioaccumulation through consumption of poisoned invertebrates. As such, the effectiveness and long-term sustainability of the existing localised control programme, or an expanded programme, is highly questionable.

If the eradication proceeds and is successful, rodents will be completely eliminated from LHI. There will be no need to further implement the current rodent control program run by the LHIB, or for residents to bait within their own properties.

2.8.3 Preferred Scenario - Eradication

The 'do nothing' scenario and continuation of the current control situation on LHI are both considered unacceptable in the short term, medium term and long term, primarily because they fail to mitigate threats from rodents to threatened species and World Heritage values and will result in further species loss and degradation of values on the LHIG.

Eradication has become a powerful tool to prevent species extinctions and to restore damaged or degraded ecosystems (Towns and Broome 2003). The biodiversity benefits of removing rodents from islands are well recognised.

The eradication techniques proposed for LHI are neither novel nor experimental. They are the culmination of more than 30 years of development and implementation involving more than 380 successful eradications worldwide (Howald *et al.* 2007 and DIISE, 2016). Systematic techniques for eradicating rodents from islands were first developed in New Zealand in the 1980s (Moors 1985; Taylor and Thomas 1989; Taylor and Thomas 1993). Since then techniques have improved significantly, and eradications are now being attempted and achieved on increasingly larger and more complex islands, including those with human populations.

Aerial broadcasting of bait using helicopters has become the standard method used in eradications, particularly those on large islands (Towns and Broome 2003). This method has proven to be a more reliable and more cost-effective option than the previous ground based techniques. Depending on the nature of the area to be treated, aerial baiting has been combined with hand broadcasting of bait and the use of bait stations, particularly around areas of human habitation. The use of new tracking and mapping technologies such as global positioning systems and geographic information (computer mapping) systems has increased the efficacy of aerial-based eradication programmes (Lavoie *et al.* 2007).

The largest island successfully treated this way to date is 12,700 ha Macquarie Island in 2011 which saw the successful eradication of ship rats, house mice and rabbits (*Oryctolagus cuniculus).* The island housed 41 people at the time.

Similar operations to that proposed for the LHI Group that have been completed include:

- Campbell Island (11 300 ha) in the New Zealand subantarctic, where Norway rats (*Rattus norvegicus*) were eradicated.
- seven species including ship rats and house mice from Rangitoto and Motutapu Islands, New Zealand (~4 000 ha) in 2009
- four species of rodents, including house mice and ship rats, from several islands in the Bay of Islands, New Zealand (605 ha) in 2009.

These operations offer opportunities to share information on techniques and planning. Not only are the target species similar, the eradication on Rangitoto and Motutapu Islands had a small number of residents and livestock and thousands of daily visitors. The Bay of Islands includes several permanent residents, a full-time tourism operation and numerous day visitors. Macquarie Island, about nine times the size of LHI, is to date the largest island from which house mice and ship rats have been eradicated, either individually or in combination.

After completing a Feasibility Study in 2001, the LHIB has carefully considered and evaluated the eradication of rats and mice on the LHIG. Due to developments in eradication techniques during the past 20 years, particularly the refinement of aerial baiting methods, the eradication of both rats and mice on the LHI Group in a single operation is now feasible and achievable.

The many successful rodent eradication programmes undertaken on islands around the world have shown that the benefits to humans and native plants and animals are both significant and immediate. Benefits include (see review in Towns *et al.* 2006):

- significant increases of seeds and seedlings of numerous plant species on islands after the eradication of various rodent species
- rapid increases in the number of ground lizards (e.g. geckos, skinks) following removal of rats – including a 30-fold increase in one case
- dramatic increases in the numbers of breeding seabirds and fledging success
- rapid increases in forest birds and invertebrates.

Apart from the benefits to biodiversity, the proposed eradication operation is considered the most appropriate course of action for a range of social, health and financial reasons.

The anticipated benefits specifically relating to a rodent eradication programme on the LHIG include:

- recovery of a range of species an ecological communities directly at risk of extinction due to rodents such as the LHI Placostylus, Little Mountain Palm, Phillip Island Wheat Grass and Gnarled Mossy Cloud Forest
- a marked increase in birds, reptiles and insect density, diversity and distribution – this boost in diversity will increase food resources for predatory terrestrial vertebrates and potentially lead to population increases which will enrich the experience of both island residents and tourists
- increases in the abundance of plants, seeds and seedlings, thereby enhancing the process of forest regeneration
- removal of the economic and environmental burden of the ongoing control currently in place, eliminating the need for the ongoing use of rodent poisons in the environment and their associated long-term risks to native species, pets, livestock and people
- an increase in productivity in the island's kentia palm industry and returns to the local community
- the ability to return species (or closely related surrogates/ecological equivalents) that have long been absent due to the predation of rats and mice, such as the Island gerygone, grey fantail, Boobook Owl, LHI Wood-feeding Cockroach and LHI phasmid
- elimination of significant health risks caused by rodents, including a range of viruses, bacteria, internal parasites (such as intestinal worms) and external parasites (such as fleas, mites and lice), many of which can spread disease to humans
- elimination of the inconvenience currently experienced by residents caused by spoiled foodstuffs and rodent excrement – currently, keeping rodents out of dwellings is an ongoing task for the island's residents.
- increased agricultural productivity
- increased tourism by marketing a rodent free World Heritage Area.

Recent advances in rodent eradication techniques and the size and complexity of islands now treated, mean that eradication is now technically feasible on LHI. LHI will be the first island with a significant resident community for which both mice and rats have been targeted for eradication although other similar projects are in the planning phase elsewhere in the world, including 17000 ha Floreana Island in the Galapagos. The presence of a significant human population, associated livestock and two endemic species/subspecies at risk from poisoning, add to the complexity of the task. Notwithstanding, the eradication techniques to be used on LHI are neither novel nor experimental; they are the culmination of more than 30 years of development and implementation involving more than 380 successful eradications worldwide.

It is believed that the known ongoing and likely cumulative increasing impacts of rodents on LHI are unacceptable for the reasons stated. Any ongoing control operation requires the ongoing use of toxicants with the subsequent risks and the benefits of a control programme stop shortly after the programme stops for any reason e.g. lack of funds or toxicant resistance in rodents. This means that eradication is the only option to reduce these effects to an acceptable level in the short, medium and long term.

2.9 Selection of Eradication Technique

Systematic techniques for eradicating rodents from islands were first developed in New Zealand in the 1980s (Moors 1985; Taylor and Thomas 1989; Taylor and Thomas 1993). Since then techniques have improved, and rodents can now be eradicated from large, geographically and physically challenging and biologically complex islands. Eradication has become a powerful tool to prevent species extinctions and to restore damaged or degraded ecosystems (Towns and Broome 2003).

Early attempts at eradicating rodents from islands mainly used traps and bait stations, but as the technology has improved, aerial broadcasting of bait using helicopters has become the method of choice (Towns and Broome 2003). The use of new tracking and mapping technology such as Global Positioning Systems (GPS) and Geographic Information Systems (GIS) has increased the efficacy of aerial-based eradication programmes (Lavoie *et al.* 2007). The majority of successful eradications on large islands have used this methodology in combination with the rodenticide Brodifacoum in cereal pellets. The largest island successfully treated this way is subantarctic Macquarie Island (12700 ha), where rabbits, ship rats and mice were successfully eradicated (Springer, 2016).

A review of all rodent eradications using all methods in the Database of Island Invasive Species Eradications (DIISE, 2016) showed that

- For mice there have been 111 eradication attempts. 71 of these attempts have been declared successful, 26 have failed, and 14 are as yet unconfirmed. This gives a success rate of 73%.
- For Ships Rat there have been 428 eradication attempts. 316 of these attempts have been declared successful, 43 have failed and 69 are as yet unconfirmed. This gives a success rate of 88%.

However, as eradication techniques and understanding of the causes of failures improved over time, so has the success rate. For example:

- The success rate for mouse eradications from 1997-2014 on NZ islands using Pestoff 20R with 20 ppm Brodifacoum aerially applied is 100% or 11 from 11 attempts (Broome and Fairweather, 2016,).
- Rat eradications on islands over the period 1997- 2014 using this bait and method have been 98% successful (37 of 39 attempts) (DIISE 2016).

Failures most often occurred with mice, and the speculated causes of failure included technical issues (e.g., inadequate or insufficient bait deployment), failure to follow established protocols, observed or suspected non-target poisoning issues that halted the campaign, lack of funding and public support, and bait competition by terrestrial crabs on tropical islands. One of the problems with assessing failure rates for mice eradication attempts is that many operations were undertaken with the primary aim being to eradicate rats, without mice being specifically targeted. Examples include eradication operations on Patiti, Haulashore and Quail Islands in New Zealand, where bait stations were used at spacing suitable for rats but larger than desirable for mice. Consequently, mice were not eradicated. These operations are often recorded as failures for mice, although the methodology used was not designed for mice. On the other hand an aerial baiting operation designed to target rabbits on Enderby Island had the unexpected benefit of also eradicating mice (Torr, 2002). On LHI, both rats and mice will be specifically targeted for eradication and the operational methodology planned accordingly.

The reasons for the higher failure rate of mice eradications are unclear, but in the two major reviews of global eradication attempts (Howald *et al.* 2007; MacKay *et al.* 2007) the authors speculate that inadequate bait density on the ground could be a significant factor. Mice typically have smaller home ranges than rats, and therefore they have a lower probability of being exposed to bait that is in bait stations at standard densities for a rat eradication density i.e. 25 -50 m spacing, or is broadcast relatively sparsely. The solution for bait station operations is to use smaller spacing between stations, no larger than 10 m which is logistically challenging or often unfeasible for all but the smallest and topographically mundane islands. Possible solutions for aerial operations are to increase the bait rate (kg/ha) or to use a smaller bait that, when broadcast at the same application rate (kg per ha), provides a greater number of pellets per unit area. However, mice were eradicated from Montague Island in NSW, where small (5.5 mm diameter) and large (10 mm diameter) baits were used on different parts of the island. This operation, undertaken to compare the efficacy of the two bait sizes, demonstrated that both sizes are capable of eradicating mice, provided that there are no gaps in the distribution of bait. On LHI, adequate bait dispersal will be achieved primarily by using aerial broadcasting of large bait pellets at a nominal density of at least one bait every two square metres. In the settlement area, where mice are likely to not range as far, small bait pellets will be hand broadcast at a nominal density of at least one bait every half square metre. Where bait stations are used, these will be set at approximately 10 m spacing.

To minimise the risk of failure of the eradication it is vital to use tried-and-tested techniques that have proven repeatedly to be successful elsewhere. Use of published information, previous experience on other islands, on-site research, close collaboration with international experts, and peer-review will ensure that planning for the eradication of rodents on LHI is based on current best-practice techniques taking in to account the local situation.

2.9.1 Alternative Eradication Techniques Assessed as Unsuitable

A number of techniques were evaluated for undertaking the eradication and subsequently dismissed from detailed consideration as considered unfeasible or unproven.

2.9.1.1 Disease

While there is ongoing research focused on the development of taxon-specific diseases that can control populations of non-native species (such as by the Commonwealth Scientific and Industrial Research

Organization (CSIRO), www.cse.csiro.au/research/rodents/publications.htm), there are no pathogens with proven efficacy at eradicating rodents (Howald *et al.* 2007). Even a highly lethal rat-specific pathogen which may be suitable for ongoing control would be ineffective at eradicating rats from LHI because if the rat population rapidly declined, transmission rates of the introduced pathogen would also decline so as to be ineffective in eradicating the few remaining individuals. Furthermore, the introduction of novel pathogens into the environment carries tremendous potential risks to non-target species. Therefore, the use of pathogens is disqualified from detailed consideration.

2.9.1.2 Trapping

This alternative would involve the use of live traps and/or lethal ("snap") traps to eradicate rats and mice. This action would be extremely unlikely to succeed at LHI. In addition to the size and topography making this technique impractical and risky both for effectiveness i.e. being able to locate a trap in every rodent's territory and because of the extensive effort and considerable personnel risk required to set and monitor traps i.e. trapping cliffs. To access the traps for the 3-4 months required an extensive track network would be required which would have significant ecological impacts on vegetation including increasing the risk of erosion. Also to maximise the likelihood of success different traps would be required to target rats and mice effectively doubling the effort and impact. Also the use of live traps and/or lethal traps to remove rats and mice from an area is a strong selection agent in favour of rats that are "trap-shy". Thus, after extensive trapping the only rodents that would remain would be those that are behaviourally less likely to enter a trap, and these rodents would be very difficult to remove without the introduction of alternate methods such as toxicants. The use of live traps requires daily checking for humaneness to both target and non-target species which would be impractical given the number of traps involved. The use of kill traps presents an unquantified risk to non-target species, particularly inquisitive species such as Currawong and Woodhen, which would mean that these species would probably have to be taken into captivity for the duration of the operation, but also ground frequenting birds such a banded rail and emerald ground dove. Therefore, this alternative was excluded from detailed consideration.

2.9.1.3 Biological

The introduction of predators on rats and mice, such as snakes and cats, was dismissed because biological control most often only reduces, rather than fully eliminates the target species and thus fails to achieve the desired ecological benefit gained through complete rat removal. There is no known effective biological control agent for rats or mice on islands, and some forms of biological control would result in unacceptable damage to the environment. The introduction of cats to islands in order to control introduced rodents has been attempted numerous times since European explorers began crossing the Atlantic and Pacific Oceans. The introduction of a rodent predator, such as cats, generally results in a greater combined effect on birds than if one or the other were present alone.

When seabirds are present, cats have been shown to prey heavily on seabirds (Atkinson 1985), consuming fewer rodents during these times. When seabirds leave the islands following the end of the breeding season, cats switch prey to rodents, which allow the islands cat population to remain stable at a higher level than if no rodents were present on the island (Atkinson 1985, Courchamp *et al.* 1999, 2000). Thus, birds are affected not only by rodents but also the larger number of cats that are sustained by rodent presence on the island. Introduction of another species onto an island can have severe and permanent consequences to the ecosystem (Quammen 1996). Also introduction of any additional species, especially a predatory one such as snakes or cats would be contrary to the LHI biosecurity rules and counter to the ethos of restoring the island. Cats have already been removed from the island and there are no snakes on LHI. Therefore, this alternative was disqualified from detailed consideration.

2.9.1.4 Fertility Control

Fertility control has been used with limited success as a method of pest management in a few species, primarily larger mammals where individuals can be targeted for treatment (Fagerstone K.A, *et al.*2002). Experimental sterilization methods have included chemicals and proteins delivered by vaccine, and genetically-modified viral pathogens. However, the effectiveness of these experimental techniques in the wild, and their impacts to non-target animals are unknown.

The possibility of using a new rodent sterilisation technology called "Contrapest", developed by SenesTech Ltd was considered with the following issues identified:

- The product is not currently registered in any country. While SenesTech hope to have it registered in the USA next year it is likely to be some time before it is registered in Australia.
- The product, Contrapest, aims to *reduce* rat populations through sterilisation, by reducing fecundity but leaving some animals to defend territories i.e. **ongoing control not eradication**.
- It requires every female to be dosed with the product i.e. it needs to be regularly dispensed as there is no inherited or contagious transmission of the reduced fertility.

- The fertility control compounds (VCD and Triptolide) are not species-specific and could affect other mammals including humans.
- Currently the product is designed for rats although the developers state that it has the potential to be modified to target mice, along with other species, although dispensing the appropriate dosage is problematic at this stage.

The product is not suitable for the rodent eradication program on LHI as:

- The product is aimed at *reducing rat* numbers not eradicating them.
- The product needs to be ingested over a prolonged period (approx. 75 days) and all female rats would need to be exposed to the product. This would effectively mean that the product would need to be put out continually for the foreseeable future.
- While reducing rat numbers would have some benefits, only total eradication of rats and mice will give the anticipated ecological, social, economic and human health benefits.
- The product is currently dispensed by adding it to water. This is problematic for LHI as dispensers would need to be put over the whole island at approximately the same spacing as bait stations. The product needs to be consumed over many feeds as it affects the reproductive system slowly meaning that the bait would need to be made available in every territory for a prolonged period to affect even one generation of rats.
- Even if the product was used on the accessible areas and was able to reduce numbers, this would only be short term while the product was being dispensed. Also, rodents from the untreated areas would soon move in as resources, food and territory were freed up.
- The current product Contrapest is only for rats which would leave mice untreated.

Contrapest has been investigated for both the LHI program and by other rodent eradication organisations internationally and its use would be experimental hence it is not currently considered a feasible option for rodent eradication in the foreseeable future.

Repeated baiting of uncertain oral contraceptives on an inhabited and rugged island across seasons or capturing, vaccinating, and releasing every member of a single gender of the LHI rodent population is unfeasible. This lack of data and tools disqualifies the use of fertility control from detailed consideration (Tobin and Fall, 2005).

2.9.1.5 Fencing

We are aware that rodent proof fencing has been used with some success to create predator free enclosures in "mainland island" situations particularly in New Zealand (i.e. Zealandia and Maungatutari). These have stemmed from the success of island eradications using the techniques we propose. A significant review of fencing for conservation was undertaken by Burns et al in 2012. The inside of these enclosures are then baited with poison (most often aerially) to locally eradicate pests (Burns et al, 2012). We are not aware of fences being used as part of true island rodent eradications to date, although Stewart Island in New Zealand has considered fencing the settlement area and trialing eradication of rats, possums and cats within the settlement area first, as part of a staged eradication for the entire island (Bell, 2014). The Stewart Island eradication project has not yet been implemented. There is significant debate within the scientific community as to the value of fences for conservation and long term effectiveness is still being evaluated (Burns et al 2012).

Given the natural ocean barrier around LHI, proven effectiveness of the proposed REP bait and delivery methods, the presence of rats, mice and threatened species across the entire island and the ability of rats and mice to swim up to 500m, we see no justification or feasibility for a fence on Lord Howe Island. A fence(s) is considered unsuitable because:

- A fence would not eliminate risks to EPBC listed species currently threatened by rodent predation and competition or to EPBC species potentially impacted by implementation of the REP
- Intensive baiting is still required to eradicate rodents on whichever side of the fence was chosen to be rodent free. Control baiting in perpetuity would be required on the other side
- Fences will not eliminate all rodent invasions from the other side. Despite efficacy demonstrated in trials, ongoing reinvasions have occurred (Burns et al, 2012). Fences will slow the reinvasion rate but do not stop it (Bell, 2014). They have been demonstrated to be particularly ineffective against mice (Burns et al, 2012)
- Fence failures (i.e. tree damage, storm damage and human error such as not closing gates) are identified as major causes of reinvasion (Burns et al, 2012).

- Coastal ends of fences have proven particularly challenging (Burns et al, 2012). The fence would need to extend into the sea to prevent rodents walking around and even then rats and mice are known to swim up to 500m and could easily swim around the fence. Coastal fence ends protruding into the sea have not been used before (Bell, 2014) and would very susceptible to wave damage.
- Water ways are considered weak points for fences (Burns et al, 2012). Fences generally follow ridge lines to avoid waterways. This would be impossible on LHI
- Fences are not considered "walk away" solutions and require intensive vigilance and an ongoing inspection and maintenance regimes. They also have a finite life (about 25 years)
- Fences have high installation costs and ongoing maintenance costs relative to island eradication techniques. Average installation costs on Mainland New Zealand are approximately $225 / linear metre (Bell, 2014). Inspection and maintenance costs are around 5% of the capital every year
- Fences designed to prevent rodents will also act as barriers to threatened species movement, dispersal and breeding (Burns et al, 2012). The fence would require a curved hood, an underground skirt and mesh as small as 6mm in one dimension preventing movement of species such as woodhen and snails on LHI
- Vegetation clearing would need to occur in at least a 10m corridor around the fence. On LHI this could lead to potential disturbance to threatened species and habitat
- Movement of people and vehicles on LHI would limit effectiveness of the fence.
- Rodent proof fencing is likely to have very little community support on LHI

Fencing is therefore not considered a feasible alternative on LHI.

2.9.2 Preferred Technique – Use of Toxicant

As all other techniques above have been assessed as unsuitable and therefore eliminated from further consideration, it leaves the wide scale application of a suitable toxicant in highly palatable bait as the only feasible option for eradicating rats and mice from LHI. While this technique does entail some risks, primarily non-target species deaths, with detailed planning and implementation these risks can be minimised and mitigated to an acceptable level. The appropriate use of toxicants can meet all the criteria of a successful eradication (Cromarty 2002); this is since all individual animals at all parts of the island can be exposed to the technique within a narrow timeframe i.e. before they can reproduce. The use of toxicants is the most common and most successful method for eradicating *rodents from islands with over 300 islands worldwide having rodents eradicated using this technique. (*DIISE, 2015).

Discussion of suitability of a range of toxicants is described in the sections below.

2.10 Selection of Toxicant

2.10.1 Mortality Agents Assessed as Unsuitable

A critical component in any eradication is the choice of toxicant. A number of rodenticides have been used for rodent eradications in the past. While effective at control measures, many are unsuitable for the eradication program planned for LHI due to a range of issues including safety concerns, rodent avoidance or incomplete product development.

The use of many rodenticides was dismissed from further consideration for one or more of the following reasons: 1) greater toxicity to non-target wildlife; 2) lack of proven effectiveness in island rat eradications; 3) potential for development of bait shyness in the rat population; and 4) the lack of an effective antidote in case of human exposure. Each of these issues and the associated rodenticides are discussed below.

Most documented island-wide rodent eradication programs (226, 68 %) have used second generation anticoagulants, primarily Brodifacoum (Howald *et al.* 2007). Twenty-nine have used first-generation anticoagulants such as diphacinone. Nine additional eradications have used non anticoagulant toxicants including zinc phosphide, strychnine, and cholecalciferol. Acute rodenticides, such as zinc phosphide and strychnine, have the ability to kill rats quickly after a single feeding. However, because poisoning symptoms appear rapidly, the acute rodenticides can induce learned bait avoidance if animals consume a sub-lethal dose. Studies with zinc phosphide have demonstrated that rodents associate toxicity symptoms with bait they had consumed earlier if the onset of symptoms occurs as long as 6 to 7 hours after consumption (Lund, 1988). Thus, any individual that consumes a sub-lethal dose is likely to avoid the bait in the future (Record and Marsh, 1988). Also, acute rodenticides are often extremely toxic to humans and effective antidotes are not always available. The combination of these factors disqualifies the acute rodenticides from detailed consideration.

2.10.1.1 Cholecalciferol

A form of vitamin D that is an acute poison that to date has been used in at least three eradications, but all involved small islands and, in each case, baiting was supplemented with anticoagulants. Cholecalciferol, which is classified as a "sub-acute" rodenticide, has the ability to kill rats more quickly than the anticoagulant rodenticides, but most often more slowly than the acute rodenticides. Cholecalciferol has been used successfully to eradicate rats from very small islands (Donlan *et al.* 2003) it is less toxic to birds than Brodifacoum, but it is highly toxic to mammals, and treatment of poisoning is difficult. More importantly, there is evidence that mice can detect the poison in baits and will avoid it. This bait avoidance, while not critical in a control operation, would place an eradication programme at risk of failure. Thus, its use at LHI would be largely experimental in nature. The presence of unique taxa at LHI, and the need for a high probability of conducting a successful eradication on the first attempt, disqualifies cholecalciferol from detailed consideration.

2.10.1.2 Sodium monofluoroacetate

Commonly known as 1080, is an acute poison which can be detected by some rodents especially mice and is prone to promoting bait shyness making it unsuitable for eradication. There is also no known antidote.

2.10.1.3 Zinc phosphide

Is an acute poison that is used to control plague mice in cereal crops. Although there is little risk of secondary poisoning, this compound is a broad spectrum poison that is more toxic to birds than it is to rodents. The high risk of direct poisoning of non-target species and the risk of bait avoidance precludes its use on LHI.

2.10.1.4 Other agents

Some research has been conducted into developing toxicants that are specific to rats and mice, but these have proven not to be technically feasible at this time. Even if a new rodent specific toxicant is developed it will take many years to test and trial it to ensure it is suitable for eradications and is suitable to be used on an island the size of Lord Howe.

Similarly, long-term research to develop a mouse-specific mortality agent has been largely abandoned both in Australia and overseas. Work over the past two decades focussed on the development of a virally-vectored immuno-contraceptive agent which would be transmitted between mice, rendering females sterile. To be effective, this type of mortality agent requires ready transmission between individuals, but researchers were unable to resolve the problem of attenuation of the virus when spreading among wild mice. This attenuation ultimately halts the spread of the virus among the population. While developing an eradication tool capable of killing 100% of individuals was never a goal of the research programme, even broad-scale control is now considered unlikely. This conclusion led to the programme being abandoned.

Another rodenticide (named ***Eradibait***®) works by physically blocking water absorption in the gut of rats and mice. It is a type of cellulose that coats the fine hairs (villi) in the lower gut, disrupting messages to the rodent's brain causing it to stop drinking. This leads to dehydration, blood thickening, kidney dysfunction, coma and eventual death. The bait contains no toxicant; consequently there are no secondary-poisoning issues. Unfortunately, while the product has been used for control on farms it has never been used in eradication. Recent research conducted in New Zealand indicates that the bait has low palatability to rodents, and they will only consume it when no other food source is available. This makes it unsuitable for use in eradication, where every animal must consume a lethal dose.

2.10.1.5 Para-aminopropiophenone

(PAPP) is currently being developed for the control of feral cats, foxes and wild dogs. The need to encapsulate the poison has added considerably to the task. Trials show that PAPP does not kill rodents. It is possible that an analogue of PAPP could be developed as a rodenticide sometime in the future (Eason *et al.* 2009), but its potential effects on non-targets and its suitability for eradication are all unknown.

2.10.1.6 Anticoagulants

Anticoagulants act by effectively blocking the vitamin-K cycle, resulting in an inability to produce essential blood-clotting factors. A range of anticoagulant rodenticides are available which could potentially be utilised in an eradication operation on the LHIG. Anticoagulants are classified as either first-generation or second-generation. First-generation anticoagulants such as warfarin, diphacinone, pindone and coumatetralyl are generally of low toxicity but require a high concentration and multiple feeds over several of days to be effective (Hone and Mulligan 1982). The need for rodents to ingest large quantities of the bait to obtain a lethal dose of the poison increases the risk of failure in eradication. Second-generation anticoagulants including Brodifacoum, bromadiolone and difethiolone are more toxic, require lower concentrations and only a single feed to kill rodents and are thus preferred for use in eradications. However they do present a greater non-target risk.

Anticoagulants are defined as chronic (death occurs one to two weeks after ingestion of the lethal dose, rarely sooner), single-dose (second generation) or multiple-dose (first generation) rodenticides, acting by effective blocking of the vitamin K cycle, resulting in inability to produce essential blood-clotting factors — mainly coagulation factors II (prothrombin) and VII (proconvertin).

In addition to this specific metabolic disruption, massive toxic doses of 4-hydroxycoumarin, 4-thiochromenone and indandione anticoagulants cause damage to tiny blood vessels (capillaries), increasing their permeability, causing diffuse internal bleeding. These effects are gradual, developing over several days. In the final phase of the intoxication, the exhausted rodent collapses due to hemorrhagic shock or severe anaemia and dies calmly. The question of whether the use of these rodenticides can be considered humane has been raised. The main benefit of anticoagulants over other poisons is that the time taken for the poison to induce death means that the rats do not associate the damage with their feeding habits.

- First generation rodenticidal anticoagulants generally have shorter elimination half-lives, require higher concentrations (usually between 0.005% and 0.1%) and consecutive intake over days in order to accumulate the lethal dose, and are less toxic than second generation agents.
- Second generation agents are far more toxic than first generation. They are generally applied in lower concentrations in baits — usually on the order of 0.001% to 0.005% — are lethal after a single ingestion of bait and are also effective against strains of rodents that became resistant to first generation anticoagulants; thus, the second generation anticoagulants are sometimes referred to as "superwarfarins".

On Lord Howe Island mice are already totally resistant to warfarin and trials indicate they may also have a tolerance to Brodifacoum (Wheeler and Carlile, 2013; O'Dwyer *et al.* 2015). The suite of second-generation anticoagulants is the only tool currently available for effectively eradicating rodents from all but the smallest islands. Resistance to these poisons, if it develops, will make eradication impossible for the foreseeable future. Moreover, this could potentially result in a situation where there was no effective way to control rodents on the island, with catastrophic results for biodiversity, tourism and residents.

Diphacinone

Diphacinone is the most widely used first generation anticoagulant (FGA) for rodent eradications. And given the limited knowledge and experience on other FGA for eradications, it is the only one which would reasonably be considered for rodent eradication on LHI. Although effective at rat control in suitable conditions it has not been proven to be an effective and reliable tool for broadcast-based rodent eradications in general, largely due to the significantly greater application rates, relative to Brodifacoum, necessary for ensuring availability of bait, for a long enough period, to all rodents;

A total of 12 successful island rodent eradications have been reported using diphacinone as the primary toxicant and fifteen eradications using diphacinone are reported to have been unsuccessful (Howald *et al.* 2007, Island Conservation unpubl. data):

Toxicological Properties of diphacinone

The physiological action of diphacinone on target organisms is the same as for Brodifacoum: However, diphacinone and other first-generation anticoagulants have a reduced affinity for the enzyme that produces vitamin K-dependent clotting agents (in comparison to Brodifacoum and other second-generation anticoagulants,) resulting in a slower depletion time of these clotting agents in the bloodstream (Eason and Ogilvie 2009). Also, diphacinone is more actively metabolized and excreted by rats than Brodifacoum.

As a result of these properties, diphacinone requires multiple exposures to ensure a lethal dose is obtained. Although diphacinone can be lethally toxic to some rodents when administered in a single, large dose, it is relatively more potent in small doses administered over several days (Buckle and Smith 1994, Timm 1994). After considering these studies, we concluded that, to ensure 100 percent mortality to the rat population on LHI (eradication rather than control), if diphacinone was used, it would need to be consistently available and consumed by some rats for up to 12 days.

The primary advantage of diphacinone as a rodenticide for conservation purposes is the low risk it poses to non-target organisms in comparison to second generation anticoagulants. Diphacinone has comparatively low persistence in animal tissues, which makes toxicity to non-target birds through primary and secondary exposure less likely than for Brodifacoum (but does not eliminate the risk) (Fisher 2009). Furthermore, laboratory trials have indicated that diphacinone has low toxicity to birds when compared with Brodifacoum (Erickson and Urban 2004, Eisemann and Swift 2006). However, recent research suggests that the toxicity of diphacinone to some birds may be considerably higher than previously thought (Rattner *et al.* 2010), although the overall toxicity of diphacinone still remains low compared with Brodifacoum. From the perspective of non-target risk, particularly for birds, diphacinone is the optimum choice. However, the choice would be risky when gauged with overall baiting efficacy on LHI. The long exposure to diphacinone necessary to achieve rat and mouse mortality ultimately decreases the probability that all rodents would consume enough bait, given the conditions on the island. For example, the availability of other, natural food items and competition with other consumers both could decrease the probability of all rodents consuming enough bait. Competition with other consumers also would potentially leave some rat territories with inadequate access to bait. All of these factors increase the risk of eradication failure.

While diphacinone has been tested or used with favourable results in a number of landscape-scale rodent control efforts (Dunlevy *et al.* 2000, Spurr *et al.* 2003a, Spurr *et al.* 2003b), the success of these control efforts does not provide assurance that Diphacinone-50 would be successful as a tool for rodent eradication when competition for bait between the target species and non-target consumers is high (such as may occur on LHI).The goal of a rodent control operation is to reduce a rodent population to an acceptably small size and maintain low density populations, whereas the goal of an eradication operation is to permanently remove every rodent. This is a critical fundamental difference when assessing the relative merits of different bait products; a bait product that is available for use, attractive to rodents, but has an uncertain efficacy may be an excellent tool for a control operation but not for a broadcast eradication operation at this time.

2.10.2 Preferred Toxicant – Brodifacoum

The toxicant selected for the eradication of rats and mice from the LHIG is Brodifacoum, a second-generation anticoagulant. Mice on LHI are known to be resistant to warfarin, so there is a risk that other first generation anticoagulants such as diphacinone may also be ineffective on mice. Second-generation anticoagulants were developed specifically for use in situations where rodents had developed resistance to first- generation anticoagulants.

The second-generation anticoagulants floucoumafen and bromadiolone have both been used in eradications, but (i) the relative lack of information on the environmental effects of these poisons, (ii) uncertainty about their efficacy in such operations, as they have only had limited use (iii) the fact that they offer no appreciable advantages over Brodifacoum and (iv) there has been limited trials and field work done on these toxicants mean that they are not suitable for this project.

Like all anticoagulants, Brodifacoum disrupts the formation of blood-clotting factors. Death through internal haemorrhaging typically takes 3–10 days (Torr 2002), with mice sometimes taking longer to die than rats (Fisher 2005) and recently on LHI, to be up to two weeks longer than rats (Wheeler and Carlile, 2013 and O'Dwyer *et al.* 2016).

Characteristics supporting the use of Brodifacoum in the operation on LHI include:

- Brodifacoum has proven to be successful in over 226 eradications including all 14 eradications on islands greater than 500 ha in size.
- Brodifacoum has proven to be successful in a variety of climatic conditions including those similar to LHI.
- Brodifacoum is highly toxic to both rats and mice in minute quantities, allowing a lethal dose to be consumed in a single feed, thus avoiding the consumption of sub-lethal doses and the associated risk of bait shyness/avoidance.
- Brodifacoum is a chronic toxicant i.e. its action is delayed meaning the rodent does not associate any illness with the bait it has consumed, thus avoiding the consumption of sub-lethal doses and the associated risk of bait shyness/avoidance.
- Both target species are highly susceptible to Brodifacoum, simplifying logistics and maximising cost-effectiveness.
- When contained in Pestoff® 20R bait formulation, Brodifacoum is highly palatable to both species, as confirmed by field trials on LHI.
- Brodifacoum is highly insoluble in water, and its propensity to bind to soil particles prevents its leaching into the substrate on which it is spread. Consequently, contamination of waterways and runoff into the marine environment are negligible, and it is less likely than other poisons to accumulate in either aquatic systems or plant material (Toxikos 2010); Ogilvie *et al.* 1997)
- The half-life of Brodifacoum in the soil is reasonably short: 12–25 weeks depending on soil type and conditions.
- The non-target effects of Brodifacoum are well understood enabling planning to mitigate or minimise any non-target impacts.
- Although toxic to livestock, pets and humans if consumed, an antidote is readily available.

All second-generation anticoagulants are more toxic than the first-generation anticoagulants; consequently they have a greater potential to kill non-target species that consume bait. Also, second-generation anticoagulants persist longer in the tissues of those vertebrate animals that ingest bait; the estimated half-life of Brodifacoum in rat tissue is estimated to be 150 to 200 days (Erickson and Urban 2004), therefore, there is a greater risk of secondary poisoning. Although generally not toxic to invertebrates, anticoagulants can be ingested by some invertebrates (Spurr and Drew 1999) which may then be eaten by non-target species. Thus, the use of second-generation anticoagulants poses more of a risk than does the use of first-generation anticoagulants, but actions, as discussed elsewhere in this application can be taken to effectively mitigate or limit these risks. Acute toxicity of Brodifacoum to rats and mice is shown in Table 8. Assessment of suitability of other toxicants is considered in Table 9.

Table 8 Acute Oral Toxicity (LD50 Mg/Kg) of Brodifacoum to the Target Pests (from Broome et al.2016)

Species	**LD50 Value (mg kg -1)**	**References**
House mouse House mouse (caught from wild) House mouse (wild caught from Gough Island)	0.4 (95%CL 0.30 – 0.63) 0.52 0.44	Redfern *et al.*(1976) O'Connor and Booth (2001) Cuthbert *et al.* (2011)
Ship rat *Male*	0.73	Dubock and Kaukeinen (1978)
Female	0.65	Dubock and Kaukeinen (1978)
Ship rat (caught from wild)	0.46	O'Connor and Booth (2001))

Table 9 Suitability of Potential Toxicants for the Eradication of Rats and Mice

FGAC, first generation anticoagulant; SGAC, second generation anticoagulant; na, not applicable.

Mortality agent	Type	Palatability	Probability of killing all targeted individuals	Availability of manufactured formulations	Target specificity	Environmental persistence	Likelihood to induce aversion	Antidote available	Number of successful eradications
Cholecalciferol	Acute toxin	High	Low	High	High	Low	High	Yes	Low
Sodium monofluoroacetate	Acute toxin	High	Low	High	Low	Low	High	No	Low
Zinc phosphide	Acute toxin	High	Low	High	Low	Low	High	No	None
Rat-specific toxin	Acute toxin	Na	Low	Not available	High	Low	Low	na	None
Cellulose compound	Acute toxin	Low	Low	High	High	Low	High	na	None
PAPP	Acute toxin	Low	Low	Not available	?	?	?	Yes	None
Mouse-specific virus	Immuno-contraceptive	Na	Low	Not available	High	Low	Low	na	None
Diphacinone	FGAC	High	Low	High	Low	Low	Low	Yes	Low
Pindone	FGAC	High	Low	Low	Low	Low	Low	Yes	Low
Coumatetralyl	FGAC	High	Low	Low	Low	Low	Low	Yes	Low
Floucoumafen	SGAC	High	High	Low	Low	High	Low	Yes	Low
Bromadiolone	SGAC	High	High	Low	Low	High	Low	Yes	Low
Brodifacoum	SGAC	High	High	High	Low	High	Low	Yes	High

2.10.3 Detailed Brodifacoum Information

2.10.3.1 Overview

Brodifacoum is a second generation anticoagulant of the coumarin class. Its rodenticidal properties were first described in the early 1970s and it was first marketed in 1978. It is used globally for pest management. In Australia it is registered in all states and territories for the control of introduced rats and mice especially warfarin-resistant strains and is listed as a Schedule 6 poison (Macleod and Saunders, 2014).

2.10.3.2 Chemical name

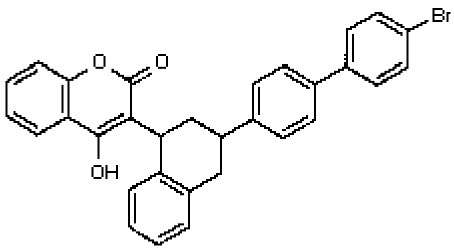
3-[3-(4'-bromo-[1,1'-biphenyl]-4-yl)-1,2,3,4-tetrahydro-1-naphthalenyl]-4-

hydroxy-2H-1-benzopyran-2-one.

2.10.3.3 Chemical and physical properties

The empirical formula for Brodifacoum is $C_{31}H_{23}BrO_3$ (see below) and its molecular weight is 523.4. Brodifacoum is an off-white to fawn-coloured odourless powder with a melting point of 228 –232ºC. It has a very low solubility in water (less than 10 mg/L at 20 ºC and pH 7). Brodifacoum is slightly soluble in alcohols and benzene, and soluble in acetone. It is stable at room temperature.

This section is from Eason and Wickstrom (2001)



2.10.3.4 Synonyms

3-(3-(4'-Bromo-(1,1'-biphenyl)-4-yl)-1,2,3,4-tetrahydro-1-napthalenyl)-4-hydroxycoumarin; Talon; Talon® Rat Bait, Talon® possum bait, Pestoff® possum bait

2.10.3.5 Mode of Action

Brodifacoum, like other anticoagulant toxicants, acts by interfering with the normal synthesis of vitamin K-dependent clotting factors in the liver of vertebrates (Hadler and Shadbolt 1975). In the liver cells the biologically inactive vitamin K1-2,3 epoxide is reduced by a microsomal enzyme into biologically active vitamin K, which is essential for the synthesis of prothrombin and other clotting factors (VII, IX, and X). Brodifacoum antagonism of the enzyme vitamin K1-epoxide reductase in the liver causes a gradual depletion of the active form of the vitamin, and consequently of vitamin K-dependent clotting factors. This results in an increase in blood-clotting time until the point where no clotting occurs i.e. blood is thinned to the point of haemorrhage which leads to death.

There is usually a lag period of 3-5 days between exposure and the onset of clinical signs. Initial clinical signs of Brodifacoum poisoning are usually characterised by depression/lethargy and anorexia. This is followed by anaemia with pale mucous membranes, dyspnoea, exercise intolerance, and haemorrhaging from numerous sites. Periarticular or intraarticular haemorrhage causing swollen joints and lameness is especially common in pigs (*Sus scrofa*), and abortion induced by placental haemorrhaging has been reported in cattle (*Bos Taurus*). Convulsions indicate bleeding into the central nervous system. Animals experiencing prolonged toxicosis may be icteric. Similar clinical signs occur in humans and include haematuria, bleeding gums, and easy or spontaneous bruising (Park *et al.* 1986).

As blood loss continues, cardiac murmurs, irregular heartbeat, weak peripheral pulses, ataxia, recumbency, and coma will be observed. Death due to hypoxia and hypovolemic shock may occur from 48 hours to several weeks after exposure. Animals may occasionally be found dead with no premonitory signs, especially if severe haemorrhage occurs in the cerebral vasculature, pericardial sac, abdominal cavity, mediastinum, or thorax (Murphy and Gerken 1989; Felice and Murphy 1995).

The greater potency of second-generation anticoagulants such as Brodifacoum compared to first-generation anticoagulants such as warfarin and pindone is likely to be related to their greater binding affinity for vitamin K-epoxide reductase (Parmar *et al.* 1987) and subsequent accumulation and persistence in the liver and kidneys after absorption (Huckle *et al.* 1988). All tissues that contain vitamin K-epoxide reductase (e.g. liver, kidney, and pancreas) are target organs for accumulating these toxicants.

This section is from Eason and Wickstrom (2001)

2.10.3.6 Pathology

Generalised haemorrhage is frequently evident at post-mortem. Areas commonly affected are the thoracic cavity, subcutaneous tissue, stomach, and intestine. The heart is sometimes rounded and flaccid with subepicardial and subendocardial haemorrhages. Histomorphological analysis of the liver may reveal centrilobular necrosis (death of liver cells at the centre of the liver lobes) as a result of anaemia and hypoxia. In brush tail possums, post-mortem findings range from mild to moderate haemorrhage in some limbs and in the gastrointestinal tract, to extensive haemorrhage throughout the body and major organs.

This section is from Eason and Wickstrom (2001)

2.10.3.7 Absorption, metabolism, and excretion

Brodifacoum is absorbed through the gastrointestinal tract. It can also be absorbed through the skin. After absorption, high concentrations in the liver are rapidly established and remain relatively constant. Disappearance from serum is slow with a half-life in rats of 156 hours or longer. The slow disappearance from the plasma and liver and the large liver: serum ratio probably contribute to the higher toxicity of Brodifacoum when compared with warfarin or pindone (Bachmann and Sullivan 1983). A proportion of any ingested dose of Brodifacoum bound in the liver, kidney, or pancreas remains in a stable form for some time and is only very slowly excreted.

Brodifacoum is not readily metabolised and the major route of excretion of unbound compound is through the faeces. Enterohepatic recirculation, the process that allows drugs and pesticides that have been absorbed to return to the gastrointestinal tract from the liver via the biliary tract, also plays an important role.

This section is from Eason and Wickstrom (2001)

2.10.3.8 Antidote

Effective antidote is Vitamin K1. As this toxin can affect the body for many months, the antidote must be administered regularly for an extended period.

2.10.3.9 Treatment

Treatment aims to stabilise (maintain airway, control shock), decontaminate (gastric lavage / emesis followed by administration of activated charcoal), reverse anticoagulant effect (Vitamin K1 antidote), and if necessary compensate for blood loss by transfusion of blood or plasma. Appropriate supportive care may include intravenous fluids and oxygen supplementation.

2.11 Selection of the Preferred Bait

2.11.1 Bait Description

The selected bait to deliver Brodifacoum is Pestoff® 20R manufactured by Animal Control Products, Wanganui, New Zealand. In New Zealand, Pestoff® 20R is registered in New Zealand for aerial and hand broadcasting in operations to eradicate rodents from non-stocked off-shore islands as well as fenced enclosures (mainland islands). In Australia the APVMA has previously approved the aerial dispersal of Pestoff® 20R on several islands in New South Wales (i.e. Montague Is), Western Australia (Hermite Is) and Tasmania (Macquarie Is). The Brodifacoum that the manufacturer of Pestoff 20R uses is currently registered for use in Australia under **Product No.: 56139**

A summary of islands that have had rodent eradication using Pestoff 20R is found in Appendix I – Island Eradications Using Pestoff.

Pestoff® 20R is a cereal-based pellet dyed emerald green to reduce its attractiveness to birds (Brown *et al.* 2006). Pestoff® 20R is produced to rigorous specifications so as to be hard enough to withstand being applied through a mechanical spreader with minimal fragmentation, and to have minimal dust residue. A trial using non-toxic bait pellets was undertaken on LHI during August 2007, and this confirmed that the baits were highly palatable to both rats and mice, and readily eaten by both species (DECC, 2007a) (in Appendix D – LHI Trials Package). Trials on LHI found that baits disintegrated completely after approximately 100 days although this is highly dependent upon precipitation and humidity.

Appreciating that it is written for the situation in New Zealand, the baiting operation will comply with the relevant conditions of the Code of Practice for Aerial and Hand Broadcast Application of Pestoff® Rodent Bait 20R for the

Intended Eradication of Rodents from Specified Areas of New Zealand. (Animal Control Products, 2006). This document is designed to achieve

- The safe utilisation of Pestoff® Rodent Bait 20R to enhance the long term survival of threatened biota or for other ecological or commercial reasons that may develop in the future.
- The containment of Brodifacoum following aerial and / or hand broadcast application of PestOff® Rodent Bait 20R within the operational boundaries of any Specified Area.
- Brodifacoum residues in meat or food products sourced from livestock farmed on land either inside the operational area or adjoining any Specified Area as a result of the aerial and / or hand broadcast application of Pestoff® Rodent Bait 20R comply with the regulatory thresholds (see NZFSA website for these prescribed limits).
- The potential for any health risk to humans, arising as a result of the aerial or hand broadcast of Pestoff® Rodent Bait 20R, is eliminated.

The cereal seed used as the base in the bait manufacture is ground to flour, screened to 1.5 mm (smaller than cereal seed) and heated, thereby denaturing the proteins required for germination. There is, therefore, no risk posed by weed invasion by using this particular bait. The amount of poison (Brodifacoum) in each bait is 20 parts per million (0.002%), much less than that present in commercial Talon® (50 parts per million), a bait readily available to purchase and currently used by the residents on Lord Howe Island. Pestoff® Rodent Bait 20R pellet product breaks down more quickly than most commercial rodenticides which tend to contain waxes and other compounds aimed at extending bait life in the field. This would extend unacceptably, the period of non-target risk. The more rapid physical bait breakdown rate for Pestoff® Rodent Bait 20R and its lower toxicity provide an effective compromise between maintaining target animal efficacy and reducing non-target risk

Typically, 10-mm diameter bait is used for eradications targeting rats. The most appropriate size bait to target mice is less certain. In light of suggestions that some failed attempts at mouse eradication may have resulted from inadequate density of bait (pellets per unit area), both 10 mm and 5 mm diameter bait was tested for eradicating mice by applying each size to different sections of Montague Island for efficacy. On average, each 5.5 mm pellet weighs approximately 0.6 g, whereas each 10 mm pellet weighs approximately 2 g. Thus, for the same application rate (kg per ha), use of the smaller bait resulted in four times the number of pellets on the ground. This increased the encounter rate for mice, improving the chances that all individuals had access to bait. Brodifacoum is highly toxic to mice (LD_{50} is approximately 0.4 mg/kg), so each individual mouse need consume only a single 5.5-mm bait to ingest a lethal dose of poison. Results from the eradication of mice from Montague Island demonstrated that mice could be successfully eradicated using bait of either 10-mm or 5.5-mm diameter.

Given that the most difficult component of the eradication will be removing mice from the settlement where alternative foods may be more readily available, a high-encounter rate is preferable. On the other hand, the practical advantages of 10 mm baits over 5.5 mm baits are:

- They have been used through aerial sowing buckets in large quantities without problems.
- The pilot can see baits being spread which can be an advantage sowing up to exclusion zones or sensitive boundaries.
- It is much more feasible to retrieve the larger baits that may be accidentally over-sown into exclusion zones.
- In contrast 5.5 baits breakdown faster in the environment and are less easily seen than the 10mm bait which means that they are likely to pose a lower risk to children and pets i.e. it is harder for children and pets to locate them so this bait size will be used around the settlement.

As a precaution against ingestion by humans, most commercial rodenticides contain a compound known as Bitrex® which is extremely bitter and highly distasteful to humans. There are indications that this additive may cause bait aversion in some rodents and this may have contributed to the failure of several operations targeting mice and rats (Cleghorn and Griffiths, 2002 and Kaukeinen and Buckle, 1992). As eradication must deliver a lethal bait to 100% of rodents Bitrex® along with any other related additive will not be incorporated into baits used in the eradication on LHI including those used in the settlement area.

The amount of Pestoff 20R bait rats and mice need to consume to result in death is shown below in Table 10.

Table 10 Amount of Bait a Target Pest Needs to Ingest to Result in Death Based on Highest LD50 mg/kg

Species	LD50 (Mg/Kg)	Average Weight Female (G)	Amount (Grams) Of 0.02 G/Kg Brodifacoum Bait for LD50
House Mouse	0.52	20	0.5
Ship Rat	0.73	160	5.8

2.11.2 On Island Trials

2.11.2.1 Efficacy Trials

An efficacy trial using Pestoff 20R undertaken on Lord Howe Island in 2013 indicated that the susceptibility of rats to Brodifacoum was in line with that for the species as a whole (Wheeler and Carlile, 2013) (see Appendix D – LHI Trials Package). That is, judging by the results of this trial, all the rats on LHI are susceptible to low levels of Brodifacoum and could consume a lethal dose in one day, but may require four or five meals to do so. The typical mouse on Lord Howe Island could consume a lethal dose in one day, requiring up to nine meals to do so. A second mouse toxicity trial undertaken in 2016 (O'Dwyer *et al.* 2016) showed that, while there is a wide range in the time until death following ingestion of Pestoff 20R, the poison will kill Lord Howe Island mice when the bait is provided in a manner that is consistent with field conditions. Efficacy is further considered by the Australian APVMA in their assessment of a Minor Use Permit application that has been lodged for the LHI REP.

2.11.2.2 Palatability and Uptake Trials

In 2007, a non-toxic bait uptake trial (DECC, 2007a) was undertaken on LHI that examined rodent and non-targets species uptake of the bait pellets, bait breakdown in the environment and spread of the bait using helicopter. The study concluded that bait was highly palatable to both rats and mice and that sufficient bait would be available for both species to receive a lethal dose under eradication conditions. It found bait breakdown in the environment was approximately 100 days. It also found that four bird species (the LH woodhen, buff banded rail and two introduced species) consumed bait along with some invertebrates (see Appendix D – LHI Trials Package).

A further study in 2008 (DECC, 2008) (see Appendix D – LHI Trials Package) examined bait sizes. Both small (5.5 mm) and large (10 mm) baits were shown to be palatable to rats and mice. Consequently, either baits would be appropriate for use in an eradication operation on LHI, however large baits are recommended for aerial operations, and small baits for hand broadcasting where it is critical to increase bait encounter rates for mice. It is believed that the benefits of using two bait sizes justify the added complexity of the operation.

2.11.3 Options for distribution

The overarching goal of successfully eradicating rodents is dependent upon ensuring the delivery of a lethal dose of toxicant to every rodent on the island in a manner that minimizes harm to the ecosystem while still maintaining a high probability of success.

There are three methods which have been considered for use either separately of in combination.

Bait stations.

Bait stations have been used successfully for rodent eradications including 5000 ha Langara Island (Taylor *et al*. 2000) however this was an exception due to the flat and open nature of the island and it was targeting Norway rats (Rattus norvegicus which have much larger territories allowing stations to be at 50 m spacing. Bait stations have several advantages over broadcast options: reduces the total amount of toxicant used; allows ongoing monitoring of bait take; restricts access to the toxicant by non-target species including humans; is more socially acceptable. However, there are also major disadvantages, namely: – inter species and intra species competition i.e. the risk that dominant individuals may exclude subdominant ones; logistics – a bait station needs to be placed in very rodent territory, this is as little as every 10 m^2 for mice (Mackay *et al.*2011). This is impractical for LHI given its size and topography which would give an unacceptable safety risk to personnel i.e. treating cliff areas.; there is a risk of neophobia i.e. that some individuals may not be willing to enter an enclosed bait station especially one that is designed to exclude other species including humans i.e. has baffles. Trials have shown that wooden tunnels have a higher acceptance rate than plastic tunnels (Spurr *et al.*2007) but are even more problematic for wide spread use due to their size and weight.

Due to both legal constraints and social demands is likely that bait stations will need to be used at specified areas around the island i.e. in and possibly around dwellings however due to the increased risk of failure identified above this will be kept to the minimum possible.

Hand Broadcast

This involves applying bait at the designated rate using teams of personnel in working in lines across a prescribed area. The technique has been used successfully on smaller islands with easy topography e.g. during trials for Palmyra Atoll (Wegman *et al.* 2012), and Rat Island in the Aleutians (Ebbert and Byrd 2000) (both only targeting rats i.e. baiting gaps are not such an issue due to larger individual territories., but is problematic on larger or steeper islands where there are problems accessing all areas by foot in a short period of time. This is important as bait needs to be available to all animals at one time otherwise there is a risk of animals moving from baited areas in to unbaited zones.

Advantages of hand broadcast: bait available to all individuals at once, if done to standard, hence no inter or intraspecific competition; no need for the animal to enter an artificial structure i.e. bait station; greater encounter rate i.e. a bait approx. every $2m^2$; better public perception due to not having helicopters flying. However the risk is that due to topography, vegetation or human error there can easily be a gap in the baiting leading to individuals not being exposed- in the case of mice this could be as small as $10m^2$.

LHI's dense vegetation would limit the distance between hand baiting transects to approx. 10m. Based on the effort required to broadcast bait by hand (19.5 person-hours/ha) (Buckelew *et al.* 2005), it would take a 30-person team over 100 days to complete each of the two bait applications. While some efficiencies could be expected with a larger operation (the 2005 trial islands were baited by teams of 4-5 people), the effort required for hand broadcast eradication at LHI would be monumental and would pose unacceptable safety risks in attempting to access all areas.

The risk to non-target species during a hand broadcast operation would not be decreased from that incurred during an aerial broadcast operation.

Due to both legal constraints and social demands is likely that hand broadcast will need to be used at specified areas around the island i.e. in and possibly around dwellings however due to the increased risk of failure and risk to staff safety identified above this will be kept to the minimum possible.

2.11.3.1 Aerial Broadcast

Using purpose designed equipment i.e. spreader buckets and technology i.e. GPS guidance systems, the ability to accurately and consistency apply bait via aerial distribution has led to major increases in both the size and difficulty of island e.g. 13000ha Macquarie Island (Springer 2015) and 50,000 ha South Georgia Island (Russell and Broome 2016).

Aerial broadcast has all of the operational advantages of hand broadcast i.e. bait available to all individuals at once, plus it is more accurate i.e. less opportunity for human error and it is feasible for an island the size of LHI with its challenging topography.

As such the aerial application of highly palatable bait containing a suitable toxicant is the preferred technique for treating the bulk of LHI i.e. everything that is legally and socially acceptable including all the PPP.

2.12 Summary Comparison of Alternatives

The earliest eradications using toxicants utilised a network of bait stations, but this technique is very costly, time consuming and generally impractical for anything other than small islands (<100 ha) especially for mice. The exclusive use of Bait Stations on LHI is not possible given size and the rugged terrain. A far more cost-effective option is to spread bait aerially using a helicopter. Consequently, this approach has become the standard technique for most rodent eradications. Depending on the nature of the area to be baited, aerial baiting may need to be combined with hand broadcasting of bait or bait stations, particularly around areas of human habitation.

Hand broadcasting of bait and the use of bait stations are extremely resource intensive and hand broadcasting has a greater risk of gaps in coverage. Bait stations are problematic due to the density of stations required, especially for mice, and issues with interspecific and intraspecific competition, i.e. both mice and rats can be prevented from entering bait stations by dominant individuals of the same or other species, as well as quality of implementation. On LHI, rats may exclude mice from entering bait stations. This type of behaviour can put eradication operations at risk by violating a fundamental pre-requisite that all target animals are exposed to the poison. This means that in order to maximise cost-efficiency and minimise the risk of failure these methods tend to be used over the minimum area possible. The exclusive use of Bait Stations or traps on LHI is not possible given the size and rugged terrain.

A range of possible methods and mortality agents were considered for use in eradicating both rats and mice on LHI (Table 9 and Table 11). The only method capable of removing every rat and mouse on LHI is aerial distribution, in conjunction with minimal hand broadcast and bait stations where required, of highly palatable bait containing an effective toxicant. An evaluation of potential rodenticides for aerial control of rodents (Eason and Ogilvie 2009) concluded that Brodifacoum was the best rodenticide for island eradications. The use of any other mortality agent would be largely experimental and pose unacceptable risks of failure. The *Island Eradication Advisory Group* for the Department of Conservation in New Zealand who are recognised as leaders in this field, is of the opinion that "*there is no other alternative rodenticide on the market anywhere in the world with which we would have the same level of confidence in using to eradicate Ship Rats and mice from an island such as Lord Howe*".

Table 11 Assessment of Eradication Options

Eradication Technique	Suitable for eradication	Feasible for Eradication on LHI	Justification
Disease	No	No	No suitable pathogen yet developed that could eliminate all individuals.
Trapping	Yes	No	May be feasible for eradication on small islands, however may cause individuals to become trap shy. Size and inaccessible terrain of LHI makes this option unfeasible
Biological	No	No	Likely to fail to completely eradicate the target species. High likelihood of unacceptable non-target species impacts.
Fertility Control	No	No	No suitable fertility control yet developed that could eliminate all individuals.
Toxicant - Bait station / hand broadcast only	Yes	No	May be feasible for eradication on small islands. Size and inaccessible terrain of LHI makes this option unfeasible.
Toxicant – Aerial Broadcast only	Yes	No	Highly successful on uninhabited islands. Socially unacceptable on LHI.
Toxicant – Combination of Aerial and Hand Broadcast / Bait Stations	Yes	Yes	Brodifacoum in the form of Pest off 20R has been selected as the preferred toxicant on LHI considering proven success, efficacy and non-target impacts

2.13 Likelihood of Success

Whilst it is difficult to predict a likelihood of success, the selected eradication techniques, toxin and bait give the LHI REP the best chance of being successful given the constraints on LHI and based on global experience developed over 30 years and more than 380 successful eradications worldwide. The success rate for mouse eradications from 1997-2014 on NZ islands using the same bait and technique is 100% or 11 from 11 attempts (Broome and Fairweather, 2016,) whilst rat eradications on islands over the same period have been 98% successful (37 of 39 attempts) (DIISE 2016).

Constraints that increase the risk of failure and how they have been considered for the LHI REP are detailed below.

Constraint	Solution
Island size and topography (including cliffs, crevices, caves	The aerial distribution of baits is the only realistic method of baiting a large topographically challenging island such LHI. Aerial application using a spreader bucket has been shown to be effective in delivering a toxic dose of bait to every rodent on similar large and rugged islands (i.e. Macquarie and Campbell Islands). GPS technology will be used to ensure total bait coverage.
Permanent human population	To minimise potential risks to human health, a combination of hand broadcasting and bait stations will be used in the settlement area. This will allow coverage to be maintained including in roofs and under buildings. A clean up of island hard waste is currently underway and has successfully removed over 150 tonnes of hard waste that was providing potential rodent habitat. Access to individual properties is still under negotiation through the Property Management Plan process. To date negotiations have occurred over 90% of all properties with no property owners refusing baiting in some form.
Access to baits and inter species competition	The LHI REP has been specifically designed to target both rats and mice. Bait will be applied at a density that will allow all rats and mice access to a lethal

	dose.
Alternative food sources	Whilst LHI has alternate foods sources available, unlike tropical islands, the sub tropical LHI has reduced alternate food availability over winter when the REP is planned. The Pestoff 20R bait proposed to be used is specially designed to be highly palatable to rodents and this has been shown on LHI even with alternate food available in the laboratory and in field conditions. The Pestoff 20R bait is much more palatable than commercial rodenticides containing Brodifacoum as these contain waxes to preserve life and taste deterrents to prevent human ingestion.
Unexpected challenges	The LHIB will continue to work with global leaders in island eradications particularly the New Zealand Island Eradication Advisory Group (IEAG) to ensure best practice and lessons learnt from other eradications are considered.

The final decision by the LHIB to proceed with the eradication or not will be informed by assessment of the technical, social and financial feasibility. This will include:

- The technical feasibility. The IEAG will undertake a critical review of the operational plan and provide advice on likelihood of success for LHIB consideration.
- Social acceptability. The LHIB will consider the level of community support once all property Management Plans are complete and all approvals are received.

The LHIB will not proceed unless the REP is considered to have high likelihood of success.

2.14 Alternative Locations and Timeframes

Alternative locations were not considered.

The baiting is planned to occur in winter (June - August) of 2018 but may extend into September if there are problems such as unfavourable weather conditions. June- August is preferred because this is the time of the year when the rodents are at their most vulnerable due to the relatively low abundance of natural food. Many of the seabird species are also absent from the island at this time of years. This is also the low season for tourists on LHI. The operation will take place in a single year sometime between 2018 and 2019. Uncertainty remains concerning the year because there are a number of approvals that have not yet been obtained.

2.15 Compliance with the Principles of ESD

The proposed LHI REP is in compliance with the Principles of Ecologically Sustainable Development (ESD)

Principles of ESD	Demonstrated Compliance
(a) Decision-making processes must effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.	The proposed REP considers both positive and negative short and long term environmental and socio-economic impacts of proceeding with the eradication compared to not proceeding. The REP will provide a range of environmental and socio-economic benefits that significantly outweigh potential negative impacts or risks. The final decision to proceed or not will be made considering whether environmental and human health risks have been appropriately mitigated and considering the technical, financial and social feasibility and acceptability of the project. Stakeholders including the local community have been extensively consulted and their concerns have been considered and addressed to the extent possible.
(b) If there are threats of serious or irreversible environmental damage, lack of full scientific certainty must not be used as a reason for postponing measures to prevent environmental degradation.	The proposed REP meets this principle. Rodents have previously been responsible or implicated in a number of extinctions on the LHIG (and around the world) and are a recognised threat to at least 13 other bird species, 2 reptiles, 51 plant species, 12 vegetation communities and numerous threatened invertebrates on the island.

	Failure to address the threat from rodents may lead to further serious or irreversible environmental damage. Significant effort has been made to ascertain potential impacts posed by the eradication based on global scientific evidence and local studies. However, full lack of scientific certainty on some aspects should not be used as a reason to postpone the eradication.
(c) The principle of inter-generational equity – that the present generation must ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.	The LHIB is directly responsible to the NSW Minister for the Environment and comprises four Islanders elected by the local community and three members appointed by the Minister. It is charged with the care, control and management of the Island's natural values and the affairs and trade of the Island. It is also responsible for the care, improvement and welfare of the Island and residents. Inter- generational equity has been a major consideration for the LHIB in its progression of the proposed REP. The LHIB recognises that long term protection of biodiversity and World Heritage values is intrinsic to the long term environmental and economic welfare of current and future generations of islanders. The implementation of the proposed REP will help to ensure the health, diversity and productivity of the LHI environment is enhanced for future generations through removal of rodent impacts on those values.
(d) The conservation of biological diversity and ecological integrity must be a fundamental consideration in decision-making.	The proposed REP will provide for conservation of biodiversity through the eradication of introduced rodents (rats and mice) from the LHIG. The eradication will permanently remove impacts from rodents to biodiversity and matters of NES including threatened and migratory species and World Heritage values.
(e) Improved valuation, pricing and incentive mechanisms must be promoted.	The REP will have significant economic benefits to LHI.

3 Initial Assessment

A general description of the threatened species or populations known or likely to be present in the area that is the subject of the action and in any area that is likely to be affected by the action (Section 110(3)(a) of the TSC Act)

3.1 Identifying Subject Species

3.1.1 Assessment of Available Information

The ecology and biodiversity of LHI has been extensively studied and documented over a long period of time providing an excellent baseline. The island has fascinated scientists since discovery in 1788 (Hutton, 1990) and a broad range of anecdotal accounts of sightings, collections and research projects relevant to the REP have been undertaken including rare plant surveys, breeding ecology of seabirds and invertebrate surveys (DECC, 2007).

Distribution and abundance, particularly of threatened and endemic species is comparatively well understood. Surveys have helped contribute to flora and fauna records for the island and the listing of many threatened species under both the EPBC Act and the TSC Act. Several surveys for rare plants have been undertaken by OEH (formerly DECC) to determine the distribution, population size and threats to a number of plant species (Hutton 2005 and Hutton 2001b). Outcomes of these surveys have resulted in the listing of several plant species on the TSC Act. The Australian Museum has been collecting systematic terrestrial invertebrate data since 1977 with results collated over time Cassis *et al.* (2003).

The bird life in particular has been extensively studied by scientists, locals and visitors. Records are kept on bird sightings and several ecological studies of the threatened seabirds on Lord Howe Island have been completed. These studies have focussed on breeding productivity and foraging ecology as a means of evaluating conservation status and threats.

Individual species such as the Lord Howe Woodhen, the LHI Currawong, and phasmid have all been well studied as part of recovery actions.

A summary of relevant studies undertaken included in Section 4.

References and studies cited include a broad range of:

- peer reviewed and published scientific literature
- Commonwealth and State government reports and website references
- unpublished reports prepared specifically for the proposed LHI REP undertaken by appropriately qualified and experienced LHIB, NSW OEH staff or consultants
- unpublished reports from a range of similar eradication projects undertaken around the world.

Of 196 references cited, 160 (81%) are from peer reviewed scientific journals, government documents and PhD thesis (92, 64 and 4 respectively). An additional nine are published books. The majority of these studies are considered to be very recent (within the last 5 years) or recent (within the last 15 years). Older studies are used where the information was considered still relevant. Studies from the scientific literature and Australian and State government reports and references were considered to be extremely reliable and credible. Studies undertaken for the LHIB by qualified and experienced staff or consultants and other global eradication projects (mostly undertaken by reputable foreign governments) were also considered reliable and credible. Uncertainties in any of the sources were noted and where relevant considered in this proposal.

Species lists, distribution and abundance of species on LHI is well summarised in resources such as the LHI Biodiversity Management Plan (DECC, 2007) and the Atlas of NSW Wildlife (www.bionet.nsw.gov.au/) which have been examined to determine what *threatened species* (as listed in the *Threatened Species Conservation Act 1995* (TSC Act) and *significant species* are present on the LHIG. These species are listed in section 3.1.2 below. Species listed in the Atlas of NSW Wildlife and/or named in the Lord Howe Island Biodiversity Management Plan (DECC 2007) are accepted as occurring on the Lord Howe Island Group and were automatically included as part of the Species Impact Statement because all of the LHIG will be subject to the rodent eradication. Data from the NSW Scientific Committee was examined for relevant Threatened Populations and Threatened Ecological Communities.

Not all species listed below, although present on LHI during certain periods of the year, are regarded as *subject species*. The reasons for their exclusion are set out in Table 12.

3.1.2 Identifying Threatened Species, Populations and Ecological Communities

3.1.2.1 Threatened Species

Species listed as threatened under the TSC Act, occurring or with the potential to occur in the project area are described in Table 12 below.

Not all species occurring or with the potential to occur will be impacted by the LHI REP. Risks to non-target species during an eradication programme are a function of the species present on the island group and their behaviour, susceptibility of those species present to the poison, composition and delivery method of the bait and the probability of exposure to the poison either directly or indirectly.

Species have been categorised based on their likelihood of occurrence and abundance on LHI at the time of the proposed REP and potential impacts. Table 12 makes assessment on whether the species are considered *subject species* and *affected species* and the associated threat category. Further validation for species not assessed as *subject species* is provided in Section 3.1.3. and validation for species considered as *subject species* but not *affected species* is provided in Section 5.2.1. Assessment of potential impacts to species identified as *affected species* is detailed in Section 5.2.2.

The threat categories used in Table 12 are:

- (A): will not be in the area during baiting or only a very small proportion of the population may be present, and although individuals may be potentially affected by the baiting programme, the species is not significantly threatened;
- (B): a vagrant or irregular visitor, therefore not a *subject* species because they are “not likely to be present in the area that is subject to the action……” (Section 110 (3) (a) TSC Act).
- (C): a marine species (fish, invertebrate, mammal or reptile) and therefore not threatened by the baiting programme (see Appendix J – Marine Hypothetical Scenario which offer arguments that discount the danger to marine life of the rodent eradication);
- (D): present on the LHIG but whose biological traits (e.g., diet, physiology) exclude them from being at risk;
- (E): a marine or migratory bird that may be present on the island group during the baiting period but whose ecology (e.g., diet, nesting habits and/or foraging area) exclude them from being at risk;
- (F): species potentially affected by the baiting programme;

Table 12 TSC Act Listed Threatened Species Occurring or with the Potential to Occur on the LHIG

Data primarily from DECC (2007), Hutton (1991), McAllan *et al.* (2004) and DoE (2016).

CE = *Critically Endangered*; E = *Endangered*; V= Vulnerable

Species	**Type of presence**	**Distribution, Abundance and Diet relevant to the LHI REP**	***Subject* species**	**Affected species (and threat category)**	**Individuals at risk (in the absence of mitigation)**	**TSC Act Listing**
Birds						
Australasian Bittern *Botaurus poiciloptilus*	Recorded Vagrant	Only one verified record for LHI (and that is from 1888) (McAllan *et al.* 2004) and not recorded as breeding. Recorded elsewhere feeding on freshwater crayfish, fish as well as frogs and tadpoles. It is therefore highly unlikely that the species will be present during the proposed baiting operations in winter and any population on LHI would be insignificant at a state, national and international scale. The impact of the proposed rodent eradication programme is assessed to be non-existent for this species.	No	No (B)	No	V
Black-browed Albatross *Diomedea melanophris*	Recorded Vagrant/irregular visitor; seabird	Only three records of occurrence in the LHIG, and all were at sea (McAllan *et al.* 2004). This species feeds on fish and squid. It is highly unlikely the species will be present during the proposed baiting operations in winter 2017. If any are present, they are highly unlikely to occur in shallower water within 2km from LHI, the Admiralty Islands and surrounding islets. The impact of the proposed rodent eradication programme is therefore assessed to be non-existent or negligible for this species.	No	No (B, E)	No	V
Black-tailed Godwit *Limosa limosa*	Irregular visitor	The five records of this species seen on LHI are confined to the spring and summer months (McAllan *et al.* 2004). The eradication programme is not a threat to this species as it would not be on the island during baiting.	No	No (B)	No	V

Species	**Type of presence**	**Distribution, Abundance and Diet relevant to the LHI REP**	***Subject* species**	**Affected species (and threat category)**	**Individuals at risk (in the absence of mitigation)**	**TSC Act Listing**
Black-winged Petrel *Pterodroma nigripennis*	Regular visitor; seabird	It is absent from the LHIG from May to October (McAllan *et al.* 2004), therefore the eradication programme is not a threat to it.	No	No (A)	No	V
Flesh-footed Shearwater *Puffinus carneipes*	Regular visitor; breeds LHIG	This deep-sea fish-eater arrives at LHI in August and departs in May (McAllan *et al.* 2004). It breeds underground (egg laying commences in December), arriving at and departing from these burrows only at night.	No	No (A, E)	No	V
Gould's Petrel *Pterodroma leucoptera*	Vagrant; seabird	Only two at-sea records and one beach-wash record for this species (McAllan *et al.* 2004). Diet of the species includes squid and fish. It is highly unlikely the species will be present during the proposed baiting operations in winter 2017. If any are present, they are highly unlikely to occur in shallower water within 2km from LHI, the Admiralty Islands and surrounding islets. The impact of the proposed rodent eradication programme is therefore assessed to be non-existent or negligible for this species.	No	No (B)	No	V
Great Knot *Calidris tenuirostris*	Vagrant; wader	Only one bird recorded on the LHIG, and that was in November 2002.The proposed baiting is not a threat to a significant population of the Great Knot.	No	No (B)	No	V
Greater Sand Plover *Charadrius leschenaultii*	Vagrant; wader	The three records for this species, spanning 1914 to 2002, are confined to spring and summer (McAllan *et al.* 2004). It is very unlikely that any Greater Sand Plovers will be on LHI during the period when baiting is proposed, therefore the species is not threatened by the rodent eradication.	No	No (B)	No	V
Grey Ternlet *Procelsterna cerulea*	Resident	These ternlets are present on the LHIG all year round (Hutton 1991). Nesting takes place from late August, eggs are laid in September and October (McAllan *et al.* 2004) and chicks fledge in December/ January (Hutton 1991). Their food consists of small fish and crustaceans collected from the sea surface. Poisoning is not a significant risk to the species but individuals	Yes	Yes (F)	Yes; but from helicopter-strike, not from poisoning	V

Species	Type of presence	Distribution, Abundance and Diet relevant to the LHI REP	*Subject* species	Affected species (and threat category)	Individuals at risk (in the absence of mitigation)	TSC Act Listing
		risk colliding with low-flying helicopters.				
Kermadec Petrel *Pterodroma neglecta*	Regular visitor; seabird	Breeds on Ball's Pyramid (which will not be baited) from November to May (Hutton 1991), and may been seen flying around Mt. Gower during summer. They are very rarely observed in the relatively shallow waters within two kilometres of LHI, the Admiralty Islands and surrounding islets (J. Shick pers. comm.). This species forages in deep water on squid, fish, crustaceans and, during the breeding season, insects. As it is not in the area when the baiting is planned it is unlikely to come into contact with bait or helicopter and therefore the eradication programme is not a threat to it.	No	No (A)	No	V
Lesser Sand Plover *Charadrius mongolus*	Irregular visitor	Approximately 23 Lesser Sand Plovers have been recorded on LHI between 1977 and 2003 (McAllan *et al.* 2004). Of the 13 records, dates on which the birds were seen are given for 11, all of which are confined to October to April. The small number of individuals involved, and the timing of their visits, indicate that the rodent eradication is not a threat to this species.	No	No (B)	No	V
Little Shearwater *Puffinus assimilis*	Regular visitor; seabird	Present on the LHIG February to October. Nests are in burrows. Most eggs are laid in July with the bulk of hatchings occurring in late August (Hutton 1991). The birds feed at sea, returning after sunset to feed their young. They depart before sunrise. Because the birds feed at sea, the population is not at risk of primary or secondary poisoning. As the adults are away from the island during daylight hours, it is very unlikely that any will be hit by the baiting aircraft.	Yes	No (E)	No	V
Little Tern *Sterna albifrons*	Vagrant	The five individuals recorded on LHI from 1967 to 2003 were seen in the period October to March (McAllan *et al.* 2004). Their diet consists of mainly fish (but also crustaceans, insects and molluscs) collected by diving into the sea or gleaning from its surface. Unlikely that this species will be affected by the baiting	No	No (B, E)	No.	E

Species	Type of presence	Distribution, Abundance and Diet relevant to the LHI REP	*Subject* species	Affected species (and threat category)	Individuals at risk (in the absence of mitigation)	TSC Act Listing
Lord Howe Island Currawong *Strepera graculina crissalis*	Endemic sub-species; land bird	This bird is a sub-species of the mainland Pied Currawong, and is endemic to the LHIG. The entire population of the Lord Howe Island Currawong is restricted to LHI and the nearby islets (Mayr and Greenway 1962; Schodde and Mason 1999). The current population is 215 ± 11 birds (Carlile and Priddell, 2007) and appears to be stable as there is no empirical evidence of an historical decline (DEWHA 2009a). The Lord Howe Island Currawong is widespread on LHI, occurring in lowland, hill and mountain regions. It mainly inhabits tall rainforests and palm forests, especially besides creeks or in gullies, but it also occurs around human habitation, and forages amongst colonies of seabirds on offshore islets (DEWHA 2009a). It breeds in the forested hills of LHI, particularly in the south (Hutton 1991, McFarland 1994). Highest densities of nests are on the slopes of Mt Gower and in Erskine Valley (Garnett and Crowley 2000). Its breeding sites are located close to water in gullies (Garnett and Crowley 2000; Hindwood 1940; Hutton 1991). The currawong occurs singly, in pairs and family groups and, in the non-breeding season, in small flocks of up to 15 birds (DEWHA 2009a). It has been recorded breeding from October to December although breeding may commence in September (McAllan *et al.* 2004). During the breeding season breeding pairs and offspring probably occupy strongly-defended territories (Knight 1987). Data from a recent mark-recapture programme undertaken by the OEH suggests that not all currawongs are able to establish a breeding territory due to the lack of appropriate habitat (Carlile and Priddel 2007). In autumn and winter the species forms flocks and can be found in the settlement area	Yes	Yes (F)	Yes	V

Species	Type of presence	Distribution, Abundance and Diet relevant to the LHI REP	*Subject* species	Affected species (and threat category)	Individuals at risk (in the absence of mitigation)	TSC Act Listing
		(DEWHA 2009a). No information is available on the ages of sexual maturity or life expectancy, but it is probably capable of surviving to more than 20 years of age (Higgins *et al.* 2006). Breeding success appears to be relatively low; the only available, though limited, data suggests that less than 42% of nests produce fledglings (DEWHA 2009a). The Lord Howe Island Currawong is omnivorous; its diet consisting of fruits, seeds, snails, insects, the chicks of other bird species, and rodents (Garnett and Crowley 2000; Hull 1910; Hutton 1991; McFarland 1994).				
Lord Howe Island Golden Whistler *Pachycephala pectoralis contempta*	Endemic sub-species; land bird	The diet of the whistler is comprised of invertebrates. It will not eat pellets so it is not at risk of primary poisoning. It may be exposed to Brodifacoum by eating insects that have fed on pellets but few, if any, whistlers will receive a lethal dose this way.	Yes	Yes (F)	No	V
Lord Howe Island Silvereye *Zosterops lateralis tephropleura*	Endemic sub-species; land bird	The silvereye is considered to be at low risk given that it eats mainly fruit, seeds and insects. Local studies found no evidence that this sub-species consumed baits. Evidence from rodent eradications in New Zealand suggests that a few silvereyes may succumb to the effects of Brodifacoum, but at the population level the species was not harmed by rodent baiting. Any losses on LHI are likely to be small and short term. Any initial decline will be followed by a marked increase in populations due to the removal of rodents and subsequent increase in invertebrate food resources.	Yes	Yes (F)	Yes	V
Lord Howe Woodhen *Hypotaenidia sylvestris*	Endemic species; land bird	The Lord Howe Woodhen is a flightless bird endemic to LHI. Annual surveys of bird number are conducted in November- December since the 1980s. The population estimate in 1997 was 220-230 individuals and 71-74 breeding pairs (NPWS 2002).	Yes	Yes (F)	Yes	End.

Species	**Type of presence**	**Distribution, Abundance and Diet relevant to the LHI REP**	***Subject* species**	**Affected species (and threat category)**	**Individuals at risk (in the absence of mitigation)**	**TSC Act Listing**
		The population of woodhen has been increasing steadily over the last ten years (LHI Board unpubl. data. 209 birds were recorded as part of the annual population survey conducted in 2015. The 2015 survey data is still being analysed to produce a total population estimate using the methodology in Harden (1999). It is expected that the population estimate will be approximately 240-300 individuals (unpublished data). Woodhens usually lay eggs from August until January (NPWS 2002) or February (Gillespie 1993) and continue raising young until April (NPWS 2002). However, the start and finish dates of breeding can vary between years and there are breeding records for much of the year (Miller and Mullette 1985). Pairs have multiple broods during the breeding season (Gillespie 1993). Juveniles can breed at nine months of age (Marchant and Higgins 1993) but juveniles that do not establish a territory by the breeding season immediately following their own hatching generally do not survive (Harden and Robertshaw 1988, 1989). About 60% of juveniles die in their first year (Harden and Robertshaw 1989) possibly due to limited high-quality habitat (NPWS 2002). Breeding success is greater in the settlement area than in the southern mountains (Marchant and Higgins 1993, Harden and Robertshaw 1988, 1989). The species is currently impacted by rodents on LHI. The woodhen occurs predominately in three vegetation types: 1) Megaphyllous Broad Sclerophyll Forest (mainly palms), which covers 19% of the island; 2) Gnarled Mossy-Forest, which covers 2% of the island; and 3) Gardens around houses. About 40 % of the population lives in the settlement area of the island				

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		(NPWS 2002). Over 80% of the woodhen's diet is comprised of earthworms (Miller and Mullette 1985). The bulk of the remaining 20% is made up of grubs, typically found in rotting logs. Snails, arthropods, seabird chicks, rodents, plant shoots, lichen and fungi are also eaten (NPWS 2002). Woodhen were observed eating non-toxic pellet baits during a trial conducted on LHI to gauge what species may eat the Pestoff 20R baits. Blue-coloured faeces have also been seen when handling some birds, indicating they had been consuming Brodifacoum wax blocks (Harden 2001). These blocks are widely dispersed around the settlement by residents. Further evidence of woodhens consuming Brodifacoum baits has come from its detection in the internal organs of several woodhens found dead along roadsides and recovery of ill birds that have been captured and treated with Vitamin K.				
Masked Booby *Sula dactylatra tasmani*	Resident; seabird	On LHI year round. Breeds from June to February with most egg-laying occurring in December. LHI is the most southerly breeding colony of boobies in the world (McAllan *et al.* 2004). This sub-species breed only on the Lord Howe, Norfolk and Kermadec island groups (McAllan *et al.* 2004). The birds feed at sea so are not, therefore, threatened by poisoning. However, boobies nest above ground so the breeding colony will be subject to disturbance from the baiting aircraft.	Yes	Yes (F)	Yes; risk of helicopter strike and disturbance at the colony.	V
Masked Owl *Tyto novaehollandiae*	Resident; land bird	Although classified as *Vulnerable* under the TSC Act, the Masked Owl was introduced to LHI (along with 5 other Australian and North American owl species) to controls rats in the 1920s and 1930s. The Masked Owl on LHI were until recently believed to be the Tasmanian race *(Tyto novaehollandiae castanops),* however genetic testing has found significant divergence of the LHI population with *T. n. castanops,* suggesting hybridisation with the Mainland race *(Tyto*	No	No Introduced	No	V

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		*novaehollandiae novaehollandiae) (*Hogan *et al.* 2013). This hybridisation and loss of genetic integrity would exclude translocation of the LHI Masked Owl to Tasmania or NSW. A recent study (Milledge, 2010) has shown that rodents currently provide the Masked Owl's main prey base on the Island, supplemented by occasional predation on other native birds but this may change if rats, the owls' staple diet, are eliminated from LHI. During the rodent eradication it is expected that most owls are likely to succumb to secondary Brodifacoum poisoning by ingestion of poisoned rodents. To avoid any remaining owls switching to a diet of solely native species in the absence of rodents, it is proposed to eradicate remaining owls via hunting or trapping before, during and after the baiting proposal.				
Painted Snipe *Rostratula benghalensis*	Vagrant; wader	There has only been one record on LHI, and that was in February 1990. Not recorded as breeding on the LHIG. Feeds on vegetation, seeds, insects, worms and molluscs, crustaceans and other invertebrates. It is therefore highly unlikely that the species will be present during the proposed baiting operations in winter and any population on LHI would be insignificant at a state, national and international scale. The impact of the proposed rodent eradication programme is assessed to be non-existent for this species.	No	No (B)	No	V
Pied Oystercatcher *Haematopus longirostris*	Vagrant	The species seen may in fact be the New Zealand South Island Pied Oystercatcher (McAllan *et al.* 2004). Five records for LHI, each of a single bird, cover the period 1950 to 1998. Pied Oystercatchers forage on rocky headlands, exposed reefs with rock pools, beaches and muddy estuaries for small fish and invertebrates such as limpets, worms, crabs and mussels but the risk of secondary poisoning is low. Unlikely to be present in significant numbers therefore	No	No (B)	Yes	E

Species	**Type of presence**	**Distribution, Abundance and Diet relevant to the LHI REP**	***Subject* species**	**Affected species (and threat category)**	**Individuals at risk (in the absence of mitigation)**	**TSC Act Listing**
		the proposed baiting is not a threat to this species.				
Providence Petrel *Pterodroma solandri*	Regular visitor; seabird	Found on LHI year-round (McAllan *et al.* 2004). The Providence Petrel feeds at sea. It is present in its breeding grounds (the two southern mountains) from March to November. In August, Providence Petrels will be tending young in the nest underground so breeding birds will not be in the area until late afternoon/evening. However, non-breeders will be present during the days until mid-August (Hutton 1991), therefore there is the possibility of collision with low-flying helicopters dropping bait.	Yes	Yes (F)	Yes; but from helicopter-strike, not from poisoning	V
Red-tailed Tropicbird *Phaethon rubricauda*	Regular visitor; seabird	Summer-breeder; with about 500 to 1,000 pairs being active. Only a few birds are present during the winter months (McAllan *et al.* 2004). As the greater majority of birds will not be on the island group during the proposed baiting, the rodent eradication does not pose a threat to this fish-eating species.	No	No (A, E)	No	V
Sanderling *Calidris alba*	Vagrant	A regular summer migrant from Siberia and other Arctic breeding grounds to most of the Australian coastline, arriving from September and leaving by May. Unlikely to be present during the REP.	No	No (B)	No	V
Sooty Oystercatcher *Haematopus fuliginosus*	Vagrant	Only one bird has been recorded on LHI (in March 1987). The Sooty Oystercatcher forages on intertidal flats, beaches and sandbanks for small fish and invertebrates such as molluscs, crustaceans, worms and echinoderms. Individual Sooty Oystercatcher foraging on the beaches on LHI in August may be at risk of secondary poisoning however it is highly unlikely that any significant numbers would be present. Therefore no impact is expected from the REP	No	No (B)	Yes	V
Sooty Tern *Sterna fuscata*	Regular visitor /resident	Up to 35,000 pairs breed on the LHIG. This species has been recorded on the LHIG in all months but it is most common from August to February (Hutton 1991). Eggs are laid from late August until early December	Yes	Yes (F)	Yes; but from helicopter-strike and disturbance of nesting birds	V

Species	Type of presence	Distribution, Abundance and Diet relevant to the LHI REP	*Subject* species	Affected species (and threat category)	Individuals at risk (in the absence of mitigation)	TSC Act Listing
		although the main laying period is from September to November (McAllan *et al.* 2004). The Sooty Tern mainly feeds on fish, squid and crustaceans caught at sea; cicadas are also taken from the forests in summer (Hutton 1991). It is not susceptible to poisoning by the rodent eradication. However, there is a risk of birds colliding with the helicopters and spreader buckets dispersing the bait if the baiting extends into late August or September which is considered unlikely.			if aerial baiting occurs in late Aug, not from poisoning	
Swift Parrot *Lathamus discolor*	Vagrant; land bird	One record only from LHI and that is of a dead bird found in 1968. Not recorded as breeding on the LHIG. Feeds on nectar, mainly from eucalypts, but also eats psyllid insects and lerps, seeds and fruit. It is therefore highly unlikely that the species will be present during the proposed baiting operations in winter and any population on LHI would be insignificant at a state, national and international scale. The impact of the proposed rodent eradication programme is assessed to be non-existent for this species.	No	No (B)	No	E
Terek Sandpiper *Xenus cinerus*	Vagrant/irregular visitor; wader	Only five Terek Sandpipers seen on LHI from 1959 to 1991 (McAllan *et al.* 2004). The four records that have dates are for spring (one for September, two in November) and summer. Baiting LHI will not threaten this species.	No	No (B)	No	V
Wandering Albatross *Diomedea exulans) (potentially five sub-species: amsterdamensis, antipodensis, dabbenena, exulans and gibsoni)*	Vagrant/irregular visitor; seabird	Only five records of occurrence in the LHIG. Three were at sea, several kilometres from LHI, one was seen from LHI and one was found washed up on Blinky Beach (McAllan *et al.* 2004). This species feeds on fish and squid. It is highly unlikely the species will be present during the proposed baiting operations in winter 2017. If any are present, they are highly unlikely to occur in shallower water within 2km from LHI, the Admiralty Islands and surrounding islets. The impact of the proposed rodent eradication programme is therefore assessed to be non-existent or negligible for	No	No (B, E)	No	E

Species	Type of presence	Distribution, Abundance and Diet relevant to the LHI REP	*Subject* species	Affected species (and threat category)	Individuals at risk (in the absence of mitigation)	TSC Act Listing
		this species.				
White-bellied Storm-petrel *Fregetta grallaria*	Regular visitor; seabird	It is present on the LHIG from September to May but only on outer islands. They are very rarely observed in the relatively shallow waters within two kilometres of LHI, the Admiralty Islands and surrounding islets (J. Shick pers. comm.). White-bellied storm-petrels forage in deep water and only come on land at night from September to May. This species is unlikely to be present during the baiting operation and thus is unlikely to come into contact with bait or helicopters. No impact on this species is expected.	Yes	No (A)	No	V
White Tern *Gygis alba*	Regular visitor; seabird	On LHI the White Tern is generally present from October to May; 60-100 pairs nest annually on LHI (Hutton 1991). Although recorded in all months, it is usually absent from the island group from June to September (McAllan *et al.* 2004). Its diet of small fish and squid, and the absence of most, if not all, terns in winter, indicate that this species is not at significant risk from the rodent eradication.	No	No (A, E)	No	V
Invertebrates						
Lord Howe Placostylus *Placostylus bivaricosus*	Endemic species	The Lord Howe Placostylus is a large land snail; the shell of a mature specimen can be up to 8 cm long. It is endemic to LHI with three sub-species recognised. *Placostylus bivaricosus* is the only sub-species of this snail known to be extant; other sub-species are either listed as extinct (*P.b. cuniculinsulae*) or have not been recorded in over 30 years (*P.b. etheridgei*). It has close relatives in New Zealand (*P. ambagiosus, P. bollonsi and P. hongii*). Other members of the genus occur in the Solomon Islands, Fiji and New Caledonia. Once rather common throughout much of the lowland, the decline of the species was first noted in the 1940s. Recently live individuals of this species have been recorded in targeted surveys at 14 out of selected 20	Yes	Yes (D;)	No	E

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		sites in 2006/2007 and in seven out of 21 selected sites in 2010. During the 2016 survey this species was only found at one site from which it had previously been reported (near Old Settlement Beach). Live animals could not be found in Stephen's Reserve in 2007, 2010 or 2016. Altogether these negative records indicate that the species is probably extinct in Steven's Reserve, where it once was very common (Kohler *et al.,* 2016). Hutton & Hiscox (in Kohler *et al.,* 2016) concluded that the greatest density of live *Placostylus* snails appear to be where the practice of a good rat baiting program is exercised and where dense, heavy leaf litter exists that precludes the snails from predation by introduced birds, which have been identified as a second probable threat. The 2016 survey at Old Settlement Beach indicates that the species is still relatively abundant at this site, but overall the species is considered to be in decline. Animals are rather long-lived (5 to 10 years). Adults are ground dwelling and aestivate, inhabiting the leaf litter of rainforest areas, burying into the sand during drier periods. They are nocturnal and crawl on the ground during humid or wet nights in the leaf litter in moist forests. Juveniles are arboreal (Kohler *et al.,* 2016). The Ship Rat identified as a major predator of the species and posing a significant threat to the Placostylus, (NPWS 2001). Continuing decline is expected in the absence of rodent eradication as current rodent control practices are not preventing decline (Kohler *et al.,* 2016). The removal of predators from all its current and previous occurrences is necessary to ensure its long-term survival.				
Gudeoconcha sophiae magnifica (a helicarionid land	Endemic species	A large shelled endemic snail, previously recorded from upper slopes and summits of both Mt Lidgbird and Mt Gower (a total of 18 specimen records from between	Yes	Yes (?)	Unknown	CE

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snail)		1914 and 2002). No live animals were found despite extensive surveys conducted by the Australian Museum in 2001 and 2002 and was not recorded during a targeted 2016 Australian Museum survey on Mt Gower despite considerable efforts (Kohler *et al.,* 2016). This lack of positive records suggest that the species is absent from or rare in the surveyed area of the summit of Mt Gower. Very little is known about the biology and ecology of this endemic snail. The nominate form of G. sophiae has been reported to be crawling on the ground during wet nights (I. Hutton pers. comm.) and the subspecies magnifica is postulated to have the same behaviour. Rats are regarded as a significant threat to this snail (Beeton, 2008a and, Kohler *et al.,* 2016) and are possibly driving this species towards extinction, if they have not done so already. Largely unprotected from rodent predation due to inaccessibility of its range. Continuing decline expected in the absence of rodent eradication, as rodent control is not practicable throughout most of its extant range (Kohler *et al.,* 2016).				
Masters' Charopid Land Snail *Mystivagor mastersi*	Endemic species	This minute snail, endemic to LHI, is only known from a few sites, including the summit of Mount Lidgbird, Mount Gower, and lowlands sites; Blinky Beach and Boat Harbour (Beeton 2008b), (a total of 10 specimen records from between 1887 and 2002). Specimens from Mt Lidgbird and Mt Gower differ in shell morphology from lowland forms and may represent a distinct, undescribed species. The lowland form has last been recorded in 1971 near Old Settlement Beach and has not been recorded during the comprehensive surveys between 1999 and 2002, or during the 2016 survey. Therefore, the lowland form may be very rare or possibly extinct.	Yes	Yes (?)	Unknown	CE

Species	**Type of presence**	**Distribution, Abundance and Diet relevant to the LHI REP**	***Subject* species**	**Affected species (and threat category)**	**Individuals at risk (in the absence of mitigation)**	**TSC Act Listing**
		By contrast, there are several more recent records of *Mystivagor* from the summit of Mt Gower, including one specimen found during the 2016 survey. The population has probably declined, due initially to pigs and goats, then later to predation by the introduced rat (Beeton 2008b). The size of the current population is unknown. Largely unprotected from rodent predation due to inaccessibility of its range. Continuing decline expected in the absence of rodent eradication, as rodent control is not practicable throughout most of its extant range (Kohler *et al.,* 2016). Charopid species generally favour moist forests where they live in leaf litter and feed on decaying plant matter or biofilm. They have a very small range of activity as they attach themselves to the underside of leaves, bark etc. Because of their small size and lifestyle, charopids have a limited dispersal capacity (Kohler *et al.,* 2016).				
Mount Lidgbird Charopid Snail *Pseudocharopa lidgbirdi*	Endemic species	This snail, endemic to LHI, is now thought to be confined to Mount Gower although its distribution, prior to 1945, also included Mount Lidgbird and Erskine's Valley (Beeton 2008c). From 1887 until 2002, 239 specimens have been collected for museums. However, the number of snails found has declined markedly since 1981, with only six specimens being recorded for the period 1981 to 2002 (none alive). Because the effort to find snails has increased since 1925, the decline in finds has been interpreted as reflecting a severe drop in the snail's population (Beeton 2008c). Recorded during the recent survey in 2016 (1 specimen on Mt Gower). The decline in the snail's population is likely to be due to damage done to its environment by pigs and goats, then subsequently to predation by the introduced rat (Beeton 2008c). The size of the current population is	Yes	Yes (?)	Unknown	CE

Species	**Type of presence**	**Distribution, Abundance and Diet relevant to the LHI REP**	***Subject* species**	**Affected species (and threat category)**	**Individuals at risk (in the absence of mitigation)**	**TSC Act Listing**
		unknown. Largely unprotected from rodent predation due to inaccessibility of its range. Continuing decline expected in the absence of rodent eradication, as rodent control is not practicable throughout most of its extant range (Kohler *et al.,* 2016). Charopid species generally favour moist forests where they live in leaf litter and feed on decaying plant matter or biofilm. They have a very small range of activity as they attach themselves to the underside of leaves, bark etc. Because of their small size and lifestyle, charopids have a limited dispersal capacity (Kohler *et al.,* 2016).				
Whitelegge's Land Snail *Pseudocharopa whiteleggei*	Endemic species	Previously recorded from upper slopes and summits of both Mt Lidgbird and Mt Gower (a total of 14 specimen records from between 1887 and 2002). Two specimens recorded during a 2016 survey on Mt Gower. This species is probably uncommon and has a restricted distribution at high altitudes of Mt Gower and Mt Lidgbird (Kohler *et al.,* 2016). The key threat to this snail is predation by introduced rats (Beeton 2008d). Largely unprotected from rodent predation due to inaccessibility of its range. Continuing decline expected in the absence of rodent eradication, as rodent control is not practicable throughout most of its extant range (Kohler *et al.,* 2016). Charopid species generally favour moist forests where they live in leaf litter and feed on decaying plant matter or biofilm. They have a very small range of activity as they attach themselves to the underside of leaves, bark etc. Because of their small size and lifestyle, charopids have a limited dispersal capacity (Kohler *et al.,* 2016).	Yes	Yes (?)	Unknown	CE
Lord Howe Island Wood-feeding Cockroach *Panesthia*	Endemic species	This cockroach was once found on the main island and several satellite islands but there are no records of it being found on the main island after the 1960s. It is	Yes	No (D)	No	E

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lata		currently thought to be restricted to rat-free Blackburn and Roach islands. The key threat to this cockroach is predation by introduced rats. Unlikely to be susceptible to poisoning.				
Lord Howe Island Earthworm *Pericryptodrilus nanus*	Endemic species	It has only been located on the ridge of Mt. Gower. Unlikely to be susceptible to poisoning.	Yes	No (D)	No	E
Marine Mammals						
Australian Fur-seal *Arctocephalus pusillus*	Irregular visitor	Principal food items are cephalopods and fish. Species unlikely to be present or present in small numbers. Unlikely to have sufficient exposure to bait.	Yes	No (C)	No	V
New Zealand Fur-seal *Arctocephalus forsteri*	Irregular visitor	Principal food items are cephalopods and fish. Species unlikely to be present or present in small numbers. Unlikely to have sufficient exposure to bait.	Yes	No (C)	No	V
Blue Whale *Balaenoptera musculus*	Rare visitor	Occasionally recorded in waters around the LHIG. Species unlikely to be present or present in small numbers. Unlikely to have sufficient exposure to bait.	Yes	No (C)	No	E
Humpback Whale *Megaptera novaeangliae*	Recorded Vagrant/irregular visitor; Marine Mammal	Occasionally recorded in waters around the LHIG. Species unlikely to be present or present in small numbers. Unlikely to have sufficient exposure to bait.	Yes	No (C)	No	V
Southern Right Whale *Eubalaena australis*	Rare visitor	Occasionally recorded in waters around the LHIG. Species unlikely to be present or present in small numbers. Unlikely to have sufficient exposure to bait.	Yes	No (C)	No	E
Sperm Whale *Physeter macrocephalus*	Recorded Vagrant/irregular visitor; Marine	Occasionally recorded in waters around the LHIG. Species unlikely to be present or present in small numbers. Unlikely to have sufficient exposure to bait.	Yes	No (C)	No	V

Species	**Type of presence**	**Distribution, Abundance and Diet relevant to the LHI REP**	***Subject* species**	**Affected species (and threat category)**	**Individuals at risk (in the absence of mitigation)**	**TSC Act Listing**
	Mammal					
Marine Reptiles						
Green Turtle *Chelonia mydas*	Recorded Vagrant/irregular visitor; Marine Reptile	In the LHIG, Green turtles regularly occur from the sheltered habitats of the lagoon through to the offshore fringing reefs and deeper shelf waters of the park. Feeds predominantly on seagrass and algae. No nesting recorded on the LHIG. Unlikely to have sufficient exposure to bait.	Yes	No (C)	No	V
Leatherback Turtle *Dermochelys coriacea*	Recorded Vagrant/irregular visitor; Marine Reptile	Has been sighted very occasionally in waters around the LHIG and is likely to migrate periodically through the park's waters; it has a carnivorous diet consisting of jellyfish and other soft-bodied invertebrates. No nesting recorded on the LHIG. Species unlikely to be present or present in small numbers. Unlikely to have sufficient exposure to bait.	Yes	No (C)	No	V
Loggerhead Turtle *Caretta caretta*	Recorded Vagrant/irregular visitor; Marine Reptile	Occasionally recorded in waters around the LHIG as a visitor in the park during trans-Pacific migrations. Loggerheads are carnivorous, eating shellfish, crabs, sea urchins and jellyfish. No nesting recorded on the LHIG. Species unlikely to be present or present in small numbers. Unlikely to have sufficient exposure to bait.	Yes	No (C)	No	E
Terrestrial reptiles						
Lord Howe Island Southern Gecko *Christinus guentheri*	Recorded land reptile	Endemic to LHI and Norfolk Island. Once abundant on the main island until the mid-1930s, after which it declined dramatically, most likely due to predation by rats. Now rare on Lord Howe Island, more common on Blackburn and Roach Islands. Possibly present on other large offshore islets. This species feeds on beetles, spiders, moths, ants and other insects amongst the leaf litter.	Yes	Yes (F)	Yes	V

Species	Type of presence	Distribution, Abundance and Diet relevant to the LHI REP	*Subject* species	Affected species (and threat category)	Individuals at risk (in the absence of mitigation)	TSC Act Listing
Lord Howe Island Skink *Cyclodina (Oligosoma) lichenigera*	Resident	Rich metallic bronze or olive above with numerous small brown longitudinal flecks or streaks, to about 80mm in length. Endemic to the Lord Howe Island Group and Norfolk Island. Rare on Lord Howe Island, more common on offshore islets – Blackburn Island, Roach Island and Ball's Pyramid, possibly other large offshore Islets. They feed on beetles, spiders, moths, ants and other insects amongst the leaf litter.	Yes	Yes (F)	Yes	V
Plants						
Knicker Nut *Caesalpinia bundoc*	Recorded	A woody scrambling shrub with bipinnate leaves and bright yellow flowers. The undersides of the leaf stems have sharp recurved hooks. The seed pod is also covered in recurved hooks, and contains two hard seeds. Rare and restricted occurrence on Lord Howe Island It is only found behind Ned's Beach and adjacent to Old Settlement Beach on Lord Howe Island. It is also found widely in the tropics and subtropics.	No	No (D)	No	E
LHI Morning Glory *Calystegia affinis*	Recorded	A delicate thin-stemmed twiner with white to pale pinky-purple flowers. Rare and very localised and restricted in its range. This species is endemic to Lord Howe Island and Norfolk Island. On Lord Howe Island it is known from eight locations; one on a slope at Old Settlement, the others at various locations in the southern mountains. Seed and seedlings potentially browsed by rodents.	No	No (D)	No	E
LHI Broom *Carmichaelia exsul*	Recorded	Broom-like leafless shrub with small white and purple pea flowers. Restricted to the southern mountains mainly around the 450-600m level, below the main cliffs of the mountains. Largest population at west end of Mount Gower north face, north edge of Big Pocket and near bottom of the	No	No (D)	No	E

Species	Type of presence	Distribution, Abundance and Diet relevant to the LHI REP	*Subject* species	Affected species (and threat category)	Individuals at risk (in the absence of mitigation)	TSC Act Listing
		Razorback.				
Chamaesyce psammogeton	Recorded	Perennial herb, glabrous. The reddish-purple stems are prostrate, to 35 cm or more. Rare on Lord Howe Island, found only on Coastal dune at Blinkie Beach but also found in coastal NSW north to Queensland	No	No (D)	No	E
Coprosma inopinata	Recorded	A compact, prostrate shrub to 0.5m with light green lanceolate, opposite leaves. Only found on two remote ridges off the southern mountains.	No	No (D)	No	E
Phillip Island Wheat Grass *Elymus multiflorus subsp. kingianus*	Recorded	A tufted perennial grass, 30–100 cm tall, with a low, spreading habit, known from the Norfolk Island group and LHI. On LHI the subspecies (about 50 individuals) is record from only 2 locations (in close proximity) occurring between exposed basalt-derived cliffs near the water's edge, with littoral rainforest upslope (Auld *et al.* 2011). Seeds presumed to be predated by rodents.	No	No (D)	No	CE
Geniostoma huttonii	Recorded	A rare scrambling shrub to 1m high. Mainly found on the remote ridges and sheltered habitats in the southern mountains. On Mt Lidgbird it occurs on the south east corner at about 500m altitude. On Mount Gower it occurs on the cliff which leads into Little Pocket and above the Get Up Place.	No	No (D)	No	E
Little Mountain Palm *Lepidorrhachis mooreana*	Recorded	A stout, dwarf palm with a trunk to 2m high endemic to LHI. Confined to higher elevations in the southern mountains, mainly above 750m altitude. Rats are known to predate heavily on the developing seeds, and also chew the stems of leaf fronds.	No	No (D)	No	CE
Rock Shield Fern *Polystichum moorei*	Recorded	A fern with distribution limited to the southern mountains, favouring sheltered cliff faces and overhangs. Also known from low elevation near Kings Beach and mouth of Erskine Creek.	No	No (D)	No	E
Xylosma parvifolia	Recorded	Shrub to 2 m high. Restricted to the remote ridges in the southern mountains. Seed and seedlings potentially	No	No	No	E

Species	Type of presence	Distribution, Abundance and Diet relevant to the LHI REP	*Subject* species	Affected species (and threat category)	Individuals at risk (in the absence of mitigation)	TSC Act Listing
		browsed by rodents.		(D)		

3.1.2.2 Threatened Ecological Communities

The following Threatened Ecological Communities are found on LHI.

Table 13 TSC Act Listed Threatened Ecological Communities Occurring or with the Potential to Occur on the LHIG

Name	Comment	TSC Act Listing
Lagunaria Swamp Forest on Lord Howe Island	Sallywood Swamp Forest is found in very limited areas of Lord Howe Island, in low sites that are occasionally inundated. Originally restricted to five small patches in the mid island lowlands of Lord Howe Island. Some of these patches have since been destroyed. It is a plant community dominated by the Sallywood tree. Other species found in this community include Mangroves, Kentia Palm, Cottonwood Hibiscus and Blackbutt (OEH, 2017). http://www.environment.nsw.gov.au/threatenedspeciesapp/	CE
Gnarled Mossy Cloud Forest on Lord Howe Island	Gnarled Mossy Cloud Forest on Lord Howe Island is confined to LHI. On the island it is restricted to the summit plateau of Mt Gower and in a greatly reduced form and extent on the narrow summit ridge of Mt Lidgbird. The Little Mountain Palm, which is listed under the TSC Act as critically endangered is confined to the Gnarled Mossy Cloud Forest as are four TSC Act listed critically endangered snails (*Gudeoconcha sophiae magnifica ms, Pseudocharopa lidgbirdi, Mystivagor mastersi and Pseudocharopa whiteleggei*) and the Lord Howe Island Earthworm, which is TSC Act listed as endangered. Rodents are listed as a key threat to the Gnarled Mossy Cloud Forest Ecological Community (OEH, 2017).	CE

3.1.2.3 Threatened Populations and Critical Habitat

No listed Threatened Populations or Critical Habitat was identified as occurring on the LHIG.

3.1.3 Threatened or migratory species not regarded as subject species

Additional detail for threatened species not regarded as *subject species* in Table 12 is provided below.

3.1.3.1 Vagrants, rare regular or irregular visitors

Records for the LHIG refer to species that rarely visit the island group, and such visits typically involve only a small number of individuals. Even if the proposed baiting constituted a real threat to these individuals, no "viable local population of the species is likely to be placed at risk of extinction…. by the proposed action" (Section 5A.2.a TSC Act). Accordingly, vagrants, rare regular visitors or irregular visitors to the LHIG are not regarded as *subject species* as they are "not likely to be present in the area that is subject to the action……" (Section 110 (3) (a) TSC Act).

3.1.3.2 Most Migratory Birds

Most of the *threatened* birds that breed on or regularly visit the LHIG will not be present, or present in very low numbers, when the baiting is proposed (July-August). As the baiting will not damage nesting habitat nor contaminate the prey species, namely fish, of these birds, they are not regarded as *subject species,* and are not noted as such in Table 12.

3.1.3.3 Plants

REP activities with the potential to impact on threatened plants are: works associated with building the captive management facility and bait distribution (through potential uptake of Brodifacoum by plants).

The captive management facility construction will occur through modification of existing greenhouses structures at the nursery site. If needed, previously cleared land at the nursery within the lowland settlement area will be used. No clearing of land is proposed.

Brodifacoum is not herbicidal, is highly insoluble (WHO, 1995) and binds strongly to soil particles, therefore it is not likely to be transported through soils and taken up by the roots of plants into plant tissues. There is no identified chemical process that would allow Brodifacoum to impact on plants. This is in contrast to 1080, which has been known to be taken up by plants, although concentrations of that toxin decline rapidly in plants (Ogilvie *et al.* 2006).

A literature search failed to find published or verified unpublished data regarding plant uptake or persistence. Sampling of grasses (Poaceae) collected 6 months following application of Brodifacoum cereal baits at 15 kg/ha on Anacapa Island in California during 2001 and 2002 found no detectable residues in the six samples tested (Howald *et al.* 2010). The fact that hundreds of Islands have been treated for rodent eradication around the globe and not a single case of terrestrial vegetation has been reported to have been affected detrimentally by Brodifacoum exposure is a clear indication that no impacts are expected on LHI.

Therefore no impact to TSC listed plants is expected. Conversely removal of rodents is expected to significantly benefit individual species (such as the Little Mountain Palm and Phillip Island Wheat Grass) and many vegetation communities through reduced predation on developing seeds, seedlings and stems of leaf fronds. Auld *et.al* (2010) found rats on LHI have increased the risk of extinction for the two endemic mountain palms for on Mt Gower. This is a consequence of rat predation of fruits which has the potential to limit recruitment in both palm species. Past observations highlight the lack of ripe fruits on *Lepidorrhachis* plants unless mesh caging was applied to exclude rats from the developing fruits. The impact of rats is greatest in *Lepidorrhachis*, where fruit losses reached 100% and small juvenile plants (<50 cm) were extremely rare in the presence of rats.

Direct and indirect impacts of poison baiting should be considered at an ecosystem level to allow anticipation of complex or interactive effects (Innes and Barker 1999; Zavaleta *et al.* 2001; Caut *et al.* 2009). Current threats to endangered plant species on LHI primarily relate to impacts of rodents and climate change. Elimination of rodents may result in increased impacts from other threats that are not currently recognised. For example, rodents consume invertebrates and compete with them for food. Hence the elimination of rodents may lead to increased population size and food consumption by invertebrates. Rodents are known to consume seeds, fruits and vegetative plant material. Consumption of seeds and seedlings is likely to have the greatest impact on demographic processes, reducing recruitment success and causing population structures to become dominated by older plants (e.g. Auld *et al.* 2010). There is no indication that invertebrates contribute to losses of similar magnitudes to those currently attributed to rodents. Hence it seems unlikely that invertebrates will maintain similar levels of seed or seedling predation after rodent elimination. There is also potential for secondary impacts resulting from increased competition from other plant species that may currently be suppressed by rodents. Of the listed species, only *Calystegia affinis* (NSW Scientific Committee 2012; Hutton *et al.* 2008) and *Elymus multiflorus* subsp. *kingianus* (Auld *et al.* 2011) are currently impacted by competition from weeds. The main competitors for *Calystegia affinis* (*Pennisetum clandestinum* and *Stenotaphrum secundatum*) rarely propagate by seed, so it is unlikely that elimination of rodents will lead to an increase in population size or vigour of these invasive grasses. In contrast, if rodents consume seeds of the main competitors of *E. multiflorus* (*Sporobolus* *africanus*, *Bromus cartharticus, B. diandrus* and *Paspalum* spp. - Auld *et al.* 2011) there is potential for increased competition. This may be offset by an increase in seed production of *E. multiflorus*. Appropriate monitoring strategies and capacity for further intervention, if required, is an important component of the eradication plan. On balance, eradication of rodents is unlikely to have significant negative impacts on threatened plant species. Their eradication is very likely to have positive impacts on several species, especially *Lepidorrhachis mooreana* which at present is known to be affected by rat seed predation (Auld *et al.* 2010).

Elsewhere it has been demonstrated that population reduction or the elimination of rodents leads to plant recruitment and recovery of vegetation on oceanic islands (e.g. Allen *et al.* 1994; Olivera *et al.* 2010; Le Corre *et al.* 2015). However, the structure and composition of vegetation is likely to be different from the pre-invasion condition, and impacts of invasive species may prevent or delay the return to the uninvaded state (e.g. due to a loss of plant species or the lack of appropriate disturbance regime – Grant-Hoffman *et al.* 2010).

It is also possible that rodent eradication coincides with impacts from other threatening processes, leading to concerns that the eradication or other management actions cause additional impacts. On Macquarie Island, declines in *Azorella macquariensis* roughly coincided with the eradication of rabbits on the island. However,

Bergstrom *et al.* (2015) (among others) concluded that this decline was coincidental rather than causally linked to the eradication program. They advise that baseline data is necessary to determine if change is 'permanent' or decadal scale cycle. Furthermore, since disease was a contributing factor, plant biosecurity efforts should be employed to minimise likelihood of introduction or spread of disease. On Lord Howe Island, introduction of myrtle rust or further spread or re-introduction of phytophthora are of concern. Protocols already exist to minimise risk of disease introduction or spread by staff involved in weed management or by bushwalkers and these protocols should also be applied to people involved in the rodent eradication program. As discussed above, understanding ecological processes, pre- and post-eradication monitoring, flexibility during the implementation phase and capacity for further interventions are all necessary to prevent manifestation of 'surprise effects' of rodent eradication on islands (Caut *et al.* 2009).

Any possible increase in weeds due to reduced seed predation, would be detected under the existing weed eradication strategy on LHI.

4 Survey

As mentioned in Section 3.1.1 above, the ecology and biodiversity of LHI particularly threatened species are well understood and documented. Habitat preferences and distribution, particularly of threatened species is well described in documents such as the Biodiversity Management Plan (DECC, 2007). Individual species such as the Lord Howe Woodhen, the LHI Currawong, and threatened land snails all been well studied as part of species recovery actions or as part of the REP. Population surveys for woodhens are undertaken annually by the LHIB, and currawong have been studied as part of the REP (Carlile and Priddel 2006). A range of biodiversity benefits monitoring studies have been undertaken for the REP (described in Section. 2.2.1.8). Key studies relevant to the REP are detailed below in Table 14.

More importantly however, the REP will take place over the entire LHIG with the exclusion of Ball's Pyramid. This means that all populations present on LHI at the time of the REP, and all listed habitats and vegetation communities on LHI will be subject to the REP. There are no alternative locations. Therefore all species documented in the NSW Wildlife Atlas and/or in the Lord Howe Island Biodiversity Management Plan (2007) as occurring in the LHIG, were automatically part of the Species Impact Statement. No additional specific surveys for threatened species and vegetation were therefore considered warranted.

Table 14 LHI Ecological Study Summary

Species / Group	Overview of Studies	Key References
LHI Biodiversity Management Plan	Collated summary of species records, distribution and abundance and key threats, particularly of threatened species. Forms a holistic management document for protection of the island's biodiversity. It also constitutes the formal recovery plan for many threatened species.	DECC, 2007. Included as Appendix H – LHI Biodiversity Management Plan
The General Zoology of Lord Howe Island	Anecdotal accounts of fauna sightings and collections made by the Australian Museum collecting party in 1887	Etheridge 1889
Environmental Survey of Lord Howe Island	Results and recommendations of a scientific survey undertaken in the early 1970s. The aim of the survey was to determine the current status of the flora and fauna and to recommend ways in which the long-term survival of the indigenous species could be assured.	Recher & Clark 1974
Vegetation of Lord Howe Island	A description and map of the vegetation of the LHIG	Pickard 1983
Mosses of Lord Howe Island	A checklist of the mosses of Lord Howe Island based on literature and collections in Australian herbaria together with a summary of their distribution patterns on the island	Ramsay 1984
Flora of Australia Volume 49 Oceanic Islands 1 - Flora of Lord Howe Island	Lists the vascular plants of the LHIG, both exotic and native, that have been recorded on the LHIG	ABRS 1994
Vegetation and Habitat of Significance Within the Settlement Area of Lord Howe Island	An update of vegetation mapping within the settlement area. Mapping of the distribution of high conservation value vegetation within the settlement area and information on the distribution of habitat for threatened flora and fauna species .	Hunter 2002
Birds of Lord Howe Is land - Past and Present	Descriptions of sea birds and land birds, both extant and extinct A recent inventory of all known bird	Hutton 1991

The Birds of the Lord Howe Island Group: A Review of Records	records from the LHIG. Management issues are discussed where relevant	McAllen et al. 2004
The Birds of Lord Howe Island	Check list of birds known from and known to have occurred on LHI	The Emu Vol XLJ July 1940 Part 1. Hindwood, K.A.
LHI Woodhen	Recovery Plan Survey Methods Census results	NSW National Parks and Wildlife Service, 2002 Harden, 1999
LHI Currawong	Population size and distribution of the Lord Howe Currawong	Carlile and Priddel 2006. Included as part of Appendix C – Captive Management Package.
Masked Owl (and	Distribution, diet and abundance on LHI Genetics	Milledge, 2010 Hogan *et al.* 2013 Both included a part of Appendix F – Masked Owl Package.
Lord Howe Island: Terrestrial Invertebrate Biodiversity and Conservation Report	A synopsis of collated existing information on the terrestrial invertebrates of Lord Howe Island. It includes a statistical analysis of invertebrate biodiversity patterns across the LHIG, focussing on endemism and species richness, an assessment of the conservation status of selected terrestrial invertebrate taxa, and identifies threatening processes and conservation recommendations. This report was commissioned by DECC and the LHIB in 2003.	Australian Museum, 2003
LHI *Placostylus*	Assessing the risk of Pestoff® 20R Brodifacoum baits to the Lord Howe Island flax snail (*Placostylus bivaricosus*	Wilkinson and Hutton, 2013. Included as part of Appendix D – LHI Trials Package
Critically endangered Land snails	Australian Museum survey for critically endangered land snails (70 person hours across different parts of the island) and assessment of potential impacts from the REP.	Köhler, Hyman, and Moussalli, 2016. Report is included in Appendix K – Land Snail Survey 2016.
LHI Wood-feeding Cockroach	Abundance and occurrence study	Carlile , N., Priddel, D, 2013
Biodiversity Benefits	Distribution and abundance of key indicator species pre and post REP Land Bird Surveys	Carlile 2015 Fullagar, P., Davey, C., Nicholls, A. O., and Hutton, I, 2014 and 2015. Included as Appendix G – Biodiversity Benefits Monitoring Package
Reptiles	The reptiles of Lord Howe Island.	Cogger, H. G, 1971
Marine	Management plan for the LHI Marine Park (Commonwealth) Natural Values of Lord Howe Island Marine Park	Environment Australia, 2002. Marine Parks Authority (2010

5 Assessment of Likely Impacts on Threatened Species and Populations

An assessment of which threatened species or populations known or likely to be present in the area are likely to be affected by the action (Section 110(2)(b))

In the following sections, species identified in Table 12 as *subject species* are further assessed by:

- *Subject species* assessed as not being *affected species*
- *Subject species* assessed as being *affected species (*those species likely to be *affected* by the proposal, and to identify the nature, extent and degree of the effect).
    - Potential impacts likely to arise from the REP are well understood based on impacts (or lack of impacts) that have been documented in the global literature on similar eradications. Therefore it is considered unlikely that unknown, unexpected or irreversible impacts will occur.

The potential likelihood, consequences, duration and extent of these impacts are described in detail in the section below.

5.1 Subject species assessed as not being affected species

Table 10 also includes the *subject species* for the LHI Group. *Subject species* has been taken to refer to those *threatened, migratory* and *significant* species that will be present on the LHIG at the time of baiting, excluding those species noted in Section 5.1.1. Although a *subject species* may be present, it is not necessarily at risk of being harmed by the proposed baiting (see Section 5.2 for the assessment of *affected species*).

Validation for species assessed as not being *affected species* is presented below.

5.1.1 Terrestrial invertebrates

The only REP associated activity with the potential to impact on TSC Act listed terrestrial invertebrates is through direct consumption of bait (primary poisoning). Conversely, predation by rodents is regarded as a significant threat to many of the invertebrates on Lord Howe Island (DECC 2007), and was listed as a Key Threatening Process by the NSW Scientific Committee in 2000.

Consumption of Brodifacoum is not expected to have significant effects on invertebrates as they have different blood clotting systems to mammals and birds.

Potential impacts to individual species is detailed below.

Lord Howe Island Earthworm *Pericryptodrilus nanus*

Conservation status

Listed as E*ndangered* under the TSC Act.

This earthworm is endemic to LHI. It has only been located on the ridge of Mt. Gower were it was found in deep leaf litter in moist environments close to streams (NSW Scientific Committee 2008b).

Threats

- Potential competition with introduced earthworms (DEC 2005);
- Loss, destruction or disturbance of habitat caused by other non-native invertebrates (e.g., exotic ants) (DEC 2005);
- Habitat disturbance through trampling by people (DEC 2005);
- Predation by the Lord Howe Woodhen;
- Predation by rodents (DEC 2005);
- Potential predation by the Song Thrush *Turdus philomelos* and Common Blackbird *T. merula* (DEC 2005).

Risk Posed by the Rodent-Baiting Proposal

During a trial in 2007 (DECC, 2007a a number of non-toxic Pestoff® 20R pellets) were distributed on LHI, and observed that, typically, it took about 100 days for the pellets to breakdown in response to weathering. Although the cereal pellet disintegrates and disappears in 100 days or so, the poison may take longer to break down. Manner of use of Brodifacoum baits and physical and chemical properties of Brodifacoum suggests little accumulation of Brodifacoum in soil, with concentrations of Brodifacoum in soil predicted to be negligible/low.

Brodifacoum binds strongly to soil particles, where it is broken down by soil micro-organisms to its base components, carbon dioxide and water, the half-life being 12-25 weeks (Soil Degradation for 50% of the compound (DT_{50})– typical 84 days: Field – 157 days; Shirer 1992). In laboratory studies using radioactive-labelled Brodifacoum, less than 2% of Brodifacoum added to any of four soil types tested, leached more than 2 cm (WHO 1995).

There are a number of operations in New Zealand where soil has been tested extensively following the use of cereal-based Brodifacoum baits. During the Little Barrier Island operation in 2004, soil samples were collected from directly under decaying Pestoff® 20R baits or where they had lain. Samples were taken 56 and 153 days after the aerial bait drop. Those in grassland areas had residues of 0.2 μg/g (micrograms of poison per gram of soil) after 56 days, and 0.03 μg/g on day 153. In forested areas the figures were 0.9 μg/g on day 56 and 0.07 μg/g on day 153. Brodifacoum soil residues were also tested in a baiting trial conducted at Tawharanui Regional Park, Auckland. Soil samples were collected from directly beneath disintegrating baits at 56, 84, 122 and 153 days after first exposure to the elements. These samples produced residues of between 0.02 and 0.2 μg/g, with all positive samples occurring within the first 84 days; that is, no Brodifacoum was detectable in the soil immediately below baits after just 84 days (Craddock 2004). Analysis of soil samples from Red Mercury and Coppermine islands following rat eradication using Brodifacoum showed no residue in any samples, including samples taken only one month after the operation (Morgan 1993; Morgan and Wright 1996).

There is no specific data available about the interaction of the local earthworms with Brodifacoum. However, studies of the effect of Brodifacoum on the pasture worm (*Aporrectodea calignosa*) indicate that extremely high concentrations of Brodifacoum are required to kill worms (Booth *et al.* 2003). The concentration of Brodifacoum in soil required to cause mortality in pasture earthworms (500 to 1000 micrograms of poison per gram of soil) is more than 1000 times higher than the likely levels of Brodifacoum that would be found in soil directly below a bait pellet at the application rate proposed for LHIG. To put it another way, all the Brodifacoum present in 25 to 50 kg of bait would need to be distributed through 1 kg of soil for that soil to be toxic to earthworms (Broome *et al.* 2016). "Worms have shown no evidence of vulnerability to Brodifacoum poisoning" Broome *et al.* (2016).

No impact is therefore expected to the LHI earthworm.

Mitigation of the Proposed Rodent Eradication

In view of the high tolerance of earthworms to Brodifacoum, the extremely low concentration of Brodifacoum likely to enter the soil from Pestoff® 20R pellets, and the very limited movement of Brodifacoum away from decomposing pellets, the baiting proposal is not regarded as a threat to the Lord Howe Island Earthworm so no mitigation measures are proposed.

Lord Howe Island Wood-feeding Cockroach *Panesthia lata*

Conservation Status

Listed as *endangered* under the TSC Act.

This cockroach is endemic to the LHIG. It was once found on LHI but there are no records of it being found on the main island after the 1960s (NSW Scientific Committee 2008a). It is currently thought to be restricted to rat-free Blackburn and Roach islands (DECC 2007). Cockroach distribution on Blackburn Island appears to be limited by the exotic Rhodes Grass *Chloris gayana,* a dense mat grass impenetrable to the cockroach.

Ecology

Panesthia lata prefers damp and shaded locations where it burrows in soil under logs and rocks. They feed on leaf litter and rotting wood.

Threats

- The key threat to this cockroach is predation by introduced rats (DECC 2007);
- Mice may also prey on juveniles of this species (DECC 2007);
- The loss, destruction or disturbance of habitat caused by people, wildfire, or the invasion of weeds such as Rhodes Grass.

Risk Posed by the Proposed Rodent-Baiting

Unpublished data from Landcare Research (and cited in Booth *et al.*2001) shows the Tree Weta *Hemideina crassidens*, a member of the grasshopper group of insects, to have both high tolerance to Brodifacoum and a short retention time. Weta orally dosed up to 62.5 ug/g with Brodifacoum survived. This is a relatively large amount of Brodifacoum considering one 10 mm Pestoff bait pellet contains about 40 ug/g of Brodifacoum. Weta were also dosed with 10 ug/g of Brodifacoum to determine retention time; no Brodifacoum was detected after four days. Cockroaches on Henderson Island were fed Pestoff 20R pellets (the type proposed for the eradication on Lord Howe Island) for four days; 12 days later the concentration of Brodifacoum in these insects was 0.061 ug/g which is less than 1/300 of the concentration of the Brodifacoum in the baits they ate (Brooke *et al.* 2013).

Crabs on Ascension Island survived being fed 7 to 20 pellets containing Brodifacoum at 20 parts per million; no residues were detected in these crabs more than a month after they ate the pellets (Pain *et al.*2000).

The extent of residual Brodifacoum in arthropods examined in the days after the local application of Brodifacoum baits varies. On Stewart Island, less than 5% of beetles collected at bait stations contained residues (Wright and Eason 1991, and the highest residue was only 3.3 ug/g which is less than 9% of that found in a single 10 mm Pestoff pellet. No arthropods collected from Copper and Red Mercury islands had traces of Brodifacoum in them after baiting took place Morgan *et al.*1996). On Lady Alice Island, cockroaches were collected in the days and weeks after aerial baiting and tested for Brodifacoum; none was detected. However, 51% of invertebrates (including beetles, cockroaches and Weta) from another study contained traces of Brodifacoum (range 0.02 – 7.47 ug/g) after baiting (Both *et al.* 2001). Notwithstanding the presence of Brodifacoum residue in arthropods, the populations of arthropods either increases (Brown 1997) or remains the same as in adjoining non-baited areas (Spurr 1996), indicating that arthropod populations are not significantly harmed by Brodifacoum baiting programmes.

Although research on the effects of Brodifacoum on arthropods is limited, three general trends are apparent; 1) high doses of Brodifacoum are not lethal to the arthropod taxa; 2) baiting with Brodifacoum does not harm arthropod populations (Broome *et al.* 2016) and 3) the retention time of Brodifacoum within arthropods is short, and can be measured in days, not the months typical for vertebrate species. These three factors suggest that Lord Howe Island's arthropods will not be harmed by the rodent baiting.

Mitigation of the Proposed Rodent Eradication

As it is unlikely that the proposed rodent eradication will harm *Panesthia lata*, no mitigation actions are warranted.

5.1.2 Birds

Flesh-footed Shearwater *Puffinus carneipes*

Conservation status

Listed as *vulnerable* under the TSC Act.

This shearwater has a trans-equatorial distribution over the Pacific and Indian oceans, excluding the seas north of Australia (Hutton 1991). LHI is the only eastern Australian site where the bird breeds. Here the breeding colonies are from Ned's Beach to Clear Place, below Transit Hill and at Old Settlement Beach. The population estimate for LHI is 17,500 breeding pairs.

Flesh-footed Shearwaters are present on the LHIG from September (DECC 2007) to May. Egg laying commences in December. Nests are in burrows. The birds feed at sea on fish, squid and crustaceans, returning after sunset to LHI. They depart before sunrise.

Threats

- Ingestion of plastics;
- By-catch in long-line fishing;
- Loss of nesting habitat due to the expansion of human settlement;
- Motor vehicle traffic;
- Killing by residents of those birds building under houses;
- Predation of nestlings and adults by domestic dogs.

Risk Posed by the Rodent-Baiting Proposal

Unless baiting takes place in September, this shearwater will not be on LHI during the rodent eradication. If the birds are present during the rodent eradication they will not be harmed by the baiting as the birds feed at sea, more than two kilometres from the island therefore the population is not at risk of primary or secondary poisoning. Flesh-footed shearwaters begin to fly close to the island in the late afternoon; some individuals will land at this time but most individuals land during or following dusk (N. Carlile and D. Portelli pers. obs.) therefore it is very unlikely that any could be hit by the baiting aircraft.

Mitigation of the Proposed Rodent Eradication

No mitigation is required.

Red-tailed Tropicbird *Phaethon rubricauda*

Listed as *vulnerable* under the TSC Act.

The distribution of this species covers the tropical and sub-tropical waters of the Pacific and Indian oceans (DEC 2005). Breeding for this species is confined to oceanic islands, with the largest breeding concentration believed to be on the LHIG (ibid). During the summer months, between 500 to 1000 pairs of tropicbirds can be found on the LHIG nesting along the cliffs from North Head to Malabar and around the cliffs of the southern mountains as well as on the Admiralty Islands and Balls Pyramid (McAllan *et al*. 2004). Only a few birds are present during the winter months (McAllan *et al*. 2004).

Threats (DEC 2005)

- Invasion of breeding grounds by weeds, particularly Bitou Bush;
- Juveniles are susceptible to a common fatal disease.

Risk Posed by the Proposed Rodent Baiting

As the greater majority of birds will not be on the island group during the proposed baiting, and because this species solely feeds on fish, the rodent eradication does not pose a threat to the tropic bird.

Mitigation of the Proposed Rodent Eradication

None required.

White Tern *Gygis alba*

Listed as *vulnerable* under the TSC Act.

This species is widely distributed in the Pacific and Indian oceans, as well as, to a lesser extent, the Atlantic (Higgins and Davies 1996). It breeds on islands throughout its distribution. Eggs are laid directly onto horizontal branches, typically into a depression or damaged section of the branch (Hutton 1991). The sub-species *G. a. candida* breeds in the tropical Pacific Ocean, including on LHI, Norfolk Island, and the Kermadecs, as well as in the tropical Indian Ocean (Higgins and Davies 1996). A minimum of 334 pairs of White Terns nested on LHI in 2006 (Carlile and Priddel 2015) compared to the 2,000 – 2,500 pairs found on Norfolk Island (Higgins and Davies 1996). On LHI the White Tern is generally present from October to May. Although recorded in all months, it is usually absent from the island group from June to September (McAllan *et al*. 2004). Its diet is made up of small fish and squid.

Threats

- Predation of nestlings by currawongs;
- Predation of nestlings and adults by Masked Owls.

Risk Posed by the Proposed Rodent Baiting

Its diet, and the absence of most, if not all, terns in winter indicate that this species is not at significant risk from the rodent eradication.

Mitigation of the Proposed Rodent Eradication

None proposed.

White-bellied Storm-petrel *Fregetta grallaria*

Conservation status

Listed as *vulnerable* under the TSC Act.

The White-bellied Storm-petrel is widely distributed in the Southern Hemisphere over most of the Pacific and Atlantic oceans as well as extending into the Indian Ocean (Hutton 1991). Although it breeds on a number of island groups throughout its range (e.g., Kermadec, Austral, Juan Fernandez, Rapa, Tristan da Cunha and Gough (Hutton 1991)), the LHIG is the only breeding site in Australian waters. Here it breeds on Roach Island, Mutton Bird Island, Balls Pyramid and possibly Blackburn Island. It has not been recorded breeding on the main island since the arrival of rats. The small size of storm-petrel adults, nestlings and eggs make them especially vulnerable to predation by rats.

The population of this storm-petrel on the LHIG is estimated to be somewhere between 100 and 1,000 pairs (Hutton 1991). It is probably present on the island group all year but the highest concentration is from November until May. Egg laying commences in January, and chicks fledge in May. Nests are usually located amongst large rocks. The birds feed at sea in deep water on crustaceans and squid collected from the ocean surface, returning after sunset to change-over egg-sitting duties or to feed young. They depart before sunrise.

Threats

- Possible establishment of rats on islands containing storm-petrel nesting grounds (DECCW 2009);
- Local extinction due to small population size (DECCW 2009).

Risk Posed by the Rodent-Baiting Proposal

Because the birds feed at sea, the population is not at risk of primary or secondary poisoning. Few birds will be in the area during the proposed baiting, and these will only be present at night so there is no risk of collisions with low-flying aircraft. No impact on this species is expected.

Mitigation of the Proposed Rodent Eradication

No mitigation is required.

5.1.3 Marine Species

Potential impacts to TSC Listed threatened marine species are limited to accidental bait entry into the water (either through aerial distribution or a spill) leading to pollution of water, primary or secondary poisoning.

Pollution of marine water resulting in impacts to threatened marine species is considered extremely unlikely considering the minimal amount of bait likely to enter the water, the insolubility of Brodifacoum and the huge dilution factor which was discussed in 2.7.1.4.

Appendix J – Marine Hypothetical Scenario contains a number of hypothetical examples where the contamination levels resulting from that bait spill have been assumed to exist off the Lord Howe Island Group, and involve representatives of some of the fauna that may be found in the area. This analysis demonstrates that the risks to marine species around the Lord Howe Island Group are negligible, and, accordingly, marine species are not *affected species*.

5.1.3.1 Marine Mammals

There is no realistic pathway by which threatened marine mammals can be significantly exposed to rodenticide at the LHIG as a result of the proposed aerial baiting with Pestoff® 20R. The combination of Brodifacoum being practically insoluble in water, the infinitesimal amount of Brodifacoum that may land in the sea and the huge dilution factor preclude any significant effect upon marine mammals. Marine mammal species are also rare visitors to LHI waters, passing through on the annual migration and are therefore unlikely to encounter the bait.

The movement of aircraft involved in the baiting does have the potential to disturb marine mammals. Further detail provide in Appendix J – Marine Hypothetical Scenario.

5.1.3.2 Turtles

It is very unlikely that Green Turtles *Chelonia mydas* could be exposed to rodenticides by consuming baits directly or prey items that have ingested rodenticides. Adult Green Turtles feed exclusively on various species of seagrass and seaweed. Plants have not been documented to take up and store anticoagulants; therefore no effect on adult Green Turtles is expected to occur from ingestion of rodenticide in their food.

Juvenile Green Turtles and the other four species of turtle (Flatback Turtle *Natator depressus*, Hawksbill Turtle *Eretmochelys imbricata*, Leatherback Turtle *Dermochelys coriacea* and Loggerhead Turtle *Caretta caretta*) that may be encountered in the marine park are carnivorous, and will eat soft corals, shellfish, crabs, sea urchins and jellyfish. However, it is unlikely that these turtles will encounter marine invertebrates that may have been contaminated with Brodifacoum as a result of aerial baiting the LHIG with Pestoff® 20R. Evidence against the existence of a significant dietary exposure pathway for invertebrates is outlined in section 2.7.2. No turtle nesting occurs on the LHIG.

In summary, the proposed baiting of LHI does not pose a threat to threatened marine life because:

- The use of specialised equipment on the bait hopper will ensure minimal bait entry to the water. The amount of bait that may bounce off the cliffs to fall into the sea will be minimal (Howald *et al.* 2005; Samaniego-Herrera *et al.* 2009);
- The breakdown of baits that do land in the sea will be rapid (Empson and Miskelly 1999), therefore the opportunity for fish to take baits will be limited;
- Fish have shown a lack of interest in baits (Samaniego-Herrera *et al.* 2009, U.S. Fish and Wildlife Service and Hawai'i Department of Land and Natural Resources 2008), so it is unlikely that many fish will take baits;
- The possible death of those few fish that find and eat enough baits to prove fatal does not pose a threat at the population level;
- Baiting other islands using similar methods, although sometimes using significantly more bait, has not resulted in adverse effects on the marine environment as a whole. (Cole and Singleton 1996; Empson and Miskelly 1999; Howald et al. 2005; Samaniego-Herrera et al. 2009).

- Potential impacts are likely to be very localised and temporary in nature.

5.2 Subject species assessed as being affected species

For each *affected species*, the TSC Act requires information relating to conservation status (local, regional and State-wide), habitat requirements, relevant key threatening processes, and recovery and threat-abatement plans. Pertinent sections of that Act are as follows:

1) An estimate of the local and regional abundance of those species or populations {Section 110(2)(d)};
2) An assessment of whether those species or populations are adequately represented in conservation reserves (or other similar protected areas) in the region {Section 110(2)(e)};
3) An assessment of whether any of those species or populations is at the limit of its known distribution {Section 110(2)(e1)};
4) A full description of the type, location, size and condition of the habitat (including critical habitat) of those species and populations and details of the distribution and condition of similar habitats in the region {Section 110(2)(f)};

As discussed in Section 4, the entire LHIG excluding Ball's Pyramid will be subject to the REP. Therefore discussions regarding habitat are considered irrelevant. Similarly as LHI is separated from the mainland by more than 600km, regional representation is only discussed where it is considered valid, for example migratory birds.

In addition, Section 112D of the Environment Planning & Assessment Act states that, in determining whether or not concurrence should be granted, the Chief Executive of the Office of Environment and Heritage must take certain matters into consideration. These matters include:

- s.112D(e) "*whether the activity is likely to reduce the long-term viability of the species, population or ecological community in the region*"
- s.112D(f) "*whether the activity is likely to accelerate the extinction of the species, population or ecological community or place it at risk of extinction".*

Assessment of potential impacts to affected species is discussed below.

5.2.1 Terrestrial invertebrates

The only REP associated activity with the potential to impact on TSC Act listed terrestrial invertebrates is through direct consumption of bait (primary poisoning).

Consumption of Brodifacoum is not expected to have significant effects on invertebrates as they have different blood clotting systems to mammals and birds.

Introduced slugs and snails used as analogues for native snail species in experiments suggest NZ terrestrial molluscs are not susceptible to Brodifacoum poisoning (Broome *et al.*2016). Whilst most studies of molluscs indicate a lack of impact of Brodifacoum (Booth *et al.* 2003; Bowie and Ross 2006), a study conducted in Mauritius reported mortality in two snail species after reports of snails consuming toxic baits (Gerlach and Florens 2000). Trials done in NZ so far have failed to show any effect on invertebrates feeding on Brodifacoum baits (Booth *et al.* 2001; Booth *et al.* 2003; Craddock 2003; Bowie and Ross 2006).

Booth *et al.* (2003) carried out a laboratory evaluation of the toxicity of Brodifacoum to native snails, using introduced common garden snails as a model. In one experiment, common garden snails were exposed to soil contaminated with Brodifacoum at 0.02 to 2 mg ai/kg. In a second experiment, snails were exposed to contaminated soil (100 to 1000 mg ai/kg) and Talon® 20P pellets. No snail mortality was observed in either experiment. The authors concluded that primary poisoning of native *Powelliphanta* snails from cereal pellets containing Brodifacoum was unlikely.

Bowie and Ross (2006) allowed introduced slugs (*Deroceras* spp.) held in captivity, to feed freely for 40 days on Talon 50WB® wax baits containing 0.05 mg/kg Brodifacoum. No mortality was observed.

Gerlach and Florens (2000) reported 100% mortality of two Seychelles Islands snails (*Pachnodus silhouettanus* and *Achatina fulica*) after they consumed Brodifacoum baits. Lethal doses varied with snail size, with 15-20mm *P. silhouettanus* being killed by a dose of 0.01 to 0.2 mg/snail within 72 hours. This is equivalent to a *P. silhouettanus* eating between 0.5 and 10 g of 0.02 g/kg Brodifacoum bait. *A. fulica* were killed by a dose of 0.04 mg/kg in 72 hours (Booth *et al.* 2003). This is equivalent to an *A. fulica* eating approximately 0.2 g of 0.02 g/kg Brodifacoum bait. Both species are ground-dwellers and ecologically similar to the larger, ground-dwelling species on LHI, such as *P. bivaricosus*, *G. sophiae* and *G. s. magnifica*.

Gerlach and Florens (2000) also reported observing *Pachystyla bicolor* eating baits and finding significant numbers of recently dead snails following a Brodifacoum operation to control rats in Mauritius.

In another experiment by Brooke *et al.* (2011) native snails were collected from the litter layer on Henderson Island in the Pitcairn group and held on the island in plastic boxes to which broken pieces of Pestoff 20R cereal pellets containing 20mg/kg Brodifacoum were added. A control group of snails in boxes were kept in similar conditions with no exposure to Brodifacoum. Each of seven species (Orobophana spp and Achatinellids spp) was tested this way for 10 days. After 10 days exposure a total of 3 snails from the treatment groups were found dead from a total of 57. In the control boxes a total of 4 snails were found dead from a total of 53 held. None of the dead snails were found to contain Brodifacoum residues.

During 2007, a study using non-toxic baits (similar to those cereal pellets to be used in the proposed eradication operation) was conducted on LHI to examine bait uptake by non-target species (DECC, 2007a) (in Appendix D – LHI Trials Package). These baits contained a fluorescent dye that glowed under ultraviolet light. During the trial conducted on LHI, some ants, slugs, cockroaches and snails (not Placostylus) were observed feeding on baits (DECC, 2007a). For each of these groups only a small proportion of individuals had consumed bait.

Research was conducted in 2009 to assess the vulnerability of the endangered LH Placostylus to Brodifacoum baits (Wilkinson and Hutton, 2013) (in Appendix D – LHI Trials Package). When given a choice between their natural diet and bait pellets, Placostylus will feed preferentially on their natural diet, ignoring bait. When all other feed was denied to them, they fed exclusively on Brodifacoum baits, but no mortality occurred. These findings demonstrate that there is negligible risk posed to *Placostylus bivaricosus* by the proposed eradication operation as the probability of a significant proportion of the *Placostylus bivaricosus* population consuming and dying from toxic baits in the wild is extremely unlikely. This is supported by an Australian Museum assessment in 2016 (Kohler *et al.*, 2016). Full report attached in Appendix N – Land Snail Survey 2016.

The assessment also considered the probability of the other four listed land snails coming contact with the broadcasted baits (at a density of 1 per 2 m^2) based on their ecology and behaviour.

Three of the critically endangered land snails, minute to small leaf litter-dwellers with small activity ranges (*Mystivagor mastersi*, *Peudocharopa ledgbirdi*, *P. whiteleggei*) were considered at moderate risk of exposure to bait placed (i.e. some but not all individuals may get in contact with baits). Susceptibility to Brodifacoum was unknown.

The fourth species *Gudeconcha sophiae magnifica*, a large ground-dwelling species with large activity ranges was considered to be at high risk of exposure to bait. This taxon belongs to the same family and is ecologically similar to *Pachystyla bicolor* from Mauritius, a species shown to be susceptible to Brodifacoum.

The study recommended experimental testing be conducted to examine the susceptibility of the common subspecies *G. sophiae sophiae* to Brodifacoum as surrogates for the critically endangered subspecies *magnifica*. It also recommended that, where possible, insurance populations of listed or Brodifacoum-susceptible species are kept in captivity over the duration of the baiting program but noted this is probably not a realistic option for the very rare and hard to find species *M. mastersi*, *P. ledgbirdi*, and *P. whiteleggei* and may also prove challenging for the rare taxon *G. sophiae magnifica* (Kohler *et al.*, 2016). Therefore it is considered that the extreme rarity of these species precludes any testing of their susceptibility to Brodifacoum, or capturing the species to safeguard them in captivity.

The one endangered: *Placostylus bivaricosus* and four critically endangered species of land snails on LHI: Masters' charopid land snail, Mount Lidgbird charopid land snail, Whitelegge's land snail and *Gudeoconcha sophiae magnifica* are highly threatened by rat predation and it is likely that if rats are not removed these species will become extinct; some may already be extinct. (Kohler *et al.*, 2016). Whilst it is possible that some individuals of these species may be at risk of poisoning, this possibility must be weighed up against the threats associated with not removing rodents including almost certainty that predation by rats will result in the extinction of these species, in particular the critically endangered species living at high altitudes, where they are currently largely unprotected from rodent predation due to the inaccessibility of the area. Therefore a significant impact to these species is not expected from the REP when compared to not proceeding with the eradication. Proceeding with eradication of rats is listed as a priority action in the Commonwealth Conservation Advices for these species.

Gudeoconcha sophiae magnifica

<u>Conservation status</u>

Listed as *critically endangered* under the TSC Act.

Very little is known about the biology and ecology of this endemic snail which is, or was, predominantly confined to Mount Gower and Mount Lidgbird (Beeton 2008a). This habitat is protected in the island's Permanent Park Preserve.

<u>Threats</u>

- The key threat to this snail is likely to be predation by introduced rats (Beeton 2008a; NSW Scientific Committee 2015a);
- The Song Thrush and Common Blackbird are known to prey on the Lord Howe Placostylus, so they probably prey on this species as well (Beeton 2008a);

- Loss or destruction of habitat caused by wildfire, the invasion of weeds or trampling by tourists and other people (Beeton 2008a).

Population estimate

It appears that this endemic species has never been relatively common on LHI, at least in historic times. Only 76 specimens have been collected by the Australian Museum between 1907 and 2002. This represents only 0.34% of the total snail collection from LHI (Beeton 2008a). Evidence also indicates that numbers may have declined over time (Beeton 2008a). A recent survey undertaken to specifically search for this snail (Kohler *et al*. 2016) failed to find any specimens, including shells.

Risk Posed by the Rodent-Baiting Proposal

Laboratory tests, involving the administering of Brodifacoum, conducted on two species of snails in the Seychelles resulted in the death of all test subjects (Gerlach and Florens 2000) although laboratory tests conducted in other parts of the world indicated that other snails are not susceptible to Brodifacoum baits (Booth *et al.* 2003). In Mauritius dead snails of the species *Pachystyla bicolour* were found near bait stations, suggesting that this species may be harmed by Brodifacoum baits. It may also suggest nothing more sinister than large numbers of snails congregating at bait stations, and that this concentration of snails makes it easier to find snails that have died from a variety of reasons.

Kohler *et al.* (2016) state that *P. bicolour* is ecologically similar to *Gudeoconcha s. magnifica*, and have suggested that, because of this similarity, the LHI snail may be placed at high risk by the REP. However, Kohler *et al*. do acknowledge that this assessment is made without knowing if the LHI snail is susceptible to Brodifacoum, and is based solely on the ecological attributes of the snail. These authors also say “The eradication of both rats and mice (both equally important) is the most cost efficient and only feasible way to ensure the survival of the critically endangered (snail) species in the long term” (page 17); and on page 2 “Overall, we consider the eradication of rodents which represent the greatest threat to the indigenous snails, to outweigh any potential short-term negative effect” of the REP. It appears that baiting could place *G.s. magnifica* at risk of extinction but the continued presence of rodents will send (or has already sent) this subspecies to extinction. The threat posed by rodents to this species is highly significant (Beeton 2008a; NSW Scientific Committee 2015a), and justifies the use of Brodifacoum during the REP to remove such a major threat.

Mitigation of the Proposed Rodent Eradication

Testing this species for vulnerability to Brodifacoum or collecting a representative sample of the population for safe keeping is not feasible. This species is so rare (only 29 specimens, most of which were dead, were collected from 1998 and 2002, and none was found during the last three years of survey on Mount Lidgbird {Beeton 2008a}) that it is very unlikely animals could be found to take into captivity. None were found in an intensive search undertaken in 2016 (Kohler *et al.* 2016). Rats are regarded as a significant threat to this snail (Beeton 2008a; Kohler *et al.* 2016) and are possibly driving this species towards extinction, if they have not done so already. Current data indicates that long-term viability of this species, under present circumstances, is unlikely (Beeton 2008a). The method proposed for the eradication of rodents from LHI may potentially place *Gudeoconcha s. magnifica* at risk of poisoning, but this possibility must be weighed up against the high probability that predation by rats will result (or has resulted) in the extinction of this snail.

Lord Howe Placostylus *Placostylus bivaricosus*

Conservation Status

Listed as *endangered* under the TSC Act.

The Lord Howe Placostylus is a large land snail, the shell of a mature specimen can be up to 8 cm long. It is endemic to LHI but has close relatives in New Zealand (*P. ambagiosus, P. bollonsi and P. hongii*). Other members of the genus occur in the Solomon Islands, Fiji and New Caledonia. The Lord Howe Placostylus was once abundant and widespread on the island, inhabiting the leaf litter of rainforest areas. The decline of the species was first noted in the 1940s (NSW NPWS 2001).

Three recent sub-species of the Lord Howe Placostylus are recognised:

1) *Placostylus bivaricosus bivaricosus* is *endangered*, having declined in extent and number. It was formerly common over the northern end of LHI from sea level to the top of Malabar Hill (approximately 200 m).The current stronghold for this sub-species is the Settlement but other sites where the snail has been recorded since the 1970s are North Bay, near Transit Hill and the vicinity of the airport (NSW NPWS 2001).
2) *Placostylus bivaricosus etheridgei* occurred in the mountains at the southern end of the Island up to an altitude of 350 m. It is probably extinct (Ponder 1997, Beesley *et al.* 1998) although it is still hoped that this sub-species exists as isolated local populations on Little Slope and Big Slope (NSW NPWS 2001).

3) *Placostylus bivaricosus cuniculinsulae* was restricted to Blackburn Island. It is now believed to be extinct due to the loss of the original forest cover from this island as a result of grazing/browsing by rabbits (NSW NPWS 2001).

Habitat

Observations of Placostylus in the 19th Century indicate that this snail prefers shady, damp situations, preferably on scrubby calcarenite hillsides (NSW NPWS 2001). Ponder and Chapman (1999) found Placostylus "sheltering under well-developed, moisture-retaining leaf litter in forests" often in the vicinity of Banyan trees *Ficus columnaris,* and mostly on calcarenite-derived soils and sandy soils. All recent records have been in made in evergreen closed forests dominated by either Kentia Palm or Greybark *Drypetes australasica/*Blackbutt *Cryptocarya triplinervis* association (or ecotones between the two) (NSW NPWS 2001).

Habitat Protection

Areas providing habitat for the Lord Howe Placostylus are protected in the Permanent Park Preserve and Environment Protection areas, the latter as delineated in the LHI Regional Environmental Plan 1986.

Ecology

Lifespan for the Lord Howe Placostylus is unknown but its close relatives in New Zealand may live for 20 years, with maturity reached after three to five years (NSW NPWS 2001). Eggs are laid in the soil under leaf litter. Fallen dead leaves from broadleaf trees are thought to be its food source (NSW NPWS 2001).

Threats (NSW NPWS 2001)

- Loss of habitat through clearing of lowland forest. Forty-four per cent of the prime habitat for this snail has been cleared since settlement. Presently only 128 ha remains.
- The Ship Rat is a significant threat to the Placostylus, being a major predator of the species; the eradication of rats from LHI is a key recommendation of the Recovery Plan for the Lord Howe Placostylus.
- Flesh-footed Shearwaters *Puffinus carneipes* nest in prime snail habitat in the coastal evergreen closed-forests growing on calcarenite in the northeast of the island. Large numbers of snail shells have been found in the nesting areas of this seabird but no live snails have been found suggesting that disturbance of snail habitat by expanding populations of this shearwater is a major threat to the Lord Howe Placostylus.
- The introduced Song Thrush and Common Blackbird prey on the Lord Howe Placostylus, and maybe a significant threat to it.
- The invasion of snail habitat by introduced plants is likely to diminish the quality of the habitat for the snail. The effect on the snail of the use of herbicides to control these weeds is unknown.
- The use of snail bait around gardens in the Settlement Area to control the introduced garden snail is likely to threaten the Lord Howe Placostylus.
- Free-ranging chooks *Gallus gallus domesticus* feed on snail eggs and hatchlings.

Risk Posed by the Rodent-Baiting Proposal

When laboratory-acclimated Lord Howe Placostylus were exposed to non-toxic baits (containing the biomarker pyranine that fluoresces under ultra violet light) along with natural food in a feed-choice trial, they fed exclusively on natural food as no fluorescing faecal samples were detected. This finding suggests that the likelihood of significant proportions of the species consuming toxic baits is extremely small. When snails were only offered toxic baits, they ate the baits but no mortalities resulted from the exposure indicating that Placostylus is not vulnerable to Brodifacoum (Wilkinson and Hutton, 2013).

Mitigation of the Proposed Rodent Eradication

None proposed.

Masters' Charopid Land Snail *Mystivagor mastersi*

Conservation status

Listed as *critically endangered* under the TSC Act.

This snail, endemic to LHI, is only known from a few sites, including Mount Lidgbird, Mount Gower, Blinky Beach and Boat Harbour (Beeton 2008b). However, recent surveys suggest that the species is now confined to the summits of the two southern mountains (Beeton 2008b). Only 17 specimens have been collected by the Australian Museum in 140 years (Beeton 2008b). An eighteenth snail was found in 2016 (Kohler et al. 2016).

Ecology

Little is known about the biology of this species, including its habitat requirements but this snail is believed to be arboreal (Beeton 2008b). Masters' Charopid Land Snail is a relatively uncommon snail and although there is insufficient quantitative data available to prove that the snail population has declined, it is probable that it has (Beeton 2008b). The size of the current population is unknown.

Threats

- The key threat to this snail is predation by introduced rats (Beeton 2008b; NSW Scientific Committee 2015b);
- The Song Thrush and Common Blackbird are known to prey on the Lord Howe Placostylus, so they may prey on this species as well (Beeton 2008b);
- Loss, destruction or disturbance of habitat caused by exotic ants, wildfire, the invasion of weeds or trampling by tourists and other people (Beeton 2008b).

Risk Posed by the Rodent-Baiting Proposal

As the ecology of this species is mostly unknown (Beeton 2008b), there is little data available to indicate that this snail is not at risk of either primary or secondary poisoning. Based solely on ecological data, Kohler *et al*. (2016)) place this species in the moderate risk category. However, if it is arboreal (Beeton 2008b) then baiting is unlikely to pose a threat to it as the greater majority of baits will be distributed onto the ground surface.

Mitigation of the Proposed Rodent Eradication

Testing this species for vulnerability to Brodifacoum or collecting a representative sample of the population for safe keeping is not feasible due to this snail's rarity. Only 18 Masters' Charopid Land Snails have been found since 1869 (Beeton 2008b; Kohler *et a*l. 2016). Only one of these 18 was alive when collected so, therefore, it is very unlikely any could be found to take into captivity. Rats are regarded as the major threat to this snail (Beeton 2008b) and are possibly driving this species towards extinction. The proposed eradication of rodents from LHI may place Masters' Charopid Land Snail at risk of poisoning, but this possibility must be weighed up against the high probability that predation by rats will result in the extinction of this snail.

Mount Lidgbird Charopid Snail *Pseudocharopa lidgbirdi*

Conservation status

Listed as *critically endangered* under the TSC Act.

This snail, endemic to LHI, is now thought to be confined to Mount Gower although its distribution, prior to 1945, also included Mount Lidgbird and Erskines Valley (Beeton 2008c).

Ecology

Little is known about the biology of this species, including its habitat requirements apart from its association with wet rock surfaces (Beeton 2008c).

From 1887 until 2002, 239 specimens have been collected for museums. However, the number of snails found has declined markedly since 1981, with only six specimens being recorded for the period 1981 to 2002. Because the effort to find snails has increased since 1925, the decline in finds has been interpreted as reflecting a severe drop in the snail's population (Beeton 2008c). Additionally, only one live specimen has been found since 1979 (Beeton 2008c; Kohler *et a*l. 2016). The decline in the snail's population is likely to be due to damage done to its environment by pigs and goats, and predation by the introduced rat (Beeton 2008c). The size of the current population is unknown.

Threats

- The key threat to this snail is predation by introduced rats (Beeton 2008c; NSW Scientific Committee 2015c);
- The Song Thrush and Common Blackbird are known to prey on the Lord Howe Placostylus, so they may prey on this species as well (Beeton 2008c);
- Loss, destruction or disturbance of habitat caused by exotic ants, wildfire, the invasion of weeds or trampling by tourists and other people (Beeton 2008c).

Risk Posed by the Rodent-Baiting Proposal

As the ecology of this species is mostly unknown (Beeton 2008c), there is little data available to indicate whether this snail is at risk of either primary or secondary poisoning.

Mitigation of the Proposed Rodent Eradication

Testing this species for vulnerability to Brodifacoum or collecting a representative sample of the population for safe keeping is not feasible due to this snail's rarity. Only seven Mount Lidgbird Charopid Snails have been found since 1981 (Beeton 2008c; Kohler *et a*l. 2016). Based on its ecological attributes, Kohler *et a*l. (2016) regard this species as at medium risk from the REP. It is very unlikely that a captive colony could be established. Rats pose a significant threat to this snail (Beeton 2008c) and, unless eradicated, they may drive this species towards extinction.

Whitelegge's Land Snail *Pseudocharopa whiteleggei*

Conservation status

Listed as *critically endangered* under the TSC Act.

Ecology

Little information on the natural history and biology of this species is known. It has been recorded living under and inside logs and in moss (Beeton 2008d). Once found on both of the southern mountains, it now appears to be limited to Mount Gower (Beeton 2008d).

Only 36 specimens have been lodged with the Australian Museum. This represents 0.15% of the Museum's total collection of LHI snails, and suggests that this species is uncommon. Furthermore, in spite of increased survey effort, only four specimens have been found since 1971 compared to 32 before 1920, indicating a significant decline in snail abundance (Beeton 2008d; Kohler *et a*l. 2016).

Threats

- The key threat to this snail is predation by introduced rats (Beeton 2008d; NSW Scientific Committee 2015d);
- The Song Thrush and Common Blackbird are known to prey on the Lord Howe Placostylus, so they may prey on this species as well (Beeton 2008d);
- Loss, destruction or disturbance of habitat caused by exotic ants, wildfire, the invasion of weeds or trampling by tourists and other people (Beeton 2008d).

Risk Posed by the Rodent-Baiting Proposal

As the ecology of this species is mostly unknown (Beeton 2008d), there is little data available to indicate whether this snail is at risk of either primary or secondary poisoning. Based on its ecological attributes, Kohler *et a*l. (2016) regard this species to be at medium risk from the REP.

Mitigation of the Proposed Rodent Eradication

Testing this species for vulnerability to Brodifacoum or collecting a representative sample of the population for safe keeping is not feasible. This species is so rare (just four specimens, only three of which were alive when found, have been collected since1971) that it is very unlikely animals could be found to safely take into captivity. Rats are regarded as a significant threat to this snail (Beeton 2008d). The eradication of rodents is the best course of action to ensure the protection of Whitelegge's Land Snail.

5.2.2 Terrestrial reptiles

REP activities with the potential to impact on TSC Act listed terrestrial reptiles include distribution of the bait through primary poisoning (direct consumption) and secondary poisoning (consumption of poisoned invertebrates).

There are two species of native terrestrial reptile on LHI, the LHI Skink *Oligosoma lichenigera* and the LHI Gecko *Christinus guentheri*. Both species occur on the offshore islets around LHI as well as on Norfolk Island, although each island group may have different sub-species. Although once widespread across the main island (DECC 2007), the skink now seems to be confined to sedge-grass habitat (Bray personal communication, Wheeler and Madani 2015), the dense structure of which may protect the skink from predators such as rodents. Predation by introduced rodents is regarded as the major threat to these species (DECC 2007).

Each species is considered to be at low risk of poisoning, and both are likely to substantially increase in abundance following the removal of rodents (Towns and Daugherty 1994, Hoare *et al.* 2006).

There is little published information on the interactions between reptiles and Brodifacoum worldwide (Hoare and Hare 2006). There has only been one reported incident of widespread death amongst reptiles following eradication operations that have used Brodifacoum baits (Merton 1987). In general, reptiles do not appear to be interested in cereal pellets (Merton 1987) but, after cereal-based pellets were dispersed onto Round Island, Mauritius, Telfair's Skinks *Leiolopisma telfairi* were seen eating rain-softened Talon pellets containing Brodifacoum at 20 parts per million (Merton 1987). A number of larger (80–100 g) skinks were later found dead (ibid). Ten skinks were autopsied but only one showed evidence of internal bleeding. The low proportion of deaths that could be attributable to haemorrhaging plus the observation that it was only larger skinks found dead, and for death to be associated with warm days, led Merton (1987) to conclude that Brodifacoum interfered with this reptile's ability to thermoregulate. Despite these deaths the number of reptiles, including Telfair's Skink, on Round Island has markedly increased since the baiting was undertaken (North *et al.* 1994).

Gunther's Gecko *Phelsuma guentheri,* although present during the same baiting programme as Telfair's Skink*,* showed a lack of interest in pellets (Merton 1987). Reluctance to eat bait was also shown by the skink *Oligosoma maccanni* (which is a close relative of the LHI Skink). When lizards in the laboratory were offered cereal-based pellets as their sole source of food, only a relatively small amount of bait was consumed (Freeman *et al.* 1996). However, two species of New Zealand geckos have been observed consuming Brodifacoum baits (Christmas 1995; Hoare and Hare 2006); therefore it is possible that the Lord Howe Gecko may eat Pestoff® 20R pellets. A number of skinks and geckos have been recorded eating Brodifacoum baits but without apparent harm. Wright's Skink (Mabuya wrightii) commonly took Brodifacoum baits from bait stations on Fregate Island but no mortality was observed (Thorsen *et al.* 1999). Fisher and Campbell (2012) noted that at least 25% of the population of Lava Lizards (Microlophus duncanensis) would sample bait on Pinzon Island but considered that there was no population level effect. Most (i.e., 60-80%) of bait stations at Tauwharanui showed regular visitation by Oligosoma smithii between February and April 2007 but no dead skinks were ever found, and out of 802 captures in pit traps, no live-trapped skinks showed signs of poisoning (Wedding 2010 Aerial application of Brodifacoum baits was undertaken on Palmyra Atoll and followed up with sampling 28 geckoes (Mourning Gecko Lepidodactylus lugubris and the Common House Gecko Hemidactylus frenatus) for Brodifacoum residues; it was found in 14 of them (Pitt *et al.* 2012).

The two LHI species are considered at risk of ingesting Brodifacoum if they feed on invertebrates that have themselves fed on Brodifacoum-laced baits. However the risk of secondary poisoning for these species is low because:

- Baiting will take place in winter when reptiles may be relatively inactive. Unpublished reports by Rebecca Bray (Monash University) to the LHIB indicate that both species of reptile are active in autumn, and that, for the skink, this level of activity is less than half that which occurs in summer; pitfall trapping in November/December 2010 and February 2011 caught 244 and 266 skinks respectively while the same trapping effort in April/May 2010 resulted in 117 captures. No comparable surveys were conducted in winter. However, in keeping with the precautionary principle, it is accepted that a number of reptiles will be active during the baiting period.

- the proportion of invertebrates that will have fed on Brodifacoum baits will be small so even if they are foraging at this time then most of the potential prey that they will encounter will not be poisoned (on Red Mercury Island for example, no Brodifacoum residue was found in 99% of the sample of invertebrates collected after the aerial application of Brodifacoum baits (Morgan *et al.* 1996);

Although there is potential for the two threatened reptiles to ingest Brodifacoum, the world-wide trend for reptiles on islands that have been baited with Brodifacoum to eradicate introduced mammals such as rodents, is to greatly increase in number (Towns 1991, 1994; North *et al.* 1994).

Two months after the application of Brodifacoum baits on Stanley Island, lizard pitfall capture rates were 29% higher than the previous best (Towns *et al.* 1993). The population of the Spotted Skink Oligosoma lineoocellatum on Nukuwaiata Island increased by 67% over the two years following aerial baiting with Brodifacoum (Brown 1997). There was no change in the abundance of the population of the gecko *Tarentola bischoffi* immediately after baiting with Pestoff 20 was undertaken on Selvagem Grande Island; but there was a significant population increase after three years (Olivera *et al.* 2010). The number of skinks on Korapuki Island in New Zealand increased 30 fold within 5 years of rats being removed (Towns 1994).

Another potential source of ingesting Brodifacoum for reptiles is through their consumption of invertebrates that have fed on baits (that is, through secondary poisoning). However, most invertebrates are unlikely to contain Brodifacoum; published values for the proportion of invertebrates containing Brodifacoum residue after baiting range from 1% (Morgan *et al.* 1996) through to 4% (aerial baiting) and 44% (baiting using bait stations) (Broome *et al.* 2016) on to 51% (Booth *et al.* 2001).

Because the available world-wide evidence indicates that skinks and geckos either do not eat baits, or if they do, with the exception of Telfair's Skink, they do so with impunity, then both species are not in danger of primary poisoning leading to haemorrhaging. The positive response of geckos and skinks after baiting referred to above also indicates that secondary poisoning is not a threat. This is evidenced on LHI, where the main population of the LHI skink occur at North Bay, which is currently extensively baited for rodents. If consuming Brodifacoum from any source risks compromising the ability of the two reptiles to thermoregulate as may have been the case with Telfair's Skink (Merton 1987) then such a possibility is mitigated by conducting the rodent eradication in winter.

The Lord Howe Island Gecko *Christinus guentheri*

Listed as *Vulnerable* under the TSC Act.

<u>Distribution and Ecology</u>

This gecko species is found only on the LHIG and on Norfolk Island. On the LHIG it is present on the main island, Balls Pyramid, Blackburn Island and Roach Island (DECC 2007). It may be present on other islets (ibid). The species was abundant on LHI until the mid-1930s when its numbers declined dramatically (ibid). The timing of the decline and the fact that it is still common on rat-free Blackburn and Roach islands suggest that predation by the rat was the cause for the population collapse.

A wide range of vegetation communities, ranging from lowland rainforest to montane rainforest as well as grasslands on the islets appear to be acceptable to the gecko provided there are abundant rocks to provide shelter for it.

It feeds on beetles, spiders, ants and other invertebrates amongst the leaf litter (DECC 2007).

<u>Threats</u>

- Predation by introduced rodents;
- Habitat disturbance due to weed invasion, clearing and trampling;
- Possible competition for food with the introduced skink *Lampropholis delicata*.

<u>Risk Posed by the Proposed Rodent Baiting</u>

There is little published information on the interactions between reptiles and Brodifacoum worldwide (Hoare and Hare 2006). Merton (1987) reported Telfair's Skink (*Leiolopisma telfairi*) as feeding on rain-softened pellet bait, and this apparently led to a number of deaths in this species. However, Gunther's Gecko *Phelsuma guentheri,* although present during the same baiting programme as Telfair's Skink*,* showed a lack of interest in pellets (Merton 1987). Reluctance to eat bait was also shown by the skink *Oligosoma maccanni* (which is a close relative of the LHI Skink). When lizards in the laboratory were offered cereal-based pellets as their sole source of food, only a relatively small amount of bait was consumed (Freeman *et al*.1996). However, two species of New Zealand geckos have been observed consuming Brodifacoum baits (Christmas 1995; Hoare and Hare 2006), therefore it is possible that the Lord Howe Gecko may eat Pestoff® 20R pellets.

Another potential source of ingesting Brodifacoum for reptiles is through their consumption of invertebrates that have fed on baits (that is, through secondary poisoning). That this secondary poisoning poses a significant risk to the Lord Howe Island Gecko is unlikely as the number of invertebrates that will have fed on Brodifacoum baits and retained the toxin before being consumed by the gecko is likely to be small (on Red Mercury Island for example, no Brodifacoum residue was found in 99% of the sample of invertebrates collected after the aerial application of Brodifacoum baits (Morgan *et al.* 1996)).

Although there is potential for this gecko to ingest Brodifacoum, the world-wide trend for reptiles on islands that have been baited with Brodifacoum to eradicate introduced mammals such as rodents, is to greatly increase in number (Towns 1991, 1994; North *et al*. 1994).

<u>Mitigation of the Proposed Rodent Eradication</u>

No mitigation is proposed as baiting is very unlikely to pose a significant threat to the Lord Howe Island Gecko.

The Lord Howe Island Skink *Oligosoma lichenigera*

Listed as *Vulnerable* under the TSC Act.

<u>Distribution and Ecology</u>

This skink is restricted to Norfolk Island and the LHIG (DECC 2007) although Cogger *et al*. (2006) suggest that the two island populations are genetically distinct, and should be placed into different taxa.

Rats prey upon this species and are probably the principal reason for its decline on the main island (DECC 2007). The introduced Delicate Skink *Lampropholis delicata,* which arrived in the early 1990's, has spread from the settlement to the Northern Hills and Intermediate Hill, and may compete for food with this species (DECC 2007). Possibly the effect of rodents on Delicate Skinks is less severe than it is on the LHI Skink because the Delicate Skink is much smaller, thereby better able to use small rock crevices and dense vegetation to evade rats.

On the LHIG the Lord Howe Island Skink is present on the main island, Balls Pyramid, Blackburn Island and Roach Island (DECC 2007). It may be present on other islets (ibid).

A wide range of vegetation communities, ranging from lowland rainforest to montane rainforest as well as grasslands on the islets appear to be acceptable to the skink provided there are abundant rocks to supply shelter for it (DECC 2007). However, on the main island, the skink now seems to be confined to sedge-grass habitat (Bray personal communication, Wheeler and Madani 2015), the dense structure of which may protect the skink from predators.

It feeds on beetles, spiders, ants and other invertebrates amongst the leaf litter (DECC 2007) and fruit (Bray personal communication).

<u>Threats</u>

- Predation by introduced rodents;

- Habitat disturbance due to weed invasion, clearing and trampling;
- Habitat loss due to storm surge (Wheeler and Madani 2015);
- Possible competition for food with the introduced skink *L. delicata*.

<u>Risk Posed by the Proposed Rodent Baiting</u>

In general, the risk of primary poisoning in reptiles is minimal as reptiles do not appear to be interested in cereal pellets (Merton 1987). However, after cereal-based pellets were dispersed onto Round Island, Mauritius, Telfair's Skinks were seen eating rain-softened Talon pellets containing Brodifacoum at 20 parts per million (Merton 1987). A relatively small number of larger (80–100 g) skinks were later found dead (ibid). Based on circumstantial evidence Merton (1987) concluded that Brodifacoum interfered with this reptile's ability to thermoregulate, and some of the larger individuals died from overheating. Despite these deaths the number of reptiles, including Telfair's Skink, on Round Island has markedly increased since the baiting (North *et al.* 1994). Therefore, it is possible that the Lord Howe Island Skink may eat Pestoff® 20R pellets, and this could lead to some deaths, but the overall effect on the species will not be detrimental. To the contrary, the removal of rodents will likely result in a substantial increase in reptile numbers (Towns 1991, 1994; North et al. 1994). It may be no co-incidence that the last remaining stronghold of the LHI Skink on the main island is the sedge-grass habitat of the beach dunes at North Bay in the immediate vicinity of bait stations set to protect the local population of the LH Placostylus (Wheeler and Madani 2015).

Merton postulated that the cause of death of Telfair's Skink was that Brodifacoum interfered with the inability of larger skinks, those over 80 grams, to thermoregulate, and so these larger skinks died from overheating. If so, then baiting LHI in winter should negate such a possibility especially as LHI skinks are relatively small, the heaviest caught in April 2015 was 9.7 g (Wheeler and Madani unpublished data).

Insectivores such as this skink risk ingesting Brodifacoum if they feed on invertebrates that have fed on Brodifacoum-laced baits. However the risk of secondary poisoning for this skink is low because:

- the proportion of invertebrates that may have fed on Brodifacoum baits will be small so even if skinks are foraging then most of the potential prey that they will encounter will not have been exposed to Brodifacoum (Morgan *et al.* 1996);
- the coagulation chemistry in reptilian blood is different to that found in mammals and birds, and as such, the risk posed to reptiles from baiting programmes using Brodifacoum is considered low (Merton 1987).

It is also unlikely that this species will feed on pellets considering that another *Oligosoma* species (*O. maccanni*) did not feed on poisoned cereal pellets (Freeman *et al*. 1996).

<u>Mitigation of the Proposed Rodent Eradication</u>

No mitigation is proposed as baiting is very unlikely to pose a significant threat to the Lord Howe Island Skink.

5.2.3 Birds

Potential impacts to TSC listed threatened birds from the proposed LHI REP include:

- Primary poisoning from consumption of bait pellets
- Secondary poisoning from consumption of poisoned rodents, fish or invertebrates
- Disturbance as a result of helicopter activities
- Collisions with the helicopter
- Impacts as a result of handling and captive management during the captive management program (LHIC and LHW only)

Emerald Dove *Chalcophaps indica*

<u>Conservation status</u>

-a regionally *significant* species

Although the species is common and relatively widespread, being found in India, China, south-east Asia, the Philippines, New Guinea, islands in the western Pacific including Norfolk and Lord Howe islands as well as northern and eastern Australia (Higgins and Davies 1996), the Lord Howe population may be significant. The local birds behave somewhat differently to other members of the species in that they are very tame. This may represent a trait typical of island species that have evolved in isolation, suggesting that the Emerald Dove has been established on LHI for some considerable time. However, Hindwood (1940) suggests that the dove may have been introduced about 150 years ago.

Their main habitat is the open lowland forest (Hutton 1991). Favoured food is fallen forest fruit fervently foraged from forest floors.

The breeding season occurs in spring and summer (Hutton 1991).

Risk Posed by the Rodent-Baiting Proposal

During 2007, a study using non-toxic pellet baits of various colours was conducted on LHI to examine bait uptake by birds (DECC 2007a). Emerald Doves consumed red baits and brown baits, but completely ignored green baits, which supports the view that colouring baits green deters many bird species from eating them. Therefore they are considered unlikely to be impacted by the REP.

Mitigation of the Proposed Rodent Eradication

Non-toxic bait trials indicated that the Emerald Dove will not consume bait if it is dyed green, which they will be for the eradication. No mitigation, other than the use of green baits, is proposed.

Grey Ternlet *Procelsterna cerulea*

Conservation status

Listed as *vulnerable* under the TSC Act.

The Grey Ternlet has a widespread distribution over the tropical and sub-tropical sections of the Pacific Ocean (Hutton 1991). Its only breeding sites in Australian waters are on Norfolk and Lord Howe islands (ibid). On the LHIG they nest along the cliff faces of North Head, the Admiralty Islands, Mutton Bird Island, Gower Island and Balls Pyramid. These ternlets are present on the LHIG all year round, and are estimated to number 100 to 1,000 pairs (Hutton 1991). Nesting takes place from late August, eggs are laid in September and October (McAllan *et al.* 2004) and chicks fledge in December/ January (Hutton 1991). Their food consists of small fish and crustaceans collected from the sea surface.

Threats

- Predation of eggs and young by rodents at nesting sites on LHI (rodents are absent from the other islands in the LHIG) (DECCW 2009);
- There is potential for loss of nest sites on the sea cliffs of the northern hills due to competition with introduced pigeons *Columba livia* (DECCW 2009).

Risk Posed by the Rodent-Baiting Proposal

Poisoning is not a significant risk to the species as it feeds on fish but individuals risk colliding with low-flying helicopters. Baiting will take place in winter and whilst it is possible that unseasonable wet or windy weather may delay the second baiting run until very early September, this is considered very unlikely. Birds may be disturbed from the nest sites by over-flying helicopters but, unless baiting takes place in September (the month when egg laying starts), this limited disturbance is unlikely to significantly affect breeding.

Mitigation of the Proposed Rodent Eradication

Aircraft altitude during the flying of transects will be set so as to cause minimal disturbance to roosting birds while still achieving baiting efficiency. If major disturbance eventuates then the transect altitude will be adjusted and set at a height which does not significantly unsettle roosting birds. Such an adjustment is also necessary to ensure the safety of the helicopter and its crew.

Kermadec Petrel

Conservation status

Listed as *vulnerable* under the TSC Act.

The Kermadec Petrel ranges over subtropical and tropical waters of the South Pacific. The only known breeding sites in Australian waters are Balls Pyramid (near Lord Howe Island) and Phillip Island (near Norfolk Island). This species breeds on Balls Pyramid from November to May (Hutton 1991), and may been seen flying around Mt. Gower during summer. The Kermadec Petrel (western) feeds on squid, fish, and crustaceans.

Threats

- Possible introduction of the Black Rat to offshore islands.
- Risk of local extinction due to small population size.

Risk Posed by the Rodent-Baiting Proposal

This species is unlikely to be present during the baiting operation and thus is unlikely to be exposed to bait.

Mitigation of the Proposed Rodent Eradication

No mitigation is required.

Little Shearwater *Puffinus assimilis*

Conservation status

Listed as *vulnerable* under the TSC Act.

In the Southern Hemisphere the distribution of the Little Shearwater is from the mid South Pacific Ocean, around the southern coastline of Australia, across the Indian and Southern Atlantic oceans and past the west coast of the tip of South America. In the Northern Hemisphere it is found in the Atlantic Ocean to the west of North Africa and south-western Europe (Hutton 1991). The breeding colony on the LHIG (estimated to contain between 1,000 and 10,000 pairs – Hutton 1991) is one of the larger breeding colonies in the Australasian region (Hutton 1991). The main breeding site on the LHIG is Roach Island. There are smaller breeding groups on Blackburn Island, Mutton Bird Island and Mutton Bird Point (ibid).

This shearwater is present on the LHIG from February to October. Nests are in burrows. Most eggs are laid in July with the bulk of hatchings occurring in late August (Hutton 1991). The birds feed at sea, returning after sunset to change-over egg-sitting duties or to feed young. They depart before sunrise.

Threats

- Predation by rodents at the nesting grounds (DECCW 2009);
- Encroachment of the nesting grounds by weeds (DECCW 2009).

Risk Posed by the Rodent-Baiting Proposal

Because the birds feed at sea, the population is not at risk of primary or secondary poisoning. Adults sitting on eggs in burrows are unlikely to be overly disturbed by over-flying aircraft. Adults moving to and from the nesting-sites to feed do so at night so it is very unlikely that any will be hit by the baiting aircraft.

Mitigation of the Proposed Rodent Eradication

No mitigation is required.

Lord Howe Island Currawong *Strepera graculina crissalis*

Conservation status

Listed as *vulnerable* under the TSC Act.

This bird is a sub-species of the mainland Pied Currawong, and is endemic to the LHI Group. The entire population of the Lord Howe Island Currawong is restricted to LHI and the nearby islets (Mayre and Greenway 1962; Schodde and Mason 1999). The current population is 215 ± 11 birds (DECC 2007) and appears to be stable as there is no empirical evidence of an historical decline (DEWHA 2009).

The Lord Howe Island Currawong is widespread on LHI, occurring in lowland, hill and mountain regions. It mainly inhabits tall rainforests and palm forests, especially those beside creeks or in gullies, but it also occurs around human habitation, and forages amongst colonies of seabirds on offshore islets (DEWHA 2009). Its breeding sites are located in gullies, close to water, in undisturbed forests on the slopes of hills and mountains (Garnett and Crowley 2000; Hindwood 1940; Hutton 1991; McFarland 1994). Highest densities of nests are on the slopes of Mt Gower and in Erskine Valley (Garnett and Crowley 2000).

The currawong occurs singly, in pairs and family groups and, in the non-breeding season, in small flocks of up to 15 birds (DEWHA 2009). It has been recorded breeding from October to December although breeding may commence in September (McAllan *et al.* 2004). During the breeding season it occurs in strongly defended territories that are probably occupied by a breeding pair and its offspring (Knight 1987). In autumn and winter it forms flocks and can be found in the settlement areas (DEWHA 2009).

No information is available on the ages of sexual maturity or life expectancy, but it is probably capable of surviving to more than 20 years of age (Higgins *et al.* 2006). Breeding success appears to be relatively low; the only available, though limited, data suggests that less than 42% of nests produce fledglings (DEWHA 2009).

The Lord Howe Island Currawong in omnivorous; it eats fruits and seeds, snails, insects, rodents and the chicks of other bird species (Garnett and Crowley 2000; Hull 1910; Hutton 1991; McFarland 1994).

Threats

- The small size of the population makes it highly vulnerable to threatening processes.

- Two potential threats have been formally identified: namely the introduction of an exotic predator, and persecution by humans attempting to protect other bird species and/or domestic fowls (Garnett and Crowley 2000; Hutton 1991).

Mitigation of the Proposed Rodent Eradication
The proposed rodent eradication poses a significant threat to Lord Howe Pied Currawong (LHPC). LHPC were not found to consume non-toxic baits during a trial conducted in 2007 (Appendix D – LHI Trials Package), thus they are highly unlikely to eat the baits deployed in the REP but there is a risk that some individuals will succumb to secondary Brodifacoum poisoning by eating poisoned rodents even though most poisoned rodents will die underground. Fenn *at el (*1987) found that during the rat poisoning on English farms that the "majority" of rats died underground, while Harrison *et al.* (1988) estimated that only 4% of rats died above ground during baiting programs. Although approximately 90% of those rodents poisoned are likely to die in dens underground or amongst dense vegetative cover (Taylor 1993, Howald 1999, Buckelew 2007), it is possible that a number of free-ranging LHPC will consume baited rodents during the eradication, thereby placing some of the current population at risk. To mitigate this impact, as many individuals of the population as possible (approximately 50-60%) from across the island (to maintain genetic diversity) will be captured immediately prior to the baiting, and will remain in captivity until baits and rodent carcasses have disintegrated, which is expected to take 100 days after final baiting. After this time the risk of secondary poisoning for currawongs is likely to be negligible (as by then poisoned rodents will no longer be a potential food source). Once breakdown of bait and carcasses has been confirmed, captured birds will be released regardless of whether the eradication was a success or not.

A mortality rate for free-ranging Currawongs cannot be predicted with any certainty but it is expected to be low and thus not have a significant impact on the population. Studies of the diet of LHC have shown that rodents make up only a small proportion of the food taken by LHPC: of 441 identified items of food provided to nestlings only 11 (2.5%) of those items were rodents (Carlile and Priddel 2006). Moreover, 50% of breeding pairs (2 of 4 nests that were closely observed) provided no rodents to their chicks. Further evidence that it is unlikely that a large number of LHPC will succumb to secondary poisoning is provided by the LHIB's practice of collecting dead or moribund birds that are suspected to be suffering from Brodifacoum poisoning as a result of eating rodents that have been poisoned from baits used in the current control programme. Subsequent testing of those birds for Brodifacoum residues have shown that since 2009, no LHPC have been observed or collected with suspected Brodifacoum poisoning, This is in contrast to the 14 individuals of other species processed, 11 (two Masked owls, eight LHW, and one Buff-banded rail) of which tested positive for Brodifacoum residues. Therefore, while 40-50% of LHPC will not be taken into captivity it is unlikely that a significant proportion of these birds will die from eating poisoned rodents.

The stability displayed in the present population size and the presence of non-breeding LHPC during the breeding season (a result of a lack of availability of unoccupied breeding territories), suggests that LHI is currently at carrying capacity for LHPC. If so, the potential death of a proportion of the free-ranging LHPC population from poisoning due to the proposed REP does not, in itself, threaten the long-term viability of the population. It is expected that losses due to poisoning will be compensated by increased breeding success of the survivors, including those released from captivity. The removal of rodents may also lead to an increase in the carrying capacity of LHI and/or a rise in breeding success as there will be substantially more food available for LHPC (e.g., forest fruits, seeds, invertebrates, reptiles and small birds).

In the unlikely event a large number of free-ranging individuals die from secondary poisoning, the genetic diversity in the LHPC population could be reduced. No genetic studies of LHPC have been undertaken, so current levels of genetic diversity or whether any genetic population structure exists, are not known. However, the remoteness of LHI from the mainland source populations suggest that the LHPC population is likely to have been founded by a small number of individuals and thus may already have low levels of genetic diversity (e. g. Bollmer *et al*. 2011). Thus it is difficult to predict the genetic consequences of losing some of the free-ranging individuals from the population. Nonetheless, to mitigate the potential impact of a loss in genetic variation a relatively large number of individuals will be taken into captivity (100 to 120 individuals or 50-60% of the population) and LHPC will be caught from across their island range. This strategy should ensure that a large proportion (>95%) of the current genetic variation is included in the captive population (Weeks *et al.* 2011). An integral component of the captive management of LHPC is the capture of free-ranging LHPC. Carlile and Priddel (2007) noted that LHPC can be caught in reasonable numbers in the period from June to October but are more difficult to catch outside this period. To ensure that LHPC can be caught outside of this optimal period, a number of feeding stations will be established across the island in winter-spring 2016. In 2013 a trial captive management and release of LHPC and LHW was managed by Taronga Zoo staff (Taronga Conservation Society Australia, 2014) with the assistance of OEH Science Manager. The LHPC for the trial were sourced from a single location where a local resident had been regularly feeding the birds. At this single location, not only were the 10 pairs caught and removed for three months of the trial, but a subsequent 55 individuals were caught at the site prior to their release. The feeding station provided an ideal location for capture and monitoring of individuals within a section of the island. The 2007 report by Carlile and Priddel had relied on broad-scale locations for trapping where a maximum of 10 birds could be caught at a single site over an eight–day period. Using the feed station in 2013, 50 birds were caught in a seven–day period (Australian Bird and Bat Banding Scheme data). The feeding table attracts good numbers of visiting birds outside the 'optimum period' determined by Carlile and Priddel (2007) and presents a far superior opportunity for capture of LHPC than previously available. The established stations will provide a reliable source of food for LHPC and will become focal points for captures. Already established stations indicate that LHPC readily use the stations and it is expected that this strategy will enable the necessary number of LHPC to be caught during the time available prior to commencement of rodent baiting.

Holding LHPC in captivity from approximately June until October may disrupt the birds' breeding season for one year. However, it is unlikely that all birds left in the wild will be poisoned by the operation and thus disruption would not impact the entire population, and given that currawongs can live for more than 20 years (David Drayman ABBBS pers com) such disruption is not expected to result in a significant long-term impact to the population.

The captive facility will be located on LHI and will be managed by a highly experienced team of aviculturists most likely from Taronga Zoo. The LHIB is unaware of any previous attempts to hold or breed LHI currawong away from LHI. To ensure all husbandry protocols are correct, a trial involving 10 LHPC was conducted in 2013 (Taronga Conservation Society Australia, 2014) with all birds successfully released. One critical lesson learnt from this trial was how currawongs reacted to being confined with or near other currawongs during the breeding season. Further detail on the proposed captive management is provided in Section 2.2.1.2. The trial report is included in Appendix C – Captive Management Package**.** Surveys will be performed post-eradication to monitor the outcomes of the mitigation strategy (for details see Section 7.5.1).

In summary, in the absence of mitigation, a significant impact to LHPC is likely to occur from the LHI REP. With the proposed mitigation in place, it is considered possible that the REP will still have a significant impact on LHPC through the temporary disruption of a breeding cycle, although it is unlikely that a long-term population decrease will occur. Any potential impacts will be temporary. This temporary potential impact, will be substantially offset by the improvement in biodiversity if impacts of rodents are removed as a result of the REP. No other offsets are proposed.

In the event that rodents are detected after the eradication attempt and contingency measures are considered, potential impacts to the captive managed population will be reassessed.

Lord Howe Island Golden Whistler *Pachycephala pectoralis contempta*

Conservation status

Listed as *vulnerable* in the TSC Act.

This sub-species, endemic to LHI, is widely distributed in the forests of the main island, ranging from sea level to mountain tops. It is often seen feeding, typically on spiders, insects and their larvae, around homes in the settlement area.

Breeding season: from September to January.

Population size: 100 – 1,000 pairs (Fullagar *et al.* 1974).

Threats:

- Predation by rodents
- Clearing of lowland forests;
- Possible competition for food resources from the introduced Common Blackbird and Song Thrush;
- Risk of extinction due to small population size and restricted distribution; and
- Invasion of habitat by introduced plants.

Risk Posed by the Rodent-Baiting Proposal

The diet of the whistler is comprised of invertebrates. It will not eat pellets so it is not at risk of primary poisoning. It may be exposed to Brodifacoum by eating insects that have fed on pellets but few, if any, whistlers will receive a lethal dose this way. There have been no reports of whistler deaths in the settlement area where this bird is quite common, and where far-more potent Brodifacoum baits than those proposed for the eradication, are presently widely used.

Mitigation of the Proposed Rodent Eradication

No mitigation is proposed; advice from Taronga Zoo suggests that catching and holding LHI Golden Whistlers in captivity, as an insurance population, will likely result in the death of those birds.

The eradication of rodents from the LHIG is expected to benefit the whistler by the elimination of a probable predator and the increase in food resources.

Lord Howe Island Silvereye *Zosterops lateralis tephropleura*

Conservation status

This sub-species, endemic to LHI, is listed as *vulnerable* under the TSC Act.

It is widely distributed on the main island, occurring in all habitats except open fields. Its diet consists of insects, fruit and nectar.

Breeding season: from spring to summer.

Population size: 100 – 1,000 pairs (Fullagar *et al.* 1974).

Threats

- Predation by introduced rodents;
- Predation by the Lord Howe Island Currawong, Australian Kestrel and Sacred Kingfisher; and
- Risk of extinction due to small population size and restricted distribution.

Risk Posed by the Rodent-Baiting Proposal

The silvereye is considered to be at low risk given that it eats mainly fruit, seeds and insects. Local studies found no evidence that this sub-species consumed baits although Eason and Spur (1995) suggest that the New Zealand silvereye would probably eat cereal-based baits if encountered. Results from rodent eradications in New Zealand suggests that a few silvereyes may succumb to the effects of Brodifacoum, but at the population level the species was not harmed by the rodent baiting. Any losses on LHI are likely to be small and short-term, as they were in New Zealand. Any initial decline will be followed by a marked increase in populations due to the removal of rodents and subsequent increase in invertebrate and fruit food resources.

Mitigation of the Proposed Rodent Eradication

No mitigation is proposed; advice from Taronga Zoo suggests that catching and holding LHI Silvereyes in captivity, as an insurance population, will likely result in the death of those birds.

Lord Howe Woodhen *Hypotaenidia sylvestris*

Conservation status

Listed on Schedule 1 of the TSC Act as an *endangered* species.

The Lord Howe Woodhen is a flightless bird endemic to LHI (NSW NPWS 2002). The population estimate for 2012 is at least 250 individuals (LHIB unpublished data). The population of woodhen has remained relatively static over much of LHI (DECC 2007) with the exception of those birds in the settlement where numbers have more than tripled (47 in 2002 (NSW NPWS 2002) to 153 in 2012 (LHIB unpublished data)), possibly in response to the provision of supplementary feed and water to settlement birds by the islanders.

Woodhens usually lay eggs from August until January or February and continue raising young until April (NSW NPWS 2002). However, the start and finish dates of breeding can vary between years and there are breeding records for much of the year (Miller and Mullette 1985). Pairs have multiple broods during the breeding season (Gillespie 1993). Juveniles can breed at nine months of age (Marchant and Higgins 1993) but juveniles that do not establish a territory by the breeding season immediately following their own hatching generally do not survive to reach adulthood (Harden and Robertshaw 1988, 1989). About 60% of juveniles die in their first year (Harden and Robertshaw 1989) possibly due to limited high-quality habitat (NSW NPWS 2002). Breeding success is greater in the settlement area than in the southern mountains (Marchant and Higgins 1993, Harden and Robertshaw 1988).

Habitat

The woodhen occurs predominately in three vegetation types:
1) Gnarled Mossy-Forest, which covers 2% of the island;
2) Megaphyllous Broad Sclerophyll Forest (mainly palms), which covers 19% of the island; and
3) Gardens around houses. About 40 % of the population lives in the settlement area of the island (NSW NPWS 2002).

Diet

Over 80% of the woodhen's diet is comprised of earthworms (Miller and Mullette 1985). The bulk of the remaining 20% is made up of grubs, typically found in rotting logs. Snails, arthropods, seabird chicks, rodents, plant shoots, lichen and fungi are also eaten (NSW NPWS 2002). Woodhen were observed eating non-toxic pellet baits during a trial conducted on LHI to gauge what species were likely to eat the Pestoff® 20R baits proposed for use in the rodent eradication. Blue-coloured faeces have also been seen when handling some birds, indicating they had been consuming dyed wax bait blocks containing rodenticide (Harden 2001). These blocks are widely dispersed around the settlement by residents. Evidence of Brodifacoum poisoning has been detected during post-mortems conducted on woodhens found dead along roadsides in the settlement.

Threats (NSW NPWS 2002)

- Loss of preferred habitat through clearing for agriculture or development, or the encroachment of weed species;
- Vulnerable to disease and natural disaster due to its limited distribution;
- Increased rat control may lead to increased owl predation on woodhen;
- Competition for food in the settlement area from Common Blackbirds, Song Thrushes, Buff-banded Rails and Purple Swamphens;
- Consumption of rat bait used in the on-going rodent control; and
- Domestic dogs.

Risk Posed by the Rodent-Baiting Proposal

This species is at risk of both primary and secondary poisoning. Woodhen have been recorded eating non-toxic bait pellets. They are also known to eat rodents that have been poisoned during the ground baiting that currently takes place around the Settlement.

Mitigation of the Proposed Rodent Eradication

This species is at risk of both primary and secondary poisoning. Woodhen have been recorded eating non-toxic Pestoff bait pellets (DECC, 2007a). They are also known to eat rodents that have been poisoned during the ground baiting that currently takes place around the Settlement and will also consume poisoned birds.

The protection of this species requires that it be taken into captivity during the eradication. Approximately 80 - 85% of the population will be captured prior to the baiting and will remain in captivity for the duration of the operation; that is, until the baits (and rodent carcasses) have disintegrated and pose no further risk approximately 100 days (Craddock, 2004). After this time the risk of secondary poisoning for woodhens is likely to be negligible (as by then poisoned rodents will no longer be a potential food source). Once breakdown of bait and carcasses has been confirmed, captured birds will be released regardless of whether the eradication was a success or not.

It is expected that individuals that are not captured may succumb to primary or secondary poisoning, however a mortality rate cannot be accurately predicted. Studies of similar species in New Zealand (Weka and Kiwi) have found a wide range in mortality rates to the species from similar eradications. Weka mortality rates as high as 80-90% was observed during a rodent eradiation on Ulva Island (Eason et al. 2002) whilst on Taukihepa Island a deliberate attempt to eradicate introduced weka following a rodent eradication was abandoned due to a higher than expected survival of weka post poisoning (P. McClelland pers comm.). Little Spotted kiwi were monitored through the Kapiti Island rat eradication using 50 banded birds, 10 of which also had radio-transmitters (Robertson and Colbourne 2001). Two of the 10 birds with radio-transmitters died (a mortality rate of 20%) within a month of the poison drops. Six months after the eradication, 46 of the banded birds were still alive. Robertson and Colbourne (2001) estimated that in the worst-case, poison induced mortality was 8%. Two brown kiwi were found dead following aerially applied Pestoff 20R on Motuarohia Island as part of Project Island Song in 2009. One was confirmed to have Brodifacoum residues and the other was too decomposed to test. Anecdotal reports of kiwi calls after the operation did not indicate a change in population (Vestena and Walker 2010). At Rarewarewa and Riponui, Northland, none of 55 radio collared brown kiwi died from Brodifacoum poisoning after eradication (Robertson et al. 1999).

The captive population will include both adults and juveniles, and will be collected from across LHI to ensure that the deepest practical gene pool is maintained. It should be noted however that the gene pool experienced a severe bottle neck with the reduction in numbers prior to the captive breeding program in the 1980s. Birds originating from the remotest parts of LHI (e.g., the summit of Mt Gower) will be transported to, and back from, the holding facility by helicopter to minimise transport time and its associated stress on the birds. The captive facility will be located on LHI and will be managed by a highly experienced team of aviculturists most likely from Taronga Zoo. Woodhen have previously been successfully held in captivity (Gillespie, 1993) so information is already at-hand for captive management. A trial involving 22 birds was conducted in 2013 to ensure all husbandry protocols are correct (Taronga Conservation Society Australia, 2014). No aggression was noted during the 2013 trial with many birds per aviary. The trial report is included in Appendix E – Captive Management Package. As part of the recovery program and captive breeding program on LHI in the late 1980s, there is anecdotal evidence that two woodhens (a male and a female) were removed to Taronga Zoo on the mainland in 1989. The birds were observed mating but were not bred. The female died in 1990 after 11 months in captivity, with post mortem revealing that she died as a result of being egg bound. The male died in 1994 after more than 4 years in captivity. Results of the post mortem examination indicated that the male died of trauma. There was no indication of what had caused the trauma (Fry, G, pers comms, 2013). A captive colony could be established on the Australian mainland, subject to finding a zoo that is interested. Discussions with Taronga Zoo have indicated that they do not have available space or interest in establishing a LHW population. Discussions are continuing with other zoos. These actions, namely the establishment of on-site and off-island captive facilities, are in accordance with recommendations made in the “Recovery Plan for the Lord Howe Woodhen Gallirallus sylvestris” (NPWS 2002) which calls for the development of a plan for the establishment of an on-island captive-breeding facility in the event of a substantial reduction in woodhen numbers; and the establishment of captive populations at sites other than LHI as insurance against a catastrophe affecting the wild population. Further detail on the proposed captive management is provided in Section 2.2.1.2.

Woodhens are to be held in captivity during most of the duration of one breeding season. Although the release of the birds is dependent on how long it takes the baits and carcasses to breakdown, it is likely that the woodhen will be released by December, a hundred or so days after the second aerial bait-drop. If so, then the birds will have up to two months of the current breeding season to lay eggs (Gillespie 1993). Body conditioning through diet manipulation, such as the provision of woodgrubs in the weeks leading up to release, may also be able to improve reproduction immediately post release (Gillespie, 1993). Woodhens have also been bred very successfully in captivity on LHI (in pair cages) and may therefore breed in captivity. The full or partial loss of one breeding season is unlikely to have a significant effect on the population particularly given the lifespan can be in excess of 15 years. Similarly, the death of many of those woodhen that are not taken into captivity is also unlikely to result in long-term harm to the overall population. Presently, about 60% of juveniles die in their first year (Harden and Robertshaw 1989) and this is more than likely a result of a lack of high-quality habitat (NPWS 2002) for them to occupy. The death of the adult birds that are not taken into captivity will provide vacant territories for many, otherwise doomed, juveniles that fledge in the years immediately following the rodent eradication.

Previous post-release monitoring of captive LHW shows that the captive breeding programme is likely to be successful. An integral component of the conservation recovery programme for the LHW was an in situ captive breeding program established in 1980 (Miller and Mullette 1985). Between 1981 and 1985, 82 captive-reared LHW were released, along with the wild LHW taken into captivity, across six sites in the lowlands and slopes of the southern mountains (Miller and Mullette 1985). Depending on the release site, between 0% and 75% of released LHW were subsequently re-sighted (Harden et al. unpubl. data). The site where no released LHW were resighted was Little Slope, which was difficult to access and therefore poorly monitored. However, the number of LHW on Little Slope, where no wild LHW occurred, almost doubled within six years of the release of captive-bred birds (Miller and Mullette 1985; Harden 1999).This indicates survival and/or breeding success of released captive-bred LHW at Little Slope was high. Of the 20 LHW held in captivity in 2013 as part of a trial to establish captive husbandry protocols for the LHI REP (Taronga Zoo Conservation Society 2014), 25% were observed post-release in 2014 and/or 2015.

In the absence of mitigation, a significant impact to woodhens is likely to occur from the LHI REP. However with the mitigation proposed in place, it is considered unlikely that either long term population decrease or major disruption to a breeding cycle will occur. Impacts are likely to be temporary. It is therefore considered unlikely that the REP will have a significant impact on woodhens. In the event that rodents are detected after the eradication attempt and contingency measures are considered, potential impacts to the captive managed population will be reassessed.

The eradication of rodents is likely to result in an increase in terrestrial invertebrates which will likely lead to population increases for woodhen. The density of LHI Wood-feeding Cockroach on Blackburn Island (Carlile and Priddel 2013) suggests that following reintroduction of this species to the main island will present a significant increase in food availability for woodhen.

Masked Booby *Sula dactylatra tasmani*

<u>Conservation status</u>

Listed as *vulnerable* in the TSC Act.

This sub-species breeds on Lord Howe and Norfolk islands as well as on the Kermadec Islands, the latter group being administered by New Zealand (DEHWA 2009). One set of estimated population sizes for this sub-species is, for LHIG 600-900 pairs, for Norfolk Island 300 pairs, and for the Kermadec Islands <100 pairs (ibid). However, Garnett and Crowley (2000) suggest the LHI population to be only 500 individuals while Priddel (1996) estimates that there are between 200 and 300 birds nesting on LHI. Regardless which estimate is correct, the LHI birds constitute a significant proportion of the breeding population of the sub-species. In the LHIG the breeding colonies are on Balls Pyramid, Mutton Bird Island, the Admiralty Islands, and LHI (at King and Mutton Bird points) (DECC 2007). All breeding occurs in the Permanent Park Preserve. The LHIG is the most southerly breeding location of this species (all sub-species considered) in the world (McAllan *et al.* 2004).

On the LHIG the booby is resident year round. It breeds from May/June to February, with the peak of the laying season being in December (DEWHA 2009). Nests are built on the surface in high open areas.

<u>Threats</u>

- Predation of eggs and young by rodents (DECCW 2009);
- Long-line fishing (DEHWA 2009);
- Possible loss of eggs and small chicks to Buff-banded Rails (DEWHA 2009).

<u>Risk Posed by the Rodent-Baiting Proposal</u>

The birds feed at sea, so, therefore, adults are not threatened by poisoning from the rodent eradication. However, these birds nest above ground so the breeding colony will be subject to disturbance from the baiting aircraft. Disturbance at the colony may lead to egg damage and chick mortality. Also adults flying between the colonies and feeding areas are at the slight risk of helicopter-strike. The impact of helicopters (Bell 206) on Blue-footed (*S. nebouxii*) and Brown (*S. leucogaster*) booby on Isabel Island in Mexico was quantified by Samaniego–Hererra *et al.* (2010). Helicopters most commonly flew within 30-100m of nesting boobies, but sometimes as close as 10m. Nest occupancy and breeding success in the sub-colony where bait was distributed using a helicopter did not differ from two sub-colonies baited by hand. Importantly, no nest abandonment was recorded for either species and no boobies were harmed during eradication operations. Further, the most common behavioural responses to helicopter disturbance was 'no reaction' (58%) and 'became alert' (39%). 'Startle' responses (4%) and 'escape' (2%) responses were rarely observed. Most of the time (92%) when birds reacted, they resumed normal behaviour within 10 seconds. Boobies remained alert but did not exhibit signs of stress (e.g. regurgitating, nest abandonment) even during the highest level of disturbance from a helicopter (measured by sound produced, 94 decibel, helicopter height, 10m, and terrain comprised of no vegetation cover). The use of a helicopter (Bell 47) to survey nests of the critically endangered Abbott's booby (*Papasula abbotti*) on Christmas Island found that the typical response of birds sitting in their nests was to look at the helicopter but remain sitting or not respond at all (Commonwealth of Australia 2001). The trial survey recommended using helicopters in future surveys because disturbance was assessed to be negligible or non-existent. Similarly, only minor and transitory impacts from helicopter disturbance were observed in colonies of King Penguins on Macquarie Island (Springer and Carmichael 2012). Collisions with helicopters during baiting operations have been reported for Red-footed Boobies (*S. sula*): four individuals out of ~100 present at the time of baiting operations on Palmyra Atoll (Pitt *et al.* 2015; W. Pitt pers. comm.) and one individual on Enderbury Island in the Phoenix Islands (Pierce and Brown 2011). However, it is noteworthy this species, unlike the considerably larger Masked Booby, perches in trees which may place them at greater risk of taking flight and colliding with a helicopter. The risk of collisions with a helicopter for Masked booby on the LHIG is assessed to be very low because Masked booby rarely fly >10m above the height of the colony, rest and build nests exclusively on the ground, and typically depart from the colony by losing altitude from a standing position at the edge of the islet or promontory (N. Carlile and D. Portelli pers. obs., see Machovsky-Capuska *et al.* 2016).

Mitigation of the Proposed Rodent Eradication

Mitigation measures will be in place to minimise disturbance and the risk of collision. Specifically, helicopter flight times over Masked booby colonies will be restricted to periods when birds are less likely to be leaving or arriving at the colony (movements are greatest shortly after dawn and in the late afternoon), helicopters will be restricted to flying at a height of >30 above colonies and only during light wind (<15 knots), and operational speed will not exceed 50 knots in the vicinity of colonies. In light of the above, the likelihood of a significant impact from helicopter disturbance to Masked booby on the LHIG is assessed to be low.

This species maintain a cleared area with a radius of 0.75-1m from the centre of its nest (Marchant and Higgins 1990). The aerial bait delivery system will disperse baits at a density of approximately two bait pellets per square metre; thus 1-2 baits will be expected to fall within reach of nesting Masked Boobies. However, as this species feeds exclusively on prey captured at sea (Marchant and Higgins 1999), it is expected that birds will either ignore bait pellets or remove them to outside the cleared area around their nest. Most chicks are expected to hatch after the baiting operation (hatching occurs from July to December; Hutton 1991) and are fed exclusively by regurgitation from adult birds; thus they too are not expected to ingest any bait pellets on the ground around nests. Due to the remoteness and rugged terrain of the location of almost all breeding colonies (>80% of the Masked booby breeding population; it is not feasible to have human observers present within colonies during aerial baiting operations (to monitor disturbance or collect baits from the vicinity of nests). Furthermore, disturbance was slightly higher in sub-colonies of Blue-footed and Brown boobies baited by hand than in the sub-colony baited using a helicopter on Isabel Island (A. Samaniego-Herrera pers. comm.). The prolonged presence of a human observer in close vicinity of Masked booby nests—to monitor disturbance during the baiting operation or to remove bait pellets as they fall—poses a risk of nest desertion and the death of newly hatched chicks left unattended (see Burger and Gochfeld 1993). In light of the above, removal of bait pellets from the vicinity of Masked booby nests is considered unnecessary. This assessment is supported by the observation that no Blue-footed, Brown, Red-footed or Masked booby were harmed during baiting operations on five islands in the Gulf of California and Caribbean, where bait pellets were not removed from within colonies (Samaniego-Herrera *et al.* 2009, 2010, in press; A. Samaniego-Herrera pers. comm.).

A significant impact of the proposed rodent eradication programme is assessed to be highly unlikely this species. In contrast, it is expected that the REP will have long-term positive impacts on the species for example, the number of Masked Boobies breeding on Tromelin Island increased by 22-23% each year following the eradication of *Rattus norvegicus* (Corre *et al.* 2015).

Masked Owl *Tyto novaehollandiae*

Conservation status

Listed as *vulnerable* in the TSC Act.

Masked Owls were introduced to LHI in the 1920s in an attempt to control the rats. It is estimated that there are between 10 and 100 pairs present on LHI (DECC 2007). Although the species is classified as *vulnerable* under the TSC Act, on LHI these owls are regarded as exotic and seen as pests, and as such, killed under licence issued by the Office of Environment and Heritage. Masked Owls have been recorded eating a number of bird species on LHI including woodhen, terns and two of the petrel species but they are unlikely to be a significant threat to any of these species at present. The population of the woodhen, for example, has remained constant for ten years (DECC 2007), while that of the White Tern *Gygis alba*, a recent colonist, is increasing. However, this situation may change if rats, the owls' staple diet (DECCW 2009), are eliminated from LHI.

Risk Posed by the Rodent-Baiting Proposal

A large proportion of the local owl population is likely to succumb to secondary poisoning as a result of the proposed rodent eradication. Those that remain are likely to substitute native birds in place of rats in their diet and hence eradication of remaining birds will be pursued as part of the REP (see section 2.2.1.5).

Mitigation of the Proposed Rodent Eradication

No mitigation is proposed. To the contrary, the survivors will be targeted for eradication to eliminate this species from LHI.

Providence Petrel *Pterodroma solandri*

Conservation status

Listed as *vulnerable* in the TSC Act.

Although widely distributed in the western Pacific Ocean, there are only two known breeding locations for this species (Hutton 1991). The main site is LHI, specifically Mt Gower and Mt Lidgbird, where between 10,000 and 100,000 birds can be found during the breeding season spanning March to November (ibid), although numbers of Providence Petrels can be found on LHI year-round (McAllan *et al.* 2004). The other, much smaller, breeding site is Philip Island, near Norfolk Island. Both sites are conservation reserves, the former under the jurisdiction of the NSW Government, the later administered by the Commonwealth Government.

Providence Petrels construct nests in burrows.

Threats

- Heavy downpours of rain which can lead to the flooding of burrows (Bester *et al*. 2007);
- Predation of eggs and young by rodents and woodhens (Bester *et al*. 2007);
- Disturbance of birds and habitat by people (DECCW 2009).

Risk Posed by the Rodent-Baiting Proposal

In August, Providence Petrels will be tending young in the nest. Breeding birds will be in the area from late afternoon onwards to display in the airspace above the breeding sites, find mates and visit burrows (Hutton 1991). Non-breeders will also be present in the area during the day until mid-August (ibid).Therefore, there is the possibility that those petrels flying above the breeding grounds could collide with low-flying helicopters dropping bait.

It is extremely unlikely that their diet of squid and fish caught offshore of LHI will lead to secondary poisoning of petrels.

Helicopters flying over the nesting grounds are very unlikely to disturb young petrels as they are in burrows.

Mitigation of the Proposed Rodent Eradication

Helicopter strike with those birds involved in courtship and incubation will be avoided by restricting helicopter flights around the southern mountains to midday on each day of baiting. The majority of returns from foraging to provision chicks occur after early July (Marchant and Higgins 1990) avoiding any overlap with proposed helicopter movements.

The species will have limited contact with bait pellets while nesting as it nests either underground or within deep cavities on the ground; further, as stated above, this species is highly unlikely to consume any bait pellets as adults feed exclusively at sea and chicks are fed exclusively by regurgitation from adults.

A significant impact of the proposed rodent eradication programme is assessed to be highly unlikely this species. In contrast, it is expected that the REP will have long-term positive impacts on the species. The density of burrows of seven seabird species, including the Flesh-footed shearwater, increased following rat eradication on New Zealand islands (Buxton *et al.* 2016), and the breeding success of Cory's shearwater (*Calonectris* *diomedea*)—which is a similar size to Providence petrel and Flesh-footed shearwaters—increased following control of black rats at the Chafarinas Islands (Igual *et al.* 2006).

Sooty Tern *Sterna fuscata*

Conservation status

Listed as *vulnerable* in the TSC Act.

The Sooty Tern has a world-wide distribution in the tropical and sub-tropical waters of the Pacific, Indian and Atlantic oceans (Pringle 1987). Lord Howe Island is one of the species' most southerly breeding sites. Up to 35,000 pairs breed on the LHIG (Hutton 1991) although Fullagar *et al.* 1974 (cited in Higgins and Davies 1996) estimated that the breeding population on the LHIG was up to one million pairs. The only other major breeding site for the Sooty Tern in Australia is at Norfolk Island, which has an estimated 40,000 to 70,000 pairs (Higgins and Davies 1996). This species has been recorded on the LHIG in all months but it is most common from August to February (Hutton 1991). Nests may be established on sand, grass or rock, either in the open or under bushes (Pringle 1987). Eggs are laid from late August until early December although the main laying period on the LHIG is from September to November (McAllan *et al.* 2004). In August, large flocks can be seen circling over their breeding sites at the Admiralty Islands, Mutton Bird Island, Balls Pyramid, Mt Eliza, Malabar, North Head, King Point and Mutton Bird Point (Hutton 1991).

The birds mainly forage at sea, in offshore or pelagic zones; rarely do they forage around islands (Higgins and Davies 1996).The Sooty Tern typically feeds on fish, squid and crustaceans caught at sea; cicadas are also taken from the air over the forests at night in summer (Hutton 1991).

Threats

- Human disturbance of breeding colonies;
- Predation of eggs and chicks by rats;
- Infestation of colonies by virus-infected ticks.

Risk Posed by the Rodent-Baiting Proposal

Sooty Terns are not susceptible to poisoning by the rodent eradication. However, there is a risk of birds colliding with the helicopters and spreader buckets dispersing the bait. Late August nesters may also be disturbed, and this could jeopardise eggs although it is considered unlikely that aerial baiting will extend into late August

Mitigation of the Proposed Rodent Eradication

Aircraft altitude during the flying of transects will be set at a height which does not substantially unsettle nesting birds nor compromise baiting efficiency.

5.2.4 Potential Long Term Ecological Changes.

While it is difficult to predict the long term ecological changes that are expected to occur on LHI following successful rodent eradication, evidence from rodent eradication projects elsewhere has shown that a wide range of taxa benefit from the eradications of invasive mammals. For example, a recent review by Jones *et al.* (2016) found that 236 native species have benefitted from the eradication of invasive mammals worldwide. Rodent eradications made up 57% of the studies reviewed and the benefits included population recoveries, re-colonisations and re-introductions, and increases to vegetation cover. Examples relevant to this include, a doubling of reproductive output (number of chicks produced) by Wedge-tailed Shearwaters on Moko'auia Island following eradication of Black Rats (Marie *et al.* 2014); a 23% increase in the number of breeding pairs of Masked Boobies, and re-colonisation by White Terns on Tromelin Island following eradication of Norway Rats (Le Corre *et al.* 2015); an increase in the density of burrows of seven seabird species, including the Flesh-footed Shearwater, following rat eradication on New Zealand Islands (Buxton *et al.*2016); increases in abundance of four species of land birds on Hawadax Island, Alaska, five years after rodents were eradicated (Croll *et al.* 2016); recovery of invertebrate (cricket) populations after rodent eradication in the Falkland Islands (St Clair *et al.* 2011); and dramatic increases in plant cover on Tromelin Island after rodent eradication (Le Corre 2015). It is expected that LHI populations of seabirds, land birds, invertebrates and vegetation would similarly benefit in the long-term from the eradication of rodents.

Unassisted re-colonisations by species that were formerly present on LHI are also difficult to predict but two of the most likely species to re-colonise are white-bellied storm-petrel and Kermadec petrel. Both of these species formerly bred on the main island (Hindwood, 1940) with their extirpation purportedly due to the impacts of invasive rodents. Re-colonisation by the white-bellied storm-petrel could be assisted through the use of a call-playback system to attract potential re-colonisers. Re-introductions are also possible for a number of species that have been extirpated from the main island but still exist on offshore islets in the LHIG; these include the Lord Howe Island Wood-feeding Cockroach *Panesthia lata* and the Lord Howe Island Phasmid *Dryococelus australis*.

Negative impacts on native populations have also been reported following rodent eradications. Most negative impacts are due to poisoning either from consumption of baits or through secondary poisoning following consumption of poisoned rodents. Such impacts are usually short term and populations recover once the baiting operations have ceased (Jones *et al.* 2016). Species at risk of being affected by bait consumption or secondary poisoning that occur in the LHIG include the Lord Howe Woodhen and the Lord Howe Pied Currawong (DECC, 2007a). Comprehensive mitigation plans are in place for both of these species (see section 6). Other documented impacts of island eradication programs on non-target species have involved species that consumed rodents as a primary food source. No species in the LHIG are expected to be impacted in this way other than the introduced Masked Owl, which is proposed to be eradicated concurrently with the REP.

If the eradication is not successful but rodent populations are substantially reduced, it is expected that any ecological changes, positive or negative, will be only temporary until rodents return to pre-REP levels. If rats are successfully removed, but mice remain it could be expected that the mouse population would initially increase exponentially, and then settle into some sort of equilibrium at a much higher density than current levels. It is likely that major benefits would still accrue to the palm industry and to many natural environments attributes (e.g. return of smaller seabirds, recovery of *Placostylus* populations, and possible establishment of 'analogue' species to replace extinct taxa). Other benefits may accrue, such as partial recovery of lizard populations, but not to a level which could be expected if all rodents were removed. Invertebrate populations, particularly larger and/or ground-dwelling species, may not show any recovery if mice remained. Re-introduction of the Phasmid may still be possible, given that they co-existed with mice prior to the rat invasion, but population establishment may be retarded or even prevented by the population imbalance of potential predators and their prey.

The 'nuisance value' of mice around residences would be likely to increase, necessitating on-going control. Some appreciable economic, social and conservation problems will remain if mice survive an eradication attempt, but significant gains will have been made in all aspects even if rats only are removed.

Because it is difficult to accurately predict long-term ecological impacts of the REP, a series of programmes to monitor potential benefits to biodiversity (population increases, expansions of breeding areas etc.) and the outcomes of mitigation measures for non-target species have either been established or are planned for future implementation. For example, in Part 2 of the REP Action Plan, pre-eradication monitoring is being undertaken to collect baseline data to enable determination of subsequent short-, medium- and long-term trends and changes in the distribution and abundance of key taxa following the removal of exotic rodents from LHI. Taxa included in these studies are: land birds; Black-winged petrel, Little shearwater; land snails; ground and tree dwelling invertebrates; Big Mountain Palm; Little Mountain Palm and fruiting plants.

Part 3 of the Action Plan is comprised of the capture and management of LHPC and LHW, monitoring of LHPC remaining in the wild during rodent eradication activities, and the staged release and monitoring of LHPC and LHW following the bait drop. Biodiversity benefits monitoring will also continue for the range of taxa monitored in Part 2 of the Action Plan. The monitoring project will be managed by the LHI Rodent Eradication Project Manager (LHI REPM) and coordinated by the Science Division of the OEH Heritage NSW (Science Manager). Fieldwork and analysis will be undertaken by OEH staff, collaborating scientists or contractors. Involvement of the Lord Howe Island community will be encouraged for all projects, subject to skills and licensing restrictions. For details of monitoring plans see Section 6.5.

5.2.5 Cumulative Impacts

Potential cumulative impacts from the REP were considered with:

- Other potential actions - the proposed wind turbines on LHI and ;
- Other key threatening processes on the island such as weeds, habitat clearing and degradation, other human related threats and anthropogenic climate change.

The wind turbine proposal forms part of the Hybrid Renewable Energy Project, which aims to reduce diesel consumption and the costs of electricity generation on the island. The current proposal is stage 2 of the HREP. Stage 1 has been approved by the Board, and comprises an access road to the solar farm, a photovoltaic solar farm, a battery bank and associated infrastructure.

A biodiversity assessment of the wind turbine project undertaken in 2016 (NGH Environmental, 2016) found the following:

- The turbines would be sited in a cleared paddock around 1.5 hectares in size. The site carries exotic pasture and is primarily used for dairy cattle grazing. No threatened flora species recorded were recorded at the site.
- The site has minimal habitat value for wildlife. It may be used for foraging by some insect and bird species, but is unlikely to provide limiting or essential habitat resources for local fauna. Birds including the LHI currawong use the airspace above the paddock).

- Seven-part tests of significance for NSW threatened species and Assessments of Significance for nationally threatened and listed migratory species conclude that the proposal would not result in significant impact to these species.

As the LHI currawong is the only species on which the REP will have a potential significant impact (temporary disruption to one breeding cycle) and the wind turbine is unlikely to have an impact on currawongs, no significant cumulative impacts are expected from the wind turbines and REP.

When potential impacts of the REP are considered with other threats including climate change, no significant cumulative impact is expected. This is due to the localised and short term nature of potential impacts from the REP and excepted long term benefits to species and ecosystem recovery in the absence of rodents.

When considered as one action out of many related conservation and recovery actions currently being implemented or planned by the LHIB, the REP will add significant contribution to net positive cumulative impacts for species and biodiversity for the LHIG.

In contrast, not proceeding with the REP would allow continued impacts from predation and completion by rodent on a range of species, increasing cumulative impacts with other threats (DECC, 2007).

6 Assessment of Likely Impacts on Ecological Communities

Section 110(3)(a) of the TSC Act states that the SIS must provide:

……. a general description of the endangered ecological community present in the area that is the subject of the action and in any area that is likely to be affected by the action.

The TSC Act lists two threatened ecological communities on Lord Howe Island which are the *Lagunaria* Swamp Forest and the Gnarled Mossy Cloud Forest (both of which are *critically endangered).*

6.1 The Lagunaria Swamp Forest (i.e., the Sally Wood Swamp)

Conservation status

Listed as a *critically endangered ecological community* (NSW Scientific Committee 2003).

Lagunaria Swamp Forest is confined to Lord Howe Island where it is restricted to the lowland area, which has largely been cleared for settlement (NSW Scientific Committee 2003). Height of the forest is 10 -15 m tall. The major canopy dominant, *Lagunaria patersonia* subsp. *patersonia* is confined to Lord Howe Island and Norfolk Island. Other canopy trees include *Hibiscus tileaceus* (Kurrajong) and *Myoporum insulare* (Juniper) (Pickard 1983, Auld and Hutton 2002). Shrubs are generally sparse and may include *Aegiceras corniculatum* (Mangrove), *Cryptocarya triplinervis* (Blackbutt) and *Celtis conferta* subsp. *amblyphylla* (Cotton-Wood) (NSW Scientific Committee 2003). The groundcover may include *Cyperus lucidus* (Cutting grass), *Commelina cyanea* and *Hydrocotyle hirta,* and is generally sparse where the tree canopy is intact, but may be denser on edges and where the tree canopy has been disturbed.

The distribution of the community is restricted to low-lying swampy areas at altitudes below 20 m. This distribution was mapped by Pickard (1983), who estimated that its original distribution may have covered as little as six hectares, distributed across five restricted locations on the island. The community has undergone a very large reduction in geographical distribution with greater than 95% of the community estimated to have been lost (Pickard 1983, Auld and Hutton 2002). None of the locations are protected within the Lord Howe Island Permanent Park Preserve. *Lagunaria* Swamp Forest falls entirely within the jurisdiction of the Lord Howe Island Board. Individual plants of *Lagunaria patersonia* may be scattered through the forests from sea level to about 600 m elevation on Lord Howe Island, but such locations do not form a part of the *Lagunaria* Swamp Forest community (NSW Scientific Committee 2003).

Lagunaria Swamp Forest has been seriously depleted by land clearing at all sites of its occurrence. The remaining fragments are only a few square metres in area, and are degraded by edge effects, weed invasion, alteration to water regimes, and from cattle grazing. The remnants are likely to include only a sample of the original flora and at least some appear to be transitional assemblages with other vegetation communities. However there have been a number of restoration activities undertaken by the Lord Howe Island Board to begin to restore this community. Actions have involved habitat plantings and fencing of remnants, or in some cases previously occupied habitat, in order to exclude cattle (NSW Scientific Committee 2003).

Risk Posed by the Rodent-Baiting Proposal

The REP does not pose a risk to plant species (see Section 3.1.3.3) and is unlikely to have a significant impact on any resident fauna species within this threatened ecological community (discussed in section.5.2 above). Therefore no impact to this Community is expected.

Conversely removal of rodents is expected to significantly benefit individual species (i.e. sallywood) within this community through reduced predation on developing seeds, seedlings and stems of leaf fronds.

Mitigation of the Proposed Rodent Eradication

None proposed.

6.2 Gnarled Mossy Cloud Forest on Lord Howe Island

Conservation status

Listed as a *critically endangered ecological community* (NSW Scientific Committee 2011).

Gnarled Mossy Cloud Forest on Lord Howe Island is characterised by the following assemblage of species:

Asplenium pteridoides	*Asplenium surrogatum*

Atractocarpus stipularis	*Blechnum contiguum*
Blechnum fullagarii	*Blechnum howeanum*
Carex inversa	*Coprosma huttoniana*
Cryptocarya gregsonii	*Cyathea brevipinna*
Cyathea howeana	*Cyathea macarthurii*
Dendrobium moorei	*Diplazium melanochlamys*
Dracophyllum fitzgeraldii	*Dysoxylum pachyphyllum*
Elaeocarpus costatus	*Elatostema reticulatum*
Gahnia howeana	*Grammitis* spp.
Hedyscepe canterburyana	*Hymenophyllum* spp.
Lastreopsis nephrodioides	*Lepidorrhachis mooreana*
Leptospermum polygalifolium ssp. *howense*	*Lordhowea insularis*
Machaerina insularis	*Macropiper hooglandii*
Melicope contermina	*Metrosideros nervulosa*
Microlaena stipoides	*Microsorum* spp.
Negria rhabdothamnoides	*Olearia ballii*
Olearia mooneyi	*Phymatosorus scandens*
Pittosporum erioloma	*Polystichum whiteleggei*
Rapanea myrtillina	*Symplocus candelabrum*
Tmesipteris truncata	*Zygogynum howeanum*

However, the total species list of the community is considerably larger than that given above, with many species present in only one or two sites or in low abundance (NSW Scientific Committee 2011). At any one time, above-ground individuals of some species may be absent, but the species may be represented below ground in the soil seed banks or as dormant structures such as bulbs, corms, rhizomes, rootstocks or lignotubers. The list of species given above is of vascular plant species; the community also includes non-vascular plants, micro-organisms, fungi, cryptogamic plants and a diverse fauna, both vertebrate and invertebrate. These components of the community are less well documented (NSW Scientific Committee 2011).

Gnarled Mossy Cloud Forest on Lord Howe Island is confined to Lord Howe Island in New South Wales. On the island it is restricted to the summit plateau of Mt Gower (some 27 ha) and in a greatly reduced form and extent on the narrow summit ridge of Mt Lidgbird (NSW Scientific Committee 2011). Gnarled Mossy Cloud Forest on Lord Howe Island is currently recognised following the work on vegetation classification on Lord Howe Island by Pickard (1983) who describes the community as Gnarled Mossy Forest. Other studies describe the community as Moss Forest (Oliver 1916), Cloud Forest (Mueller-Dombois & Fosberg 1998) and Mossy Cloud Forest (Harris *et al*. 2005). Recent work (Harris *et al*. 2005) has detailed the species composition and internal variation within the community, along with its conservation significance. Small-scale patch dynamics such as tree death and fall, and storm and lightning damage, are likely to be key drivers of turnover in plant populations in Gnarled Mossy Cloud Forest (NSW Scientific Committee 2011). Extensive Providence Petrel (*Pterodroma solandri*) burrowing may also influence plant recruitment (NSW Scientific Committee 2011). Many non-vascular plants are dependent upon cloud cover and the structure provided by the trees and shrubs.

Gnarled Mossy Cloud Forest on Lord Howe Island is a forest of 2-8m tall, depending on aspect and whether it occurs on ridges or in drainage lines (NSW Scientific Committee 2011). On the summit plateau of Mt Gower, the dominant species are *Zygogynum howeanum* and *Dracophyllum fitzgeraldii* (Pickard 1983, Harris *et al*. 2005). Associated trees include *Cryptocarya gregsonii, Elaeocarpus costatus, Leptospermum polygalifolium* subsp. *howense, Negria rhabdothamnoides*, *Pittosporum erioloma, Symplocus candelabrum,* and the palms *Hedyscepe canterburyana* and *Lepidorrhachis mooreana* (NSW Scientific Committee 2011). Tree Ferns (*Cyathea* spp.), large tussock sedges (*Machaerina insularis* and *Gahnia howeana*), ferns *Blechnum fullagarii, B. contiguum, B. howeanum, Grammitis wattsi* and other ferns, mosses and lichens are abundant (ibid). Gnarled Mossy Cloud Forest on Lord Howe Island also occurs on the summit ridgetop of Mt Lidgbird above 750 m elevation, but is much more exposed and restricted in area (Pickard 1983). A vegetation plot on the summit of Mt Lidgbird in Gnarled Mossy Cloud Forest had a dominant canopy of *Hedyscepe canterburyana, Cryptocarya gregsonii, Dysoxylum pachyphyllum, Negria rabdothamnoides, Pittopsorum erioloma* and *Cyathea macarthurii*, along with *Grammitis diminuta, Carex* sp., *Olearia mooneyi, Rapanea myrtillina, Zygogynum howeanum, Lordhowea insularis, Gahnia howeana, Negria rabdothamnoides, Coprosma lanceolaris, Dendrobium moorei, Coprosma* *putida, Macropiper hooglandii*, *Microsorium scandens, Asplenium milnei, Asplenium surragatum, Elatostema grande, Hymenophyllum* sp. (Hutton and Auld unpublished data cited in NSW Scientific Committee 2011).

Some 86% of the vascular plant species in Gnarled Mossy Cloud Forest on Lord Howe Island are endemic to Lord Howe Island and approximately 17% are endemic to this community or only occur within it and on adjacent slopes below (Harris *et al*. 2005). There is extensive development of non-vascular epiphytes (Pickard 1983). Ramsay (1994) details the mosses of Lord Howe Island and lists 105 species, in 58 genera and 36 families. Twenty percent of these are endemic to the island and some 37 taxa are recorded from the Mt Gower area, with 15 species apparently confined to the southern mountains (Ramsay 1994).

Gnarled Mossy Cloud Forest on Lord Howe Island is a key component contributing to the southern mountains biodiversity hotspot on Lord Howe Island (DECC 2007), particularly for plants and invertebrates. Cassis *et al*. (2003) found that the assemblage of terrestrial invertebrates in the Gnarled Mossy Cloud Forest exhibits high species richness, high levels of endemism and many species are restricted to the Gnarled Mossy Cloud Forest.

Several threatened taxa occur within the Gnarled Mossy Cloud Forest on Lord Howe Island (NSW Scientific Committee 2011). These include:

<u>Birds</u>: Lord Howe Island Woodhen, Providence Petrel, Lord Howe Silver Eye and Lord Howe Island Currawong. These birds also occur at lower elevations but Gnarled Mossy Cloud Forest forms key core habitat for the petrel and woodhen in particular;

<u>Invertebrates</u>: Lord Howe Island earthworm, *Pericryptodrilus nanus* is confined to this community and dependent upon it. Four endemic snails (*Pseudocharopa whiteleggei, Pseudocharopa lidgbirdi, Mystivagor masteri* and *Gudeoconcha sophiae magnifica)* are listed under the EPBC Act as *Critically Endangered*; and all are restricted to the Gnarled Mossy Cloud Forest (NSW Scientific Committee 2011). In 2015, these four snail species were listed as *Critically Endangered* in the TSC Act. Cassis *et al*. (2003) identify a number of invertebrates (ants, beetles and spiders) that are found in the cloud forest that should be considered for listing as threatened;

<u>Plants</u>: The *critically endangered Lepidorrhachis mooreana* (Little Mountain Palm) is endemic to Lord Howe Island and is confined to the Gnarled Mossy Cloud Forest (NSW Scientific Committee 2011).

<u>Threats</u>

The Gnarled Mossy Cloud Forest on Lord Howe Island is threatened by a number of factors. The exotic Ship Rat has been on Lord Howe Island for almost 100 years. Auld *et.al* (2010) found rats on LHI have increased the risk of extinction for the two endemic mountain palms on Mt Gower. This is a consequence of rat predation of fruits which has the potential to limit recruitment in both palm species. Past observations highlight the lack of ripe fruits on *Lepidorrhachis* plants unless mesh caging was applied to exclude rats from the developing fruits. The impact of rats is greatest in *Lepidorrhachis*, where fruit losses reached 100% and small juvenile plants (<50 cm) were extremely rare in the presence of rats.

The effect of rats on other plants is poorly known, but rats consume seeds and leaves of a number of other taxa (Auld and Hutton 2004), including *Dietes robinsoniana* which occurs in the Gnarled Mossy Cloud Forest. Rats are also a serious threat to a number of invertebrates, including the threatened snails listed above (Beeton 2008 a,b,c,d). Only 7% of the summit plateau of Mt Gower is baited to reduce the effects of rats on the palm species in this community.

<u>Risk Posed by the Rodent-Baiting Proposal</u>

The REP does not pose a risk to plant species (see Section 3.1.3.3) and is unlikely to have a significant impact on any resident fauna species within this threatened ecological community (discussed in section.5.2 above). Therefore no impact to this Community is expected.

As rats are a significant threat to several plants and animals that are integral to the Gnarled Mossy Cloud Forest (NSW Scientific Committee 2011) the eradication of rodents will benefit this community.

<u>Mitigation of the Proposed Rodent Eradication</u>

None proposed.

7 Ameliorative Measures

Measures used to mitigate potential environmental harm are summarised below. The LHIB are the responsible party for implementing the mitigation measures with assistance from OEH Science Division for some monitoring aspects. Mitigation will be undertaken with regard to relevant standards, statutory obligations and relevant approval conditions from the various approvals agencies (see section 9). Costs for all mitigation measures proposed are well understood and have been included in the funded project budget. Sufficient budget remains to implement the proposed measures.

7.1 Bait selection

Baits dyed green are often avoided by birds. This has been verified in trials conducted on LHI in 2007 with non-toxic Pestoff® pellets (DECC, 2007a). In that trial the Emerald Dove ate red pellets and brown pellets when offered to it, but ignored completely the green pellets. Baits to be used for the rodent eradication will be green.

The lower concentration of Brodifacoum in the bait, namely 20 parts per million, also reduces the possibility of non-target kills while still being highly lethal to rodents. Baiting on LHI currently involves the use of bait containing 50 parts per million of Brodifacoum which is 250% as toxic as that proposed for the eradication.

Pestoff® Rodent Bait 20R pellet product breaks down more quickly than most commercial rodenticides which tend to contain waxes and other compounds aimed at extending bait life in the field. This would extend unacceptably, the period of non-target risk. The more rapid physical bait breakdown rate for Pestoff® Rodent Bait 20R and its lower toxicity provide an effective compromise between maintaining target animal efficacy and reducing non-target risk.

An expected outcome of this mitigation is reduced non target species impacts.

7.2 Timing of baiting

The eradication is proposed to occur in June – August. It is at this time of year that most migratory seabirds are absent from the LHI Group. Even though seabirds are unlikely to eat baits and rodents, conducting the baiting when they are not present eliminates the already negligible risk to them.

The risk of collision with helicopter to the several seabird species that are present during the baiting will be reduced by taking advantage of the diurnal movements of seabirds. In this way sections of LHI will be baited when those birds are foraging at sea and away from their roosting grounds. To reduce disturbance to those species that are present throughout the day, baiting height for the helicopters will be set at an altitude that does not unduly disturb roosting or nesting birds.

An expected outcome of this mitigation is reduced non target species (seabird) impacts.

7.3 Minimising Bait Entry in the Water

Baiting around the coast line will occur above the mean high water mark to minimise bait entry into the marine environment. A deflector arm can be attached to the spreader bucket to restrict the arc of the swathe to 180º and will be used particularly when baiting the edge of buffer zones and to minimise bait entry into the marine environment when baiting coastal areas.

The Lagoon foreshore and some other beaches will be hand baited.

Expected outcomes of this mitigation are minimised bait entry into the water to reduce risks of pollution, marine non target species, impacts and bioaccumulation.

7.4 Captive Management

Woodhen and currawongs are highly susceptible to poisoning; the former from eating baits and poisoned rodents, the latter from preying on poisoned rodents. A large proportion of the population of the woodhen (80-85%) and currawongs (50-60%) will be taken into captivity to mitigate the risk of poisoning from the proposed baiting.

The period of captivity will start from approximately two months before baiting commences until baits and rodent carcasses have broken down (or for a total period of up to nine months). The time that baits are available is estimated to be 100 days although the rate of bait breakdown will be monitored (as described in Section 2.7.1.2) to ensure birds are not released at a time which may put them at risk.

Significant experience has been gained in managing woodhen populations in captivity on LHI. During a recovery program for the species (1981-1983), protocols for capturing and housing woodhens were established (Gillespie, 1993). The highly successful captive breeding and release program resulted in the release of 82 birds bred from just three breeding pairs originally captured (NPWS, 2002). Prior to the commencement of the program it was estimated that only 37 individuals remained in the wild.

In preparation for the LHI REP, a captive management pilot study was conducted in 2013 for woodhen and currawongs on LHI (Taronga Conservation Society Australia, 2014) has also added significant knowledge on the captive management of the two species. The pilot study showed that woodhens and currawongs could be held in large groups for prolonged periods with no observable impact. All 20 woodhens and 10 currawongs were successfully released at their individual capture sites. The trial report is included in Appendix C – Captive Management Package.

The expected outcome of this mitigation is protection of species at risk from the REP.

7.4.1 Bird capture

Only experienced staff will be involved in the capture of both species. These include rangers on LHI who are involved in the capture of woodhen for banding as part of the annual monitoring of the population and OEH scientific officers (with assistance from the LHIB rangers) that have been catching and banding currawongs since 2005 to determine their population status and movements. Hand-nets will be used to capture woodhen, and clap-traps will be used for currawongs. Upon capture, birds will be placed into cloth bags or ventilated cardboard boxes (one bird per bag or box) and taken to the holding facility where they will be checked by a veterinarian. A veterinarian with bird experience will be on site during all capture and release operations.

Birds will be collected from across the island including Mt Gower which will be accessed by helicopter to minimise stress to the birds. The Woodhen Survey Manual (Harden, 1999) provides details around how to capture woodhens.

7.4.2 Captive Housing Design and Location

The design plans for the holding pens used for each species during the 2013 trial were prepared by an experienced aviculturist from Taronga Zoo considering knowledge gained from previous facilities built to house these birds (both at Taronga Zoo and on LHI) as well as advice from New Zealand where the Weka, a species similar to the woodhen, had been kept in captivity during rodent-eradication operations undertaken in that country. These, together with recommendations from the pilot study will be used to inform the detailed design of the larger facility needed during the REP.

Indicative plans from the 2013 pilot study are attached as part of Appendix C – Captive Management Package.

The captive management facilities will be constructed by modifying existing facilities at the Nursery, where the facilities for the pilot study were built. If required, expansion may occur on previously cleared land at the nursery Site (Figure 9).

Woodhens will held in enclosed paddocks 14 m by 14 m (see Figure 7), holding approximately 20 birds each. No aggression was noted during the 2013 trial with similar bird numbers per aviary. For the currawongs, aviaries 1.5 m wide x 3 m high x 6 m long aviaries, will be constructed, holding approximately 2 birds.

Guiding principles used in designing and determining the location of aviaries have included

- Locating the aviaries away from areas frequented by people;
- Providing adequate shade and protection from inclement weather and avian predators;
- Ensuring the birds feel secure by the provision, if need be, of screens between pens containing antagonistic co-specifics;
- Providing cover within pens in which the birds can shelter;
- Ensuring the pens can be effectively cleaned;
- Ensuring drainage is adequate;
- Ensuring internal structures are without sharp surfaces and pointed edges.

A Construction Management Plan for construction of the aviaries was developed in 2013 and will be updated to consider the expansion required for the REP. The 2013 Construction Management Plan is attached to this referral as part of Appendix C – Captive Management Package.

7.4.3 Captive Husbandry and Disease Management

At the commencement of the captive period each bird will be banded (if not already) and examined by a veterinarian from Taronga Zoo who is experienced in avian medicine. The initial health status of individual birds will be determined by detailed physical examination together with body weight measurement and faecal examination for intestinal parasites. While in captivity on LHI, the birds will be under the care and authority of Taronga Zoo. A team of aviculturists will be employed to manage the holding facility for the period that the birds are held.

During the captive period the birds' behaviour and food intake will be monitored daily by experienced keepers and body weight will be monitored regularly. Parasite loads will be monitored by faecal examination.

At the end of the captive period each bird will undergo another physical examination by a veterinarian to ensure that it is fit for release.

Previous health assessments conducted on the Lord Howe Woodhen and other avian species on the island have not identified infectious diseases causing illness (Curran, 2007, included in Appendix C). The most likely disease or injury scenarios that may arise in the captive period include trauma due to con-specific aggression, parasitism especially coccidiosis, and outbreak of stress induced disease due to opportunistic environmental organisms such as salmonellosis and aspergillosis.

Facilities will be available for isolation of sick birds. Basic veterinary diagnostic investigation of any ill birds will be undertaken on the island while samples for more detailed diagnostic testing including histopathology and more complex haematology and serum biochemistry will be sent to Taronga Zoo for processing

A scientific licence issued by the NSW OEH under Section 132C of the National Parks and Wildlife Act 1974 is required to capture woodhen and currawongs on Lord Howe Island.

The capture or housing of birds can result in the injury or death to individuals. Measures taken to reduce the likelihood of injury or death to birds in the program are:

- Experienced staff will be involved in the capture of both species
- A bird-specialist veterinarian will be on site during capture and release operations
- Experienced aviculturists from Taronga Zoo have designed the holding facilities to be sited on LHI
- Experienced aviculturists from Taronga Zoo will manage and care for birds through their period in temporary captivity
- Advice on captive management has been sought from, and will continue to be refined with, specialist aviculturists. Central to this process has been the examination of the successful captive-breeding programme for woodhen undertaken on LHI in the 1980s, the 2013 pilot study, as well as captive trials undertaken in New Zealand with Weka (a species similar to the Woodhen)
- Exclusion of rodents from the facility
- If the holding facilities are found to be inadequate after birds have been taken, attempts will be made to rectify any problems.

Notwithstanding these precautions, a small number of birds (~ 15) are likely to die in captivity due to natural mortality (e.g., due to old age) because birds captured for the trial will reflect the age structure and general health of birds on LHI.

7.5 Impact Monitoring

An extensive monitoring program will be conducted during and after the REP. This includes

- Monitoring of weather in the lead up to and during the REP. This will ensure bait can be distributed safely and effectively and not during adverse weather conditions.
- Monitoring breakdown of baits after distribution. Bait breakdown will be monitored at random sites using the Craddock Condition Index described above at approximately 30 day intervals until complete disintegration. This will provide confidence in bait breakdown prior to release of captive managed species.
- Soil Monitoring after distribution. Post operational soil samples will be collected to monitor residues of Brodifacoum in the soil. Representative samples will be collected from directly below some toxic bait and at control sites away from bait pellets. Soil samples will be collected approximately 30 days after bait disintegration and approximately every two months (if required, dependant on results). All tests will be conducted at a NATA accredited analytical laboratory. This will provide evidence that pollution has not occurred.
- Random sampling will be conducted on water bodies on the island to monitor Brodifacoum levels after the bait drop. Water samples will be collected within 2 days of each bait drop and approximately weekly 30 (if required, dependant on results). All tests will be conducted at a NATA accredited analytical

laboratory. Rain water tanks will be sampled if requested by residents. This will provide evidence that pollution has not occurred and water is safe to drink.

- Analysis of milk samples post baiting. This will provide evidence that milk is safe to drink.
- Monitoring of captive LHW post release (see details below). This will provide evidence of recovery.
- Monitoring of free-ranging LHPC and captive LHPC post-release (see details below). This will provide evidence of recovery.

7.5.1 Monitoring programme for the Lord Howe Pied Currawong

With approval of the REP (baiting) it will be necessary to have a three-phase program involving captivity, monitoring and release of the Lord Howe Pied Currawong (LHPC).

In the first phase, 50–60% of the LHPC adult population will be captured using manually operated, baited butterfly-traps and brought into captivity. This process will target breeding pairs close to the settlement and from Mount Gower to cover the range of birds from the island. Trapping will involve an intensive 3-week program in May 2017 and will include transporting LHPC from Mt Gower by helicopter in conjunction with Woodhen activities (see below). This phase will require the construction of captive management facilities within the lowlands by Taronga Zoo and the LHIB.

The second phase will involve surveys, including trapping and banding free-ranging LHPC not captured in the first phase. Understanding the movements of the free-ranging birds will allow their fate to be broadly monitored. As these individuals are to be left in the wild during the period of risk (i.e. a 6-week period during and in the period immediately following the baiting operation until rodent carcases are deemed to be no longer available for scavenging- based on the recovery and monitoring of the breakdown of fresh rodent carcases) a five-day survey effort will be implemented every two weeks (proposed dates: May 29 – June 2, June 12 – 16; June 26 – 30 July 10 – 14). Any individuals found suffering from the suspected effects of poisoning will be captured and treated in captivity by a qualified aviculturist or vet until they recover.

The final phase will involve the gradual release of captive LHPC. Initially, five pairs of birds will be released at their capture locality. These birds will be monitored using two-staged VHF transmitters (fitted with mortality switch) for a period of two weeks. If all birds remain alive and well, the remainder of the captive currawongs will be released at their capture locality (potentially commencing 31 July 2017). The transmitted birds will be re-caught to remove devices if they have not already become detached due to their inherent ‘weak-link’. Any birds recovered dead from these initial releases will be autopsied to determine cause of death and sampled for Brodifacoum contamination. If tests prove positive the re-release of the remaining birds will be delayed for a further two weeks whereupon the process will be repeated, commencing with initial monitoring of transmitter-fitted individuals.

Population size of the LHPC has been estimated previously using trapping, banding and mark-recapture analysis (Carlile and Priddel 2007). Full monitoring and population estimates will recommence in spring-summer of 2016 to obtain pre-eradication population estimates; the protocols are well-established. With Science Manager consultation, birds attracted to designated locations across the island with food, can be monitored and any unbanded birds caught, banded with an individually unique combination of colour-bands, and released. A second round of surveys will then take place to re-sight captured birds and capture unbanded birds. Population size can then be estimated using mark-recapture analysis, and the size of the population tracked over time. Similar surveys will be performed in spring-summer 2017 allowing comparisons of (i) the persistence of the population following rodent eradication with prior estimates, (ii) the survival of birds that were left in the wild during the period of risk compared to those held in captivity, and (iii) productivity of breeding birds in the first year of a rodent-free environment.

It is suggested that four ten-day survey periods (October to January) are carried out annually for three years following the eradication to monitor population changes of the species in a rodent-free environment. It is expected that if the species experiences negative impacts from a rodent-free environment (through reduced food availability, for example) these impacts will first become apparent during chick provisioning and post fledging survival. Specific attention will be paid to nesting attempts and provisioning behaviour of adults to determine any negative responses to a rodent-free environment. Post-fledging survival will be monitored through subsequent annual surveys.

7.5.2 Monitoring programme for the Lord Howe Woodhen

With approval of the REP (baiting) it will be necessary to have a three-phase program involving captivity, monitoring and release of Lord Howe Woodhen (LHW).

The first phase will be to capture LHW using standard capture techniques (Harden 1999) and bring into captivity the entire accessible LHW population (as part of annual monitoring, more than 70% of the population are captured or sighted for visual retrapping of banded birds). While the capture and transport of birds from the lowland areas will be relatively straightforward, the birds removed from Mount Gower and Erskine Valley will require considerable trapping effort and transport arrangements. Birds will be transported from predetermined 'nodes' within the landscape. OEH Science manager will manage birds at the point of capture prior to their helicopter removal from the southern mountains to captive management facilities in the settlement. Helicopters were previously used to transport LHW with no reported ill-effects (Miller and Mullette 1985).

If not already banded, all LHW held in captivity will be banded prior to release with one individually numbered stainless steel metal band supplied by the Australian Bird and Bat Banding Scheme (ABBBS) on the left tarsometatarsus and one plastic yellow band with a unique three-digit black number on the right tarsometatarsus. The yellow plastic band replaces the previous marking scheme for wild LHW that used three coloured metal bands in addition to the ABBBS band (Harden 1999). The new scheme was adopted in 2014 because the colour coating on metal bands wears off over time, precluding the individual identification of banded LHW by sight. All LHW captured for the captive management program that were banded prior to 2014 will have their three coloured metal bands removed and replaced with a single yellow plastic band as described above. The timing of banding will be at the discretion of the aviculturists and may occur at the time of capture, during health checks while in captivity, or immediately prior to release.

The second phase will involve limited release and monitoring of LHW following the disintegration of baits and rodent carcasses, expected to take 100 days after final baiting. The birds will be released in pairs at their point-of-capture and monitored using 2-stage VHF transmitters. Initially, 6 pairs will be released, three within the settlement and three within the Permanent Park Preserve in the lowlands and Erskine Valley. Following two weeks of movements the birds will be re-captured, transmitters removed and blood collected for analysis of Brodifacoum residue. Following confirmation of the absence of Brodifacoum residue, release of the remaining captive birds will commence. If tests prove positive the re-release of the remaining birds will be delayed for a further two weeks whereupon the process will be repeated, commencing with initial monitoring of a different cohort of transmitter-fitted individuals.

The final phase will involve the release of all remaining captive LHW. These birds will be released at their point-of-capture (potentially commencing 12 October 2017). Birds trapped from Mount Gower may require helicopter transport, however for birds transported by foot into Erskine Valley, the use of specifically designed transport cases may be used to transport birds to be released at sites remote from convenient transport routes. OEH Science Manager will assist LHI Board management with this final phase of the release.

Future surveys of LHW should follow the systematic approach of current annual surveys (Harden 1999) with additional surveys to monitor breeding success. These surveys will assess juvenile recruitment in the first three years following rodent eradication to determine breeding success and chick survival relative to earlier studies.

Annual surveys of LHW are carried out in November–December over two full working weeks following standardised survey protocols (Harden 1999). These surveys were instigated immediately after the 1980–1985 captive breeding and release program and will continue indefinitely. Where possible, all LHW encountered during surveys are individually identified by colour-bands or an ABBBS metal band (if recaptured), or if they are not banded are captured and banded. Surveys thus constitute a census of the population, whereby a concerted effort is made to identify all surviving LHW occupying readily accessible parts of the island (Mount Gower–Erskine Valley, Boat Harbour–Grey Face, Far Flats, Settlement, and Clear Place). Up until 2002, this intensive survey was repeated in April to record the number of surviving juveniles, and thus obtain an index of breeding success for the population. A monitoring program incorporating two surveys per year will be re-instated for three years encompassing one year before (2016–17), immediately after (2017–18), and one year after (2018–19) the captive management of LHW. Supplementary monitoring will also be undertaken in the first few months following the final releases of captive LHW (see below). The April 2017 survey will provide a contemporary estimate of the breeding success index prior to the captive management program. Within two weeks of the final release of captive, an intensive survey will be undertaken to determine the survival of released LHW and identify any surviving individuals not taken into captivity. Searches will be made in any areas normally outside the survey area where LHW are released. Following this intensive survey, fortnightly monitoring of released LHW will be undertaken in areas where high numbers of LHW currently reside. These include:

- Mount Gower (part) - surveyed by contractors experienced in trekking Mount Gower and surveying woodhens
- Golf Course and surrounds – surveyed by LHI Board staff
- Waste Management Facility – surveyed by LHI Board staff
- Residential gardens in the main Settlement – surveyed by LHI Board staff with assistance from members of the LHI community

Additionally, incidental sightings will be solicited from LHI Board staff and island residents using a pro forma and/or an online portal on the LHI Board website. Monitoring will continue until the end of March 2018, after which a second intensive survey will be undertaken in the first two weeks of April 2018. It is expected that the breeding success index will be lower than in 2017–18 because released LHW will have less time to successfully rear offspring over the optimal spring–summer breeding period. The November–December survey in 2018 will provide an estimate of the population size to compare with the estimate obtained prior to the captive management program in November–December 2016. The April 2019 survey will allow a determination of whether breeding success has returned to a level similar to that prior to the captive management program. If breeding success has not returned to a similarly high level, a survey will also be undertaken in April 2020.

7.6 Operational Non Target Species Mitigation

Non target species impacts will be mitigated during the operational phase of the REP. A Non Target Mitigation Plan has been developed to detail the mitigation measures to reduce the incidence of non-target mortalities as a result of the REP. The aim of the plan is to provide clear and effective guidance for the REP team and project stakeholders in the implementation of mitigation, monitoring and adaptive management actions to minimise impacts on non-target species. A summary is provided below and more is provided in Appendix E – Non-target Impact Management Plan.

7.6.1 Helicopter Impacts

Only experienced pilots with island eradication bait application experience will be used during the REP to aerially bait areas around Providence Petrel nest sites. Pilots will be briefed daily before flights to be well informed of the location and direction of departing foraging birds before baiting begins. Although it is very unlikely any birds will be present due to early departure from the island to foraging grounds at sea, pilot safety and bird impacts at anytime must be taken into consideration to eliminate bird strike occurrence.

Providence Petrel breeding grounds are located on the southern end of Lord Howe Island on the slopes of Mt Lidgbird and Mt Gower. Due to the inaccessible terrain, a mitigation team member will view all baiting over-flights from Capella Hill which provides a clear view of all mountainous nesting areas on the southern mountains. In order to view Providence Petrels flight paths behind the mountains a second mitigation team will be observing flight paths via a boat from the ocean behind Mt Gower. Should Providence Petrels display unusual behaviour or become overly agitated during baiting over-flights, the observer will contact the pilot by radio to instruct on an alternative action, which may include gaining further altitude to reduce the proximity to birds while maintaining the flight path, or abandoning the flight path and returning at a later time from a different altitude. Both observers will, in any case, provide a commentary on the birds' behaviour to the pilot during each flight, to supplement or confirm what the pilot will be seeing beneath the helicopter.

7.6.2 Treating and euthanasia of poisoned Non Target species

Daily monitoring for sick and dead non-target species will be undertaken throughout accessible areas of the island. Sick individuals displaying signs of poisoning will be treated with Vitamin K where possible. Where recovery is not observed, euthanasia of poisoned wildlife is considered appropriate for the welfare of affected animals, and to enable mitigation personnel to collect and dispose of what will become a toxic carcass once an animal dies. The removal of these animals may reduce the threat of non-target species poisoning. Euthanasia will only be a feasible option for those animals that are very easily caught and restrained e.g. completely or nearly immobile animals. If an animal is still mobile and not easily caught, it should not be chased. All woodhens and currawongs will all be bought in for treatment with antidote Vitamin K in all instances.

In order to euthanize moribund non target species in New South Wales, necessary training and the appropriate ethics approval to euthanize non-targets is required. Personnel will be trained in euthanasia by blunt trauma/ cervical dislocation as this method is practical for remote field use. Unless a vet is present, it is recommended that all sick animals that can be accessed to be euthanased or rendered unconscious with a strong blow to the head, sufficient for immediate loss of consciousness and for them not to recover.

- This method must be properly applied to be effective and humane; therefore training to ensure sufficient skill of the operator is essential. It is proposed that training be undertaken by a number of staff in order to meet these ethics requirements with visiting vets while on the island. These trained staff will then be assigned to search teams during the monitoring period. An appropriate mallet or similar instrument should be used and birds need to be restrained adequately with the head held against a solid surface and one blow with sufficiently force needs to be applied at an appropriate angle to the skull. If not performed correctly, various degrees of consciousness with accompanying pain can occur. All incidents of euthanasia must be documented and reported in weekly reports to SAC and the steering committee. Documentation must include details of the demeanour/condition of the bird prior to euthanasia, as well as details of the method and efficacy of euthanasia. This process will enable appropriately qualified and experienced personnel to make informed assessments and provide advice as required

7.6.3 Collection of Biological Samples

Samples from deceased wildlife may be collected for two different reasons during LHIREP; 1) to confirm species and determine sex of non-target species killed, or 2) to determine the levels of Brodifacoum in deceased individuals of the non-target populations.

The collection of samples to assess the amount of Brodifacoum within the non-target species is slightly more labour intensive than genetic samples, although very straightforward when abdomens are opened for assessment of haemorrhaging. Samples can be collected to confirm the cause of death on those carcasses where it is unclear, as well as providing information on toxic loads and potentially the longevity of the toxin within non target populations. It must be noted that sample information will have to be sent to Brisbane for testing at a NATA accredited analytical laboratory.

Livers provide the most appropriate tissue for Brodifacoum samples to be collected from. These must be frozen once collected. Ten samples to be collected from differing levels of carcass code condition as outlined in the Mitagation Plan Appendix 2. The sample collection process will be in accordance with the 'NZ vertebrate pest residue database guidelines', copies of which will be held on Lord Howe Island and used as a reference by field staff.

7.6.4 Carcass Removal and Disposal

Brodifacoum breaks down in the environment from the action of soil micro-organisms. As pellets and carcasses containing Brodifacoum decompose, the toxin also breaks down. The baits and poisoned carcasses can remain toxic for at least seven months after being broadcast. The aim of carcass removal is to remove and dispose of poisoned animal carcasses to ensure that they are unavailable to be scavenged by woodhens and currawongs when they are released. Burial and or incineration at the Waste Management Facility is a practical means of disposal available in remote field situations encountered on LHI.

All carcasses encountered during search and collection must be disposed of in an appropriate manner that ensures safe disposal and meets label requirements. A disposal protocol will be developed by the Mitigation Team Leader prior to the commencement of baiting that will ensure this objective is achieved. This will be based on 2 options for burial and incineration that exist on LHI – in preferred order these are;

- Use of the existing incinerator located at the Waste Management Facility (WMF) to incinerate carcasses (preferred option).
- purpose dug deep burial pits located at the WMF to appropriate depth to allow microbial breakdown of carcasses.

Opening of the skin and body cavity to check for haemorrhaging will also greatly assist decomposition of carcass by allowing better contact between soil and tissue rather than fur/feathers

7.6.5 Contingency planning and adaptive management measures for non target mitigation

Should unexpected impacts occur, an adaptive management framework is critical to ensure impacts are effectively managed over the duration of the operation.

The reality of logistics associated with undertaking works on Lord Howe Island means that large scale approaches for mitigating the effects of the REP baiting operation must be planned and organised and the scope for implementing new measures is limited. However, if the operation is not managed effectively it could lead to long-term and devastating impacts on populations of threatened species, in particular the LHI Woodhen and LHI Currawong. As such, all efforts must be made to ensure that impacts are minimised and this will require the investigation and implementation of appropriate mitigation measures. More detail is given in the Non Target Mitigation Plan in Appendix E.

8 Assessment of Significance of Likely Effect of Proposed Action

This SIS provides a demonstrated need for the REP based on documented evidence of significant impacts of rodents both globally and on LHI. It presents evidence of ongoing impacts at the species and ecosystem level on LHI even in the presence of ongoing rodent control. It demonstrates support for the REP through a range of legislative instruments, recovery plans and the like and outlines the unacceptable consequences of failing to proceed. It also provides evidence of expected benefits.

Detailed consideration of alternatives assessed is provided together with justification of why continuing with the current control program is unacceptable. It provides evidence of why other methods were considered unsuitable for an eradication on LHI and why the toxin, bait and delivery methods were selected based on over 30 years of lessons and experience globally.

It outlines the project details and mitigation and considers in detail, potential risks to threatened species and ecological communities based on results from numerous similar eradications around the world.

It concludes that significant impacts are highly unlikely for most threatened species and ecological communities. Species considered most at risk are the LH Woodhen and the LH Pied Currawong. In the absence of mitigation, a significant impact to woodhens is likely to occur from the LHI REP. However with the mitigation proposed in place, it is considered unlikely that either long term population decrease or major disruption to a breeding cycle will occur. Impacts are likely to be temporary. It is therefore considered unlikely that the REP will have a significant impact on woodhens

In the absence of mitigation, a significant impact to LHPC is likely to occur from the LHI REP. With the proposed mitigation in place, it is considered possible that the REP will still have a significant impact on LHPC through the temporary disruption of a breeding cycle, although it is unlikely that a long-term population decrease will occur. Any potential impacts will be temporary. This temporary potential impact will be substantially offset by the improvement in biodiversity if impacts of rodents are removed as a result of the REP. No other offsets are proposed.

With the mitigation described in Section 7 in place, the REP is not excepted to have a significant impact on any TSC Act listed threatened species or ecological community.

The REP is essential and beneficial. Risks have been addressed through proposed mitigation to the point where they are considered to be very low. Any potential impacts are localised and short term and far exceeded and offset by the benefits that will be provided by implementation of the REP. Potential impacts of the REP are also considerably less than the ongoing impact of failing to proceed.

A summary of assessment of potential impacts is presented in Table 15 below.

Table 15 Summary of Assessment of Impacts to Threatened Species and Ecological Communities

Threatened Species / Ecological Community	Potential Impacts Associated with the REP	Assessment of Impacts	Mitigation Measures	Consequences of not proceeding undertaking the REP
Threatened Birds	Direct and secondary poisoning through consumption of baits or deceased rodents	In the absence of mitigation, a significant impact to woodhens is likely to occur from the LHI REP. However with the mitigation proposed in place, it is considered unlikely that either long term population decrease or major disruption to a breeding cycle will occur. Impacts are likely to be temporary. It is therefore considered unlikely that the REP will have a significant impact on woodhens In the absence of mitigation, a significant impact to LHPC is likely to occur from the LHI REP. With the proposed mitigation in place, it is considered possible that the REP will still have a significant impact on LHPC through the temporary disruption of a breeding cycle, although it is unlikely that a long-term population decrease will occur. Any potential impacts will be temporary.	Captive management of significant portions of the population under the care of a team of specialist aviculturists from Taronga Zoo.	Continued competition with rodents for resources (woodhen). Continued exposure to direct and secondary poisoning through consumption of baits or poisoned rodents from the existing control program.
Threatened Reptiles	Primary poisoning (direct consumption) and secondary poisoning (consumption of poisoned invertebrates).	Each species is considered to be at low risk of poisoning, and both are likely to substantially increase in abundance following the removal of rodents.	No specific mitigation	Continued decline from rodent predation
Threatened Invertebrates	Direct poisoning through consumption of baits	Low risk to four species and higher risk to *Gudeoconcha sophiae magnifica*. Land snails, earth worm and wood feeding cockroach are highly threatened by rat predation and it is likely that if rats are not removed these species will become extinct.	Possible Brodifacoum testing on surrogates species	Continued decline and likely extinction from rodent predation

Threatened Marine Mammals and Reptiles	Localised and temporary pollution of water, primary or secondary poisoning.	Pollution of marine water resulting in impacts to threatened marine species is considered extremely unlikely considering the minimal amount of bait likely to enter the water, the insolubility of Brodifacoum and the huge dilution factor. Species unlikely to have sufficient exposure to the bait	Minimising bait entry into the water through the use of directional deflector arm on the bait bucket.	Unlikely impact
Threatened Plants	Works associated with building the captive management facility and bait distribution (through potential uptake of Brodifacoum by plants).	No impact is expected to listed plant species. Conversely removal of rodents is expected to significantly benefit individual species (such as the Little Mountain Palm and Phillip Island Wheat Grass) and many vegetation communities through reduced predation on seeds, seedlings and stems of palm-leaf fronds.	No clearing of vegetation	Continued seed and seedling predation from rodents causing population declines.
Threatened Ecological Communities	Potential impacts to component species	The REP does not pose a risk to plant species and is unlikely to have a significant impact on any resident fauna species within threatened ecological communities. Therefore no impact to this Threatened Ecological Communities is expected.		

9 Additional Information

9.1 Qualifications and Experience

Qualifications and experience of authors contributing to the SIS are described in Table 16.

Table 16 Qualifications and Experience of Authors

Name and Organisation	Qualifications	Input into PER
Andrew Walsh Project Manager Rodent Eradication Project Lord Howe Island Board	Bachelor of Applied Science (Ecology and Biodiversity) Diploma of Management Certificate II in Quarantine Inspection	Primary Author
Robert Wheeler Assistant Project Officer Conservation Science Team Office of Environment & Heritage	Bachelor of Science (Zoology, Botany); Associate Diploma Park Management	Primary Author
Anthony Wilson Assistant Project Manager – Community Lord Howe Island Board	Bachelor of Science (Zoology) Graduate Certificate River Health Diploma Human Resource Management	Secondary Author
Hank Bower Manager Environment and World Heritage Lord Howe Island Board	Bachelor of Applied Science (ecology) (Hons) Certificate 2 Bush Regeneration (Tafe)	LHI Biodiversity
Pete McClelland Member IEAG NZ Department of Conservation	Bachelor of Science (Zoology) Master in Applied Science	Secondary Author LHI REP Project Manager 2012-2015
Nicholas Carlile Principal Scientist Conservation Science Team Office of Environment & Heritage	Masters of Science (Botany) Bachelor of Arts (Botany) Assoc. Dip. Resource Management	Primary Author: land birds Full Critical review
Dr Terry O'Dwyer Senior Scientist Conservation Science Team Office of Environment & Heritage	Bachelor of Environmental Science (Hons) PhD (Physiological Ecology)	Fauna impact assessment Fauna monitoring plans
Dr Dean Portelli	Bachelor of Science (Honours) (Zoology) Doctor of Philosophy (Biological Science)	Lord Howe woodhen Migratory bird species
Dr David Priddel	Doctorate of Philosophy (Zoology)	Critical review

Principal Scientist (retired)	Bachelor of Science (Hons Zoology)	
Ian Wilkinson Department of Agriculture and Food Western Australia		Primary Author 2009 Rodent Eradication Plan and numerous related studies. LHI REP Project Manager 2006 - 2012
Dr Frank Koehler Senior Scientist Australian Museum	Doctorate of Philosophy (Zoology) Master of Science (Biology)	Primary Author: Land snails
Dr Isabel Hyman Scientific Officer Australian Museum	Doctorate of Philosophy (Zoology) Bachelor of Science (Zoology)	Secondary Author: Land Snails
Dr Adnan Moussalli Senior Curator Terrestrial Invertebrates Museum Victoria	Doctorate of Philosophy (Zoology) Bachelor of Science (Zoology)	Secondary Author: Land Snails
Gary Fry Taronga Conservation Society Australia Master of Wildlife Management (Habitat)	Master of Wildlife Management (Habitat)	Critical Review Captive Management
Keith Broome Technical Advisor - Threats NZ Department of Conservation	35 years' experience in invasive pest management. Chair - Island Eradication Advisory Group	Critical Review: Eradication
Cameron Miller National Practice Leader – Natural Resources AECOM Australia Pty ltd.	18 years experience Masters of Science (Ecology & Management) Bachelor of Science	External Third Party Review

We also acknowledge the previous work on the REP undertaken by Dr Ian Wilkinson concerning bait palatability to rodents, non-target reaction to baits, and to feeding trials involving PestOff 20 and the Lord Howe Island Placostylus. We have also relied heavily on a draft eradication plan written by Dr Wilkinson and Dr David Priddel in 2009. For this assistance we are grateful, however the current protocol does vary in some significant respects from the 2009 version, so this acknowledgement should not be construed as indicating Dr Wilkinson or Dr Priddel endorse wholly or in part the current eradication plan.

We also thank Keith Springer of the Tasmanian Parks and Wildlife Service for information concerning the environmental effects of Brodifacoum baits.

9.2 Other Approvals Required for the Development or Activity

The LHIB is the responsible party for obtaining all required approvals prior to commencement of the REP. The LHIB is also the party responsible for ensuring compliance with any conditions of approvals received and will comply with any monitoring, enforcement or review requirements arising from the approvals.

9.2.1 Australian Government

9.2.1.1 Approval under the EPBC Act

Approval has been sought from the Department of Environment and Energy for the REP under the EPBC Act for an action that could have a potential impact on Matters of National Environmental Significance.

The following provides an update on progress of this approval application:

- A referral was submitted on 11 May 2016. Referral # EPBC 2016/7703
- The Project was considered a " controlled action" to be assessed by Public Environment Report on the 30 June 2016
- A Draft Public Environment was accepted by the Department on 31 October and was put on public exhibition inviting submissions from 2 November 2016 to 2 December 2016
- A Final Public Environment Report addressing public submissions was submitted on 21 December 2016.
- Additional information was requested by the Department on 6 February 2017 and provided 10 February 2017.
- The assessment decision is expected in Mid to late April 2017

Contact officer is:

Mark Jenkins

EPBC Assessment Officer

Mark.Jenkins@environment.gov.au

02 6274 1558

9.2.1.2 Australian Pesticides and Veterinary Medicines Authority

Approval from the APVMA in the form of a "Minor Use Permit" for use of the bait product during the LHI REP is required under the *Agricultural and Veterinary Chemicals Code Act 1994.* As the active constituent (Brodifacoum) is currently registered for use in Australia by the APVMA and therefore has established regulatory standards, a Limited Level Environmental Assessment is applicable. The Limited Level Environmental Assessment considers fate in the environment (soil, air and water) environmental toxicology, bioaccumulation and potential impacts to all species present. The application also included a Work Health and Safety Module and a Safety and Efficacy Module that included impact to Human Health. The application for a Minor Use Permit was submitted on 19 April 2016 and assessment by the APVMA is expected to take approximately nine to ten months. Public Exhibition and Consultation is not required by the APVMA for a Minor Use Permit, however the LHIB has made the application package available to the LHI community post submission. Community feedback received over several years was addressed in the application package.

Primary contact is:

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9.2.1.3 Civil Aviation Safety Authority

Various approvals from the Civil Aviation Safety Authority will be required for the helicopter operations including flights and pilot licensing. These will be sought in conjunction with the selected helicopter provider.

9.2.2 NSW Government

Statutory environmental impact assessment will be undertaken as follows:

- The Board has received legal advice that the proposed baiting programme to be undertaken on the island does not constitute an activity for the purposes of Part 4 or 5 of the NSW *Environment Planning and Assessment Act 1979* and as such it does not require approval under the EP&A Act. In order to meet the definition of an "activity" for the purposes of the Act, the programme would need to be considered to be a "use of the land" or constitute "work on the land". The baiting of the rodents is not likely to be considered to be "work" or a "use of the land".

Advice received from the NSW OEH is that the NSW Assessment Bilateral Agreement would not apply to the Part 4 Assessment

However assessment under Part 4 of the NSW *Environment Planning and Assessment Act 1979* is required for construction of the Captive Management facility. This will be assessed via a Development Application with a statutory public notification and comment period. The LHIB is the consent authority.

In addition, given the broad public interest in the proposal, a non-statutory Public Environment Report as above will be made publicly available. That document will assist the community to understand the overall purpose of the proposal, the range of approvals required, and enable social and economic factors to be identified and considered.

  - The Development Application (DA 2017-13) was submitted on the 19 January 2017 with public exhibition from 20 Jan 2017 to 3 February 2017.
  - The Development Application will be decided at the May 2017 LHIB Board meeting in conjunction with the final Go / no go Decision for the entire REP.
  - Primary Contact is:
    - Dave Kelly
    - Manager Environment and Community Development, LHIB
    - Dave.Kelly@lhib.nsw.gov.au
    - Telephone 02 6563 2066

- A Species Impact Statement (this document), which considers the REP including capture and holding of the birds, and a Threatened Species License under Section 91 of the *NSW Threatened Species Conservation Act 1995* are also required.
- NSW Dept. of Primary Industries (Marine Parks and Fisheries) - assessment under Division 2 of the NSW *Marine Estate Management Act 2014 and Fisheries Act 1994*. This assessment will consider potential impacts to NSW listed threatened marine species, habitats and the State LHI Marine Park values.
  - A section 220ZW License to Harm application was submitted to Fisheries on 3 Nov 2016
  - A NSW Marine Parks permit application was submitted to Marine Parks on 30 December 2016
- NSW Environmental Protection Agency - owners consent to aerially bait within 150 m of dwellings and public places required under the NSW *Pesticides Act 1999*.

9.2.3 Local Government

The LHIB has the status of a local government authority, and a consent authority under the Environmental Planning and Assessment Act 1979. The Development Application for the captive management facility will be assessed under the Lord Howe Island Local Environmental Plan 2010. These assessments will consider and address statutory requirements and will include a comprehensive assessment of the impacts, risks and proposed mitigation of the eradication program relevant to each agency's jurisdiction.

Relevant Contact is:

- Dave Kelly
- Manager Environment and Community Development, LHIB
- Dave.Kelly@lhib.nsw.gov.au
- Telephone 02 6563 2066

9.3 Licensing Matters

The following licenses are required for various aspects of the REP:

- License to Harm threatened species under Section 91 of the TSC Act. It is expected that this would be an outcome of this SIS.
- License to Harm threatened species under the *Fisheries Act*. It is expected that this would be an outcome of the Section 220ZW application submitted (described above)

- License to capture listed threatened species (Woodhens and Currawongs) under Section 91 of the TSC Act.

  LHIB Staff currently have a license # 100831 – which allows LHIB staff to harm, trap, hold (including dead specimens), release fauna and pick flora for identification purposes. This would need to be renewed prior to the REP with Taronga Zoo staff added.

  OEH staff involved in capture of currawongs are currently covered under Animal Ethics Committee license 050725/02. This may need to be extended to cover the REP

- Licensing of operators under the *Pesticides Act 1999.*
  - It is expected that helicopter pilots contracted will have a commercial distribution license and a Pesticide use license for prescribed pesticide works for aerial baiting components
  - LHIB staff will require a Pesticide use license for prescribed pesticide works for ground baiting components.

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Appendices

Appendix A – Director General's Requirements for a Species Impact Statement for the Lord Howe Island Rodent Eradication Project

Appendix B – DGRs Checklist

Appendix C – Captive Management Package

Appendix D – LHI Trials Package

Appendix E – Non-target Impact Management Plan

Appendix F – Masked Owl Package

Appendix G – Biodiversity Benefits Monitoring Package

Appendix H – LHI Biodiversity Management Plan

Appendix I – Island Eradications Using Pestoff

Appendix J – Marine Hypothetical Scenario

Appendix K – Land Snail Survey 2016

Lord Howe
ISLAND BOARD

Lord Howe Island Rodent Eradication Project

NSW Species Impact Statement
February 2017
Appendix A - Director General Requirements

Office of Environment & Heritage

NSW GOVERNMENT

Our Ref: DOC16/296074
Your Ref: Letter dated 18 May 2016

Mr Andrew Walsh
Project Manager - Rodent Eradication Project
Lord Howe Island Board
PO Box 5
Lord Howe Island NSW 2898

Dear Mr Walsh

DIRECTOR-GENERAL'S REQUIREMENTS FOR A SPECIES IMPACT STATEMENT FOR THE LORD HOWE ISLAND RODENT ERADICATION PROJECT

Thank you for your letter dated 18 May 2016 seeking Director General's Requirements (DGRs) Lord Howe Island Rodent Eradication Project in accordance with Section 111 of the *Threatened Species Conservation Act 1995* (TSC Act). I appreciate the opportunity to provide input.

The Office of Environment and Heritage (OEH) understands that The Lord Howe Island Board is planning undertake to the eradication project under the Part 5 provisions and Section 112 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and the Section 91 licence provisions of the *Threatened Species Conservation Act 1995.*

In response to your request, please find attached DGRs for a Species Impact Statement (SIS) at **Attachment A**, to address all known and potential threatened species, populations and ecological communities (including their habitat).

Please note that the issuing of DGRs is a statutory requirement for the OEH and should not be construed as support or endorsement of the proposal. A check list to ensure all matters are addressed is at **Attachment B**.

OEH would be pleased to provide advice throughout the development of the SIS and review a draft prior to its finalisation.

If you require any further information about these requirements please contact Mr Krister Waern, Environmental Officer, Regional Operations, OEH, can be contacted on (02) 6640 2503 or at krister.waern@environment.nsw.gov.au.

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Yours sincerely

27 June 2016

DIMITRI YOUNG
Senior Team Leader Planning, North East Region
Regional Operations

As delegate to the Director – General

Contact officer: KRISTER WAERN (02) 6640 2503

Enclosures: Attachment A - Director-General's Requirements (DGRs) for the Lord Howe Island Rodent Eradication Project
Attachment B – Check List

ATTACHMENT A:

DIRECTOR GENERAL'S REQUIREMENTS FOR A SPECIES IMPACT STATEMENT FOR THE LORD HOWE ISLAND RODENT ERADICATION PROJECT

PURPOSE

The purpose of a Species Impact Statement (SIS) is to:

- allow the applicant or proponent to identify threatened species issues and provide appropriate amelioration for adverse impacts resulting from the proposal.
- assist the Chief Executive of the Office of Environment and Heritage in the assessment of Section 91 Licence applications lodged under the *Threatened Species Conservation Act 1995* (TSC Act).

DEFINITIONS

The definitions given below are relevant to these requirements:

- ***abundance*** means a quantification of the population of the species or community.
- ***activity*** has the same meaning as in the EP&A Act.
- ***affected species*** means subject species likely to be affected by the proposal.
- ***conservation status*** is regarded as the degree of representation of a species or community in formal conservation reserves.
- **DA** number means Development Application number.
- ***development*** has the same meaning as in the EP&A Act.
- ***Director General*** means the Director General of the Department of Premier and Cabinet, Office of Environment and Heritage (OEH).
- **DP** means *Deposited Plan* which is the **plan** number given to a subdivision that is registered by the Land Property Information.
- **EPA** means the Environment Protection Authority (formerly part of the OEH).
- **LGA** means Local Government Area.
- ***locality*** means the area within a 5 km radius of the study area.
- ***region*** has the same meaning as that contained in the TSC Act.
- ***significant species*** means species not listed in the TSC Act but considered to be of regional or local significance.
- ***study area*** is the subject site and any additional areas which are likely to be affected by the proposal, either directly or indirectly.
- ***subject site*** means the area which is proposed for development/activity.
- ***subject species*** means those threatened and significant species, populations and ecological communities which are known or considered likely to occur in the study area.
- ***threatening process*** has the same meaning as that contained in the TSC Act; the definition is not limited to key threatening processes.

All other definitions are the same as those contained in the TSC Act.

MATTERS WHICH HAVE BEEN LIMITED OR MODIFIED

The following Section 110 matters in the TSC Act need only be addressed where relevant:

- all reference to Threat Abatement Plans;
- all reference to Recovery Plans
- all Key Threatening Processes; and
- all reference to Critical Habitat. At the time of printing, the areas of declared critical habitat are not relevant to this proposal.

The proponent should be aware that recovery plans may be approved, critical habitat may be declared and key threatening processes may be listed between the issue of these requirements and the granting of approval. If this occurs, these additional matters will need to be addressed in the SIS and considered by the consent, determining or concurrence authority.

MATTERS TO BE ADDRESSED

The TSC Act provides that the SIS must meet all the matters specified in Sections 109 and 110 of the TSC Act with the exception of those matters limited above. The requirements outlined in Sections 109 and 110 (excluding the matters limited above) have been repeated below (italics) along with the specific Director General Requirements (DGRs) for your proposal. Previous surveys and assessments that are relevant to the locality may be used to assist in addressing these requirements.

Section 111 (1) of the TSC Act states that an applicant must comply with the DGRs concerning the form and content of the SIS. Failure to fully comply with the DGRs is therefore a potential breach of the legislation, and may result in the OEH being unable to grant concurrence to a request by the consent authority to carry out the activity. Accordingly, the SIS must be formatted to follow the sections and subsections provided in the DGRs.

1 FORM OF THE SPECIES IMPACT STATEMENT

1.1 *A species impact statement must be in writing (Section 109 (1));*

1.2 *A species impact statement must be signed by the principal author of the statement and by:*

(a) the applicant for the licence, or

(b) if the species impact statement is prepared for the purposes of the Environmental Planning and Assessment Act 1979, the applicant for development consent or the proponent of the activity proposed to be carried out (as the case requires) Section 109(2)).

The applicant or proponent must sign the following declaration:

> "I...[insert name], of ..[address], being the applicant for the development consent...[insert DA number, Lot & DP numbers, street, suburb and LGA names] have read and understood this species impact statement. I understand the implications of the recommendations made in the statement and accept that they may be placed as conditions of consent or concurrence for the proposal".

2. CONTEXTUAL INFORMATION

2.1 Description of proposal, subject site and study area

A species impact statement must include a full description of the action proposed, including its nature, extent, location, timing and layout (Section 110 (1))

2.1.1 Description of the proposal

A comprehensive description of the nature, extent and timing of all components and associated actions of the proposal must be provided, including actions that have effects both *on* and *off* the subject land as a result of the proposal.

As a minimum, the following operational elements require a full description:

- Capture and captive management of at-risk species
- Bait application methods
- Product storage, disposal and spill response
- Environmental monitoring
- Elimination of survivor rodents
- Rodent detection monitoring
- Masked owl eradication
- Improved Biosecurity
- Ongoing biodiversity benefits monitoring

2.1.2 Definition of SIS study area

The SIS study area must be defined. The study area will generally be larger than the development site as it includes any adjacent areas that will be directly or indirectly affected by the proposal. In defining the study area consideration shall be given to possible indirect effects of the proposed action on the area surrounding the subject site, for example habitat fragmentation, vegetation corridors, altered hydrology regimes, soil erosion, pollution, and increased human presence or associated impacts. These may include adjacent parcels of land containing suitable habitat for threatened species. It is therefore important to recognise that these parcels may need to be investigated along with the development site. The location, size and dimensions of the study area shall be provided.

The study area should be established before the list of likely impacted threatened species, populations, ecological communities (including their habitat) is determined so species etc. that are less obviously affected are also included. The study area must be clearly defined, marked on a geo-referenced map / aerial photograph (or equivalent), clearly showing the development site boundary and any additional areas facing indirect impact, and included in the final report.

Indirect impacts occur when project-related activities affect species, populations or ecological communities in a manner other than direct loss. Examples of indirect impacts include (but not limited to):

- sediment, pollutant or nutrient runoff into adjacent vegetation
- habitat fragmentation or isolation
- implementation of asset protection zones (though these may also represent direct impact)
- loss of genetic diversity of threatened species, populations or communities
- altered pollination syndromes that may adversely affect seed set
- soil erosion
- altered hydrology regimes (including downstream impacts)
- changes to the saline / freshwater balance in marine environments
- exposure to heat or predators, or loss of shade
- inhibition of nitrogen fixation
- weed invasion and feral animal incursion

- introduction and spread of pathogens,
- noise
- dust
- light pollution
- fire (such as changes to intensity and frequency)
- fertilizer drift
- increased human activity (including litter) within or directly adjacent to sensitive habitat areas.

Indirect impacts should not be just limited to the terrestrial habitats. In stances where a development site adjoins marine, estuarine and/or riparian / riverine environs / habitat, impacts on these must be considered.

Note: Indirect impacts may lead to direct loss, and as such must be adequately quantified and assessed. Both impacts within the proposed development footprint and on adjacent / surrounding lands must be taken into account, and where appropriate adequately considered and addressed.

2.1.3 Description of SIS study area

The description of the study area must include (but not limited to):

- The vegetation communities and habitat types, including identification of the classification system used in the SIS;
- The land tenure and any proposed changes (e.g. acquisition by the OEH as a Nature Reserve, National Park, Regional Park etc.), and an examination of the degree of protection that current land tenures and any proposed land tenures provides or will provide to native vegetation and threatened species in the study area;
- Relevant Local Government planning instruments, including Local Environmental Plans and Development Control Plans, such as the '*Lord Howe Island Local Environmental Plan 2010*'.

2.2 Provision of relevant plans and maps

A plan of the subject area, including the scale of the plan should be provided. An aerial photograph of the locality (or reproduction of such a photograph) shall be provided, if possible. This aerial photograph should clearly show the subject site and the scale of the photograph. It should be geo-referenced and show the date of the photograph.

A geo-referenced topographic map or equivalent of the subject site and immediate surrounds at an appropriate scale should be provided. This map should detail the location of the proposal and location of works on site (including areas of indirect impact). Additionally, to provide an overview of the natural landscape in the general locality, the map should show or be overlain with details of vegetated (i.e. woody [e.g. forests, woodland, shrubland and heath] and non-woody native vegetation [e.g. grassland, sedgeland and saltmarsh]) vs. cleared areas, as well as indicating the current activities/usage of this land, such as rural, agricultural, industrial and residential.

A map of the locality, showing any locally significant areas for threatened species such as parks and reserves, and areas of high human activity such as townships, regional centres and major roads will also be provided. The location, size and dimensions of study area shall be provided.

2.3 Land tenure information

Information about the land tenure across the study area. Any limitations to sampling across the study area (e.g. denied access to private land) shall be noted.

2.4 Vegetation

Vegetation present within the property must be mapped and described, particularly the vegetation community listed as an Endangered Ecological Community (EEC) on the TSC Act, that species being Sallywood (*Lagunaria patersonia*) Closed Swamp Forest

3 INITIAL ASSESSMENT

A general description of the threatened species or populations known or likely to be present in the area that is the subject of the action and in any area that is likely to be affected by the action (Section 110 (2)(a)).

3.1 Identifying subject species

3.1.1 Assessment of available information

In determining these species ('the subject species'), consideration shall be given to the habitat types present within the study area, recent and historic records of threatened species or populations in the locality and the known distribution of threatened species.

Databases such as the OEH's *Atlas of NSW Wildlife* (www.bionet.nsw.gov.au/), *BioBanking Credit Calculator* (www.environment.nsw.gov.au/biobanking/calculator.htm), *Atlas of Living Australia* (www.ala.org.au/), *Australian Museum* (http://ozcam.org.au/), *Birdlife Australia* (http://birdsaustralia.ala.org.au/BDRS/home.htm), and the *Royal Botanic Gardens* (http://plantnet.rbgsyd.nsw.gov.au/) should be consulted to assist in compiling the list.

The following species shall be considered for inclusion in the list of subject species, as they have either been recorded in the general area, are within the species' known geographic limits or their broad habitat preferences may be present on site:

3.1.2 Identifying Threatened Species, Populations and ecological communities

The following species must be considered as a subject species:

Scientific Name	Common Name	Legal Status
Christinus guentheri	Lord Howe Island Southern Gecko	Vulnerable under the *EPBC Act* and vulnerable under the *TSC Act*
Cyclodina (Oligosoma) lichenigera	Lord Howe Island Skink	Vulnerable under the *EPBC Act* and vulnerable under the *TSC Act*
Procelsterna cerulean	Grey Ternlet	Vulnerable under the *TSC Act*
Pterodroma neglecta	Kermadec petrel	Vulnerable under the *EPBC Act* and vulnerable under the *TSC Act*
Strepera graculina crissalis	Lord Howe Island Currawong	Vulnerable under the *TSC Act*
Pachycephala pectoralis contempta	Lord Howe Island Golden Whistler	Vulnerable under the *TSC Act*
Zosterops lateralis tephropleura	Lord Howe Island Silvereye	Vulnerable under the *TSC Act*
Gallirallus sylvestris	Lord Howe Woodhen	Recovery Plan in place - Endangered under the *TSC Act*
Sula dactylatra tasmani	Masked Booby	Vulnerable under the *TSC Act*
Pterodroma solandri	Providence Petrel	Vulnerable under the *TSC Act*
Sterna fuscata	Sooty Tern	Vulnerable under the *TSC Act*

Placostylus bivaricosus	Lord Howe Placostylus	Recovery Plan in place Endangered under the *TSC Act* and *EPBC Act*
Gudeoconcha sophiae magnifica	(a helicarionid land snail)	Critically Endangered under the *TSC Act*
Mystivagor mastersi	Masters' Charopid Land Snail	Critically Endangered under the *TSC Act*
Pseudocharopa lidgbirdi	Mount Lidgbird Charopid Snail	Critically Endangered under the *TSC Act*
Pseudocharopa whiteleggei	Whitelegge's Land Snail	Critically Endangered under the *TSC Act*

This list is not exhaustive. One of the roles of the SIS is to determine which species may be utilising a site given the limitations of existing databases.

The proponent should be aware that additional species, populations, and ecological communities could be added to the schedules of the TSC Act between the issue of these requirement as and the granting of consent. If this occurs, these additional matters will need to be addressed in the SIS and considered by the consent, determining, or concurrence authority.

4 SURVEY

4.1 Specific survey requirements

If surveys are to be undertaken, surveys are to be carried out in the appropriate season to look for evidence of breeding, moulting, nesting, foraging on the islands and access to the sites used for these purposes. The results of these surveys should be discussed in the context of the species use of habitat and the general island area where the REP is to take place.

The consultants preparing the SIS must seek the most recent information on each of the species and provide evidence that appropriate consultation has been undertaken.

Surveys must be undertaken by appropriately experienced and qualified persons. A recognised expert, from institutions such as the Australian Museum (Sydney), the National Herbarium of NSW at the Royal Botanic Gardens (Sydney) or the Queensland Herbarium (Brisbane), or who is otherwise considered acceptable by the OEH, must be used to determine or confirm the identification of species that are unknown or which have been only provisionally identified.

Survey methods adopted must be those considered by experienced wildlife surveyors to be those most likely to detect the targeted subject species (more than one survey method must be utilized for those subject species for which complementary methods have the potential to result in a significant increase in detection). Survey effort (including intensity, repetition and coverage) must be at a level that can be reasonably expected to detect the subject species if present in the study area. Surveys must be undertaken at the time of year when the subject species are most likely to be detected (e.g. targeted threatened flora should be carried out when a species is flowering and/or fruiting, as these features are typically required to positively identify species) and, where possible, in appropriate weather conditions. The OEH expects the weather conditions (e.g. minimum ambient air temperature, maximum ambient air temperature, amount of precipitation that occurs each 24 hour period, details about wind speed and direction and the amount of cloud cover) and the phase of the moon to be recorded for each day of survey (including dates) to be documented and included in the report.

Survey procedures and assessment of results should be consistent with those procedures and assessment approaches contained within the following the OEH publications:

- *Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities*' (DEC – November 2004)'. (*Note: Section 6.1 *Assessment of Significance* has now been amended by DECC 2007b)

- '*Threatened Species Survey and Assessment Guidelines: Field Survey Methods for Fauna – Amphibians* (DECC – April 2009)'

- '*Threatened Species Assessment Guidelines: The Assessment of Significance*' (DECC – August 2007b).

*Note that the OEH has recently produced new survey guidelines to cover Amphibians (frogs), which replaces the amphibian section in the DEC (2004) guidelines. However, the survey requirements for all other species (flora and fauna) are still found in the DEC (2004) guidelines.

The above documents can be located on the OEH's website under the 'Threatened species survey and assessment guidelines' at:

www.environment.nsw.gov.au/threatenedspecies/surveyassessmentgdlns.htm

If a proposed survey methodology is likely to vary significantly from widely accepted methods, the proponent should discuss the proposed methodology with the OEH prior to undertaking the SIS, to determine whether the OEH considers that it is appropriate.

In addition to the above guidelines, the OEH has recently posted new information on the OEH website to ensure appropriate surveys are completed, with particular reference to fauna surveying. Below is a summary of this information as well as other clarifying points, often relating to vegetation survey. This updated information can be accessed from:

www.environment.nsw.gov.au/threatenedspecies/surveymethodsfauna.htm

Targeted Surveys - Flora

For targeted flora surveys please note the known flowering / fruiting times for each species to time surveys appropriately (as listed above for potential 'subject species'). Surveying at known flowering times is required for all potential species that are not readily detectable (and/or are cryptic), where flowers and/or fruits are necessary for their positive identification. If targeted flora surveys for potential species are conducted outside a species known phenology then justification must be provided as to why; if this is not provided or considered inappropriate, then all such species will be considered to be present on all available habitat and in viable numbers, and as such will require suitable biodiversity offsets or their habitat avoided. For species which do not require flowers / fruits for positive identification (e.g. large trees / shrubs), then survey as appropriate (though appropriate justification on methods used is still required).

Targeted flora surveys must also adequately sample / cover all suitable habitat on the study area, and utilise suitable detection techniques such as belt transects (at appropriate widths to spot cryptic species) or random meanders (that sufficiently cover all known / potential habitat areas [i.e. not just the tracks or readily accessible areas]). If targeted flora surveys are poorly conducted and/or surveyed then appropriate justification must be provided as to why; if this is not provided or considered inappropriate, then all such affected species will be considered to be present on all available habitat and in viable numbers, and as such will require suitable biodiversity offsets or their habitat avoided.

Targeted Surveys – Fauna

When undertaking targeted fauna surveys you must be aware of: (i) habitat preferences and known distribution for each of the species as an indication as to whether they may occur in the study area, (ii) the best times of year these species may be detected if subject to surveys, and (iii) suitable survey techniques to adequately detect a potential species. If targeted fauna surveys are poorly conducted, inappropriately surveyed and/or undertaken outside known detection periods, then appropriate justification must be provided as to why; if this is not provided or considered inappropriate, then all such affected species will be considered to be present on all available habitat and in viable numbers, and as such will require suitable biodiversity offsets or their habitat avoided.

If animals are captured with an uncertain taxonomy, species should be forwarded to the Australian Museum by a suitably qualified scientific licence holder.

Habitat assessment

Habitat assessment is recommended for all sites and should be used to supplement surveying and survey design. In instances where intensive or species specific surveys have not been carried out due to either timing or seasonality constraints, habitat assessment may be used as a surrogate for intensive surveys. However, in this instance threatened species should be assumed present if their habitat requirements are met. Ensure all impact assessments include a thorough habitat assessment.

Undertaking a habitat assessment of the study area will assist with predicting the occurrence of threatened species in the study area and will guide the location of targeted surveys. A comprehensive habitat assessment should be conducted across the whole site, identifying key habitat features for both flora and fauna.

You should be familiar with the habitat requirements of each threatened species identified as possibly occurring in the study area. This information can be obtained from the OEH's recovery plans website (www.environment.nsw.gov.au/threatenedspecies/recoveryplans.htm), threatened species profiles and scientific literature. Threatened species profiles are available on the OEH website:

www.environment.nsw.gov.au/threatenedspecies/

The habitat assessment should include information on:

- landscape features in the study area (e.g. river banks, rocky outcrops, dry slopes, wetlands, undulating terrain)
- any other features that could provide habitat such as hollow-bearing trees or culverts
- the vegetation types present (such as the OEH's Biometric vegetation types (www.environment.nsw.gov.au/biobanking/VegTypeDatabase.htm) and/or appropriate vegetation mapping).

It is important to record all areas of native and introduced vegetation, as even weeds can potentially provide habitat for threatened fauna. As part of the habitat assessment, you should look for:

- hollow-bearing trees, including dead stags;
- bush rock and rocky outcrops;
- natural burrows, such as those of the Hastings River Mouse;
- large trees with basal cavities;
- logs;

- wetlands, streams, rivers, dams and other water bodies;
- nests and roosts;
- permanent soaks and seepages; and
- areas that can act as corridors for plant or animal species.

Another important factor to consider is the connectivity value of the site. If the proposal site forms an important corridor in the area, the development is likely to have an effect on threatened species in the region.

A geo-referenced map / aerial photograph (or equivalent), of the study area detailing key habitat features, including the vegetation types, must be included in the report.

Flora / Vegetation Survey and Mapping

Typically a floristic quadrat / transect will be used for vegetation based surveying. This should record the vegetation structure and cover of all structural layers, all species present, including their cover and abundance, and general location (e.g. Global Positioning System (GPS) co-ordinates etc.) and physiographic details (e.g. condition, position in landscape, soils etc.). These techniques are described in the OEH guidelines and are generally the accepted national (NVIS – National Vegetation Inventory System) standard (www.environment.gov.au/topics/science-and-research/databases-and-maps/national-vegetation-information-system). Each stratification unit must be adequately sampled.

All quadrats / transects should be adequately assessed to determine a suitable vegetation classification which accurately reflects the site. This may be done manually, or through the aid of appropriate statistical software / numerical analysis, such as cluster analysis and ordination analysis computer packages (e.g. PATN (Belbin 1989)). The latter will be dependent on how detailed the survey was, the size of the area sampled, the inherent diversity / complexity of vegetation on site and the amount of plot data collected. Details of the classification and how it was determined must be supplied in the report.

To complement and better refine the vegetation classification, ground truthing and aerial photograph or satellite imagery interpretation should be used. This will be used to generate the vegetation map and enable greater definition / delineation of vegetation communities present, and ensure a more accurate map. Ground-truthing and/or Aerial Photograph Interpretation (API) should be conducted at a level which captures all the obvious vegetation changes / communities on the subject site (particularly those that are noticeable at the ground-level) and ensure that all vegetation communities are adequately delineated on a geo-referenced map (the 'vegetation map'). Floristic quadrats / transects and any associated analysis will help define and describe the communities shown on the vegetation map. Recognition and delineation of native vegetation patterns on aerial photography may be based on combinations of:

- texture (crown size and shape)
- vegetation height and density
- vegetation and background tone and colour
- landuse pattern (non-woody areas).

Determining Biometric vegetation types

The classification of native vegetation in NSW follows the system described by Dr David Keith in '*Ocean Shores to Desert Dunes: The Native Vegetation of New South Wales and the ACT*' (Keith 2004). This classification scheme divides native vegetation into 17 broad vegetation formations. Each formation consists of a number of vegetation classes. There are 99 vegetation classes.

The OEH has developed a 'NSW Vegetation Types Database' for use with the BioMetric tool, which is designed to assist in assessing biodiversity values when preparing property vegetation plans under the *Native Vegetation Act 2003* and BioBanking agreements under the *Threatened Species Conservation Act 1995*. The OEH has provided a spreadsheet containing a definition of these vegetation types on a catchment management authority basis, which is located at:

www.environment.nsw.gov.au/biobanking/tools.htm

4.2 Documentation of survey effort and technique

4.2.1 Description of survey techniques and survey sites

Survey technique(s) must be described and a reference given, where available, outlining the survey technique employed. Specific subject species targeted by each survey technique should be listed.

Survey site(s) and stratification units must be identified on a geo-referenced map / aerial photograph (or equivalent), with a clear legend, at the same scale as previous maps where possible. The size, orientation and dimensions of a quadrat or a length of transect should be clearly noted for each type of survey technique undertaken. Full Australian Map Grid (AMG) grid (Geocentric Datum of Australia (GDA) compliant) references for the survey site(s) should be noted.

4.2.2 Documenting survey effort

The time invested in each survey technique applied shall be summarised in the SIS e.g. - number of person hours per transect, duration of call playback, number of nights traps set. It is not sufficient to aggregate all time spent on all survey techniques. Effort must be expressed for each separate survey technique and each separate vegetation community. Environmental conditions during the survey should be noted at the commencement of each survey technique.

Personnel details including name of <u>all</u> surveyor(s) and contact phone number should be provided. The person who identified records (e.g. Anabat, hair tubes, motion-sensor camera, and scat analysis) should also be identified.

4.3 Survey results

4.3.1 Subject species survey results

The report should provide a full list of all flora and fauna recorded in the study area / subject site.

Subject species recorded in the study area shall be identified, and the vegetation community in which they were recorded noted. Information concerning all records of threatened species made during the survey is to be provided in an appendix to the SIS. This information is to be in a form consistent with *Atlas of NSW Wildlife* data recording cards and include information for all fields listed on these cards.

The limitations of survey techniques employed (including survey intensity, detectability of species, seasonality, weather conditions and adverse disturbance conditions) must be considered and discussed with respect to the results of the survey, and additional subject species considered to potentially occur in the study area identified. This assessment must be robust to external evaluation.

4.3.2 General species survey results

The SIS must provide details of all the vegetation communities (including disturbed and undisturbed / modified), habitat types, and all fauna and flora recorded on the subject site and study area in general.

A full list of the protected fauna and native plant species (as defined by the *National Parks and Wildlife Act 1974*) found during the course of surveys must be included. Such information is indicative of the habitat quality of the site. This list must indicate the significance of each species, whether the species is introduced, and the habitat in which each species was recorded.

4.4 Subject species habitat mapping

Areas identified as known or potential habitat in the study area are to be mapped on a geo-referenced map / aerial photograph (or equivalent) separately for each of the subject species. These maps should be at the same scale as previous maps where feasible, and are to include any point locality records of the relevant subject species recorded from the SIS survey in the study area. Note: Records obtained from the 'Atlas of NSW Wildlife' database can be used in determining likely habitat, but they are not to be schematically mapped in the SIS, as this is considered a breach of licence conditions for such records.

While in some circumstances the task of identifying potential habitat can be problematic, the SIS should provide the best expert estimate of the habitat of each threatened species, populations and ecological communities known or considered likely to occur in the study area. This is necessary in order to clearly support conclusions concerning the quantitative significance of habitat loss associated with the proposal. Information which can be used in preparing these maps includes records of threatened species in the local area, maps of vegetation communities and broad habitat types in the study area, information on the habitat requirements of threatened species and site-specific knowledge gained through field survey and inspection during preparation of the SIS.

4.5 General report structure

In summary, the report must include details on the following (but not be limited to):

- a description of the subject site, study area and its regional context; including a geo-referenced map / aerial photograph (or equivalent) indicating their location;

- details of the survey methodology and design adopted, including:
  - the number and location of traps (e.g. cage, Elliott, hair sampling tubes etc.), call playback sites, diurnal searches, random meanders, quadrats and transects,
  - the number of repetitions (Note: – you will need to provide a justification if this differs from the recommendations in these guidelines),
  - details of all floristic plots and/or transects,
  - details of the stratification,
  - identification of the classification system used (e.g. Specht *et. al.* (1974), Walker & Hopkins (1998) [Note: the classification must have regard to both structural and floristic composition elements]),
  - timing of surveying, climatic (weather) conditions and phases of the moon during survey,

  - details of how the vegetation classification for the site was developed, including details and associated products (e.g. dendrograms / two-way tables) of any analyses used, if applicable,
  - copies of any analyses used (e.g. PATN or other statistical files) and all field data sheets, and
  - geo-referenced maps / aerial photographs (or equivalent) showing the location of all survey points, quadrats and transects, and stratification units.

- detailed description of all vegetation communities / types (both undisturbed and disturbed) on the site and study area (it is preferable to link them to, the OEH's Plant Community Types / Biometric vegetation types – in which case a step by step summary of how the site vegetation was matched with available Biometric vegetation types should also be included), including a geo-referenced map / aerial photograph (or equivalent) showing their location. The descriptions should include: - a general description, characteristic features (e.g. lacks a mid-storey, restricted to a particular geomorphic / edaphic feature etc.), their distribution and size (e.g. hectares), their vegetation structure (including cover), their condition, key diagnostic species, relationship to other communities, species richness and any significant species present (e.g. threatened species, Rare or Threatened Australian Plants (ROTAP: Briggs & Leigh 1996), regionally significant taxa);

- details of all habitat features / types should be included and mapped (where appropriate), such as frequency and location of stags, hollow bearing trees (including size), mature / old growth trees, culverts, rock shelters, rock outcrops, presence of feed tree / shrub / groundcover species (e.g. winter-flowering eucalypts, Acacia and Banksia trees, Casuarina / Allocasuarina and areas of native grasses], crevices, caves, drainage lines, soaks etc.;

- a list of all flora and fauna detected on the study area / subject site during the surveys, including threatened species. All threatened species, populations and ecological communities must be clearly marked on geo-referenced map / aerial photograph (or equivalent);

- details of how the proposal will impact (both direct and indirect) and affect known and potential threatened species, populations and ecological communities (including their habitat). This is likely to include a revised 5A assessment of significance;

- details of how the proposal may impact on corridors, connective links and fragmentation;

- details of how the proposal will impact (both directly and indirectly) on adjacent and/or nearby OEH conservation estate and/or if applicable, other internationally / nationally important areas, (e.g. Ramsar wetlands, wetlands listed in the Directory of Important Wetlands and Forestry flora reserves);

- details of any impacts on or relevance of other environmental policies and/or guidelines (as outlined in Section 2.1.3);

- details of mitigation and offset / compensatory habitat measures;

- details of any other approvals required under any other State and/or Federal legislation;

- names, qualifications and experience of all personnel involved in the field surveys, analysis of results and report writing;
- paper copies of any maps of proposed biodiversity offset areas at A0 or A1 scale that clearly show the location and boundaries of any proposed offset area. These maps must be prepared by a registered surveyor and be proper survey plans that are acceptable to local Councils;
- an assessment of how the project meets the principles of Ecologically Sustainable Development, as defined in section 6(2) of the *Protection of the Environment Administration Act 1991;*
- a discussion of the likely social and economic consequences of granting or of not granting concurrence; and
- any other information outlined elsewhere in these guidelines, such as background and comparisons to previous studies (e.g. vegetation mapping reports), mitigation and offset measures etc. that should be included in the report.

5 ASSESSMENT OF LIKELY IMPACTS ON THREATENED SPECIES AND POPULATIONS

Assessment of impacts must include the assessment of indirect impacts and those of associated activities, including, but not restricted to: installation and maintenance of utilities, access and egress routes; and changes in surface water flows. These actions or impacts may occur on or off the subject land.

Assessment of impacts must also include an assessment of impacts from the provision of fire protection zones. If, as part of the development, there will be a requirement to provide fuel free and/or fuel reduced zones in retained bushland, the impacts of this on any threatened species and/or populations must be addressed as part of the impacts of the overall proposal. Proponents should also consider recommendations in '*Planning for Bushfire Protection*' (NSW Rural Fire Service 2006) and consider the use of perimeter roads as an option in providing fuel free zones and reducing impacts on retained bushland.

5.1 Assessment of species likely to be affected

An assessment of which threatened species or populations known or likely to be present in the area are likely to be affected by the action (Section 110(2)(b)).

This requirement is asking you to refine your list of subject species and populations (given the outcome of survey and analysis of likely impacts) in order to identify which threatened species or endangered populations may be affected and the nature of the impact.

The remaining requirements in this section need only be addressed for those species that are likely to be affected by the proposal.

5.2 Discussion of conservation status

For each species or population likely to be affected, details of its local, regional and State-wide conservation status, the key threatening processes generally affecting it, its habitat requirements and any recovery plan or threat abatement plan applying to it (Section 110 (2)(c)).

An assessment of whether those species or populations are adequately represented in conservation reserves (or other similar protected areas) in the region (Section 110 (2)(e)).

An assessment of whether any of those species or populations is at the limit of its known distribution (*Section* 110 (2)(e1)).

Assessment should include reference to the threatening processes that are generally accepted by the scientific community as affecting the species or population and are likely to be caused or exacerbated by the proposal. Assessment should also include reference to any approved or draft recovery plans which may be relevant to the proposal; including those prepared by other state Governments of the Commonwealth Government.

5.3 Discussion of local and regional abundance and distribution

The following are further requirements related to your obligations under Section 110(2)(d), they need to be addressed:

An estimate of the local and regional abundance of those species or populations (Section 110 (2)(d)).

5.3.1 Discussion of other known local populations

A discussion of other known populations in the locality shall be provided, along with an assessment of their regional significance. The long-term security of other habitats shall be examined as part of this discussion. The relative significance of the subject site for threatened species or endangered population in the locality shall be discussed.

5.3.2 Discussion of habitat utilisation

An estimate of the numbers of individuals utilising the area and how these individuals use the area (e.g. residents, transients, adults, juveniles, nesting, foraging). This should include discussion of the significance of these individuals to the viability of the threatened species or endangered population in the locality.

5.3.3 Description of vegetation

The vegetation present within the study area and the area covered by each vegetation community should be mapped and described, as previously stated in Section 4.3.2.

5.4 Assessment of habitat

A full description of the type, location, size and condition of the habitat (including critical habitat) of those species and populations and details of the distribution and condition of similar habitats in the region (Section 110 (2)(f)).

5.4.1 Description of habitat values

Specific habitat features shall be described, such as frequency and location of stags, hollow bearing trees (including size), mature / old growth trees, culverts, rock shelters, rock outcrops, presence of feed tree / shrub / groundcover species areas of native grasses, crevices, caves, drainage lines, soaks etc, and density of understorey vegetation / groundcover.

The condition of the habitat within the study area shall be discussed, including the prevalence of introduced species, species of weeds present and an estimate of the total weed cover as a percentage of each vegetation community, whether trampling or grazing is apparent, effects of erosion, prevalence of rubbish dumping, history of resource extraction or logging and proximity to roads, and assessment of the potential for native seed bank resilience in disturbed areas.

Details of the fire history of the subject site (e.g. frequency, time since last fire, intensity) and the source of fire history (e.g. observation, local records) shall be provided.

5.4.2 Impacts on Threatened Species and/or Populations in the OEH Estate

This section only needs to be addressed when threatened species and/or populations in the OEH estate (e.g. National Parks, Nature Reserves) are likely to be either directly or indirectly impacted upon.

The SIS must assess the potential impacts on any threatened species and/or populations which may likely be directly or indirectly impacted upon that reside with the OEH estate, including but not limited to fragmentation or loss of connective linkages, edge effects (e.g. increased boundary to area ratio), increased predation potential, weed invasion, loss or impacts on pollination vectors, changes to hydrology, nutrient increases, pollution, anthropogenic impacts (e.g. increased visitation, refuse) etc.

5.5 Discussion of the likely effect of the proposal at local and regional scales

The following are further requirements related to your obligation under Section 110(2) (g) to address the following:

> *A full assessment of the likely effect of the action on those species and populations, including, if possible, the quantitative effect of local populations in the cumulative effect in the region*

5.5.1 Significance within a local context.

Provision of information to allow adequate determination of the significance of the effects of the proposal in accordance with Section 5A of the EP&A Act is required. The significance of impacts in the study area for conservation of affected threatened species or endangered populations in the *locality* must be discussed. An assessment of the significance of such impacts must compare and take into account the differences in the type, condition, and the tenure and long-term security, of other areas of known habitats in the *locality* with those in the study area.

5.5.2 Discussion of connectivity

The potential of the proposal to increase fragmentation of the habitat or decrease the ability for movement of individuals and/or gene flow between habitats or populations of a threatened species or population must be appraised.

5.5.3 Consideration of threatening processes

Assessment of effects must not be limited only to threats that are recognised as key threatening processes, but must include other threatening processes that are generally accepted by the scientific community as affecting the species or population and are likely to be caused or exacerbated by the proposal. Assessment should also include consideration of the information in the Priorities Action Statement (http://www.environment.gov.ai/threatendspecies/pas.htm) and any approval or draft recovery plans or threat abatement plans which may be relevant to the proposal.

5.6 Description of feasible alternatives

A description of any feasible alternatives to the action that are likely to be of lesser effect and the reasons justifying the carrying out of the action in the manner proposed, having regard to the biophysical, economic and social considerations and the principles of ecologically sustainable development (Section 110(2)(h)).

Where a Statement of Environmental Effects (SEE), Environmental Impact Statement (EIS) or Review of Environmental Factors (REF) deals with these matters, the SIS may refer to the relevant section of the SEE, EIS or REF.

This section must include details of the condition and use of other parts of the subject area and why these can or cannot be considered as feasible alternatives.

6 ASSESSMENT OF LIKELY IMPACTS ON ECOLOGICAL COMMUNITIES (ENDANGERED AND CRITICALLY ENDANGERED)

Section 6 need only be addressed when ecological communities are likely to be affected.

Assessment of impacts must include the assessment of indirect impacts and those of associated activities, including, but not restricted to: installation and maintenance of utilities, access and egress routes; and changes in surface water flows. These actions or impacts may occur on or off the subject land.

Assessment of impacts must also include an assessment of impacts from the provision of fire protection zones. If, as part of the development, there will be a requirement to provide fuel free and/or fuel reduced zones in retained bushland, the impacts of this on any endangered and/or critically endangered ecological communities must be addressed as part of the impacts of the overall proposal.

6.1 Assessment of ecological communities (both endangered and critically endangered) likely to be affected

A general description of the ecological community present in the area that is the subject of the action and in any area that is likely to be affected by the action (Section 110(3)(a)).

This must include reference to the ecological community as described by the NSW Scientific Committee, including maps of the extent and condition of the community with particular reference to those parts of the community that may only be represented by soil stored seed with no above ground components of the community present.

6.2 Discussion of conservation status

For each ecological community present, details of its local, regional and State-wide conservation status, the key threatening processes generally affecting it, its habitat requirements and any recovery plan or any threat abatement plan applying to it (Section 110(3)(b)).

An assessment of whether those ecological communities are adequately represented in conservation reserves (or other similarly protected areas) in the region (Section 110(3)(b1)).

An assessment of whether any of those ecological communities is at the limits of its known distribution (Section 110(3)(b2)).

Assessment should include reference to the threatening processes that are generally accepted by the scientific community as affecting the endangered and/or critically endangered ecological community and are likely to be caused or exacerbated by the proposal. The assessment should also include reference to any approved or draft recovery plans which may be relevant to the proposal.

6.2.1 Significance within a local context

An assessment of the community on the subject site in relation to other sites in the study area and in the locality. The tenure and long term security of other localities shall be examined as part of this discussion.

The relative significance of the subject site for the endangered and/or critically endangered ecological community shall be discussed. The assessment of the community should be considered in terms of the following features including, the size of the remnant, the quality of the habitat and the level of disturbance on this site in comparison to other sites in the locality.

6.2.2 Discussion of corridor values

The potential of the proposal to increase fragmentation of the community and increase edge effects.

If corridors that allow connectivity between localities of endangered and/or critically endangered ecological communities are present within the subject site, the impact of the proposal on these areas shall also be discussed.

6.2.3 Discussion of regional significance

The significance of the locality for the community from a regional perspective shall be noted and discussed.

6.2.4 Impacts on Ecological Communities in the OEH Estate

This section only needs to be addressed when endangered and/or critically endangered ecological communities in the OEH estate are likely to be either directly or indirectly impacted upon.

The SIS must assess the potential impacts on any endangered and/or critically endangered ecological communities which may likely be directly or indirectly impacted upon that reside with the OEH estate.

6.3 Assessment of habitat

A full description of the type, location, size and condition of the habitat of the ecological community and details of the distribution and condition of similar habitats in the region (Section 110 (3)(c)); and,
a full assessment of the likely effect of the action on the ecological community, including, if possible, the quantitative effect of local populations in the cumulative effect in the region, (Section 110 (3)(d));

6.3.1 Description of disturbance history

If the site shows signs of disturbance, details should be provided of the site's disturbance history and an assessment should be made of the ability of the ecological community to recover to a pre-disturbance condition.

6.3.2 Extent of habitat removal

The location, nature and extent of habitat removal or modification which may result from the proposed action including the cumulative loss of habitat from the study area (including all proposed DAs and those areas in the subject area already with development consent or identified for development) and the impacts of this on the viability of the endangered and/or critically endangered ecological community in the locality.

This shall include an assessment of the proportion of the ecological community to be affected by the proposal, in relation to the total extent of the ecological community, and the impact of this on the viability of the ecological community in the locality.

6.4 Description of feasible alternatives

A description of any feasible alternatives to the action that are likely to be of lesser effect and the reasons justifying the carrying out of the action in the manner proposed having regard to the biophysical, economic and social considerations and the principles of ecologically sustainable development (Section 110(3)(e)).

Where a Statement of Environmental Effects (SEE), Environmental Impact Statement (EIS) or Review of Environmental Factors (REF) deals with these matters, the SIS may refer to the relevant section of the SEE, EIS or REF.

In the discussion of feasible alternatives to the proposed development with regards to biophysical, economic and social considerations, and the principles of ecologically sustainable development, the SIS must also include details on the condition and use of other parts of the subject area and why these can or cannot be considered as feasible alternatives.

7 AMELIORATIVE MEASURES

7.1 Description of ameliorative measures

A full description and justification of the measures proposed to avoid or mitigate any adverse effect of the action on the species and populations and ecological community including a compilation (in a single section of the statement) of those measures (Section 110 (2)(i) and Section 110 (3)(f)).

7.1.1 Long-term management strategies

Consideration shall be given to developing long-term management strategies to protect areas within the study area which are of particular importance for the threatened species, endangered populations or endangered / critically endangered ecological communities likely to be affected. This may include proposals to restore, improve or provide long term protection for habitat on site where possible. Any such proposal is to be accompanied by a plan of management identifying the specific areas to be restored, improved or protected, the threatened species / ecological community values of those areas, and detailing the management actions to be implemented to maintain and protect those values, including corrective actions to be taken in the event that monitoring indicates that management does not achieve specified objectives.

8 ASSESSMENT OF SIGNIFICANCE OF LIKELY EFFECT OF PROPOSED ACTION

An 'Assessment of Significance' (s. 5A EP&A Act) is to be provided for each of the affected species (threatened species, populations or ecological communities) identified in the SIS, incorporating relevant information from sections 5.1 to 7 of the SIS. On the basis of these assessments a conclusion is to be provided concerning whether, based on more detailed assessment through the SIS process and consideration of alternatives and/or ameliorative measures proposed in the SIS, the proposal is still considered likely to have a significant effect on threatened species, populations or ecological communities or their habitats.

The threatened species 'Assessment of significance' should be consistent with those procedures and assessment approaches contained within the OEH publication:

'*Threatened Species Assessment Guidelines: The Assessment of Significance*' (DECC – August 2007b). This document is available from the OEH's website: www.environment.nsw.gov.au/threatenedspecies/tsaguide.htm

9 ADDITIONAL INFORMATION

9.1 Qualifications and experience

A species impact statement must include details of the qualifications and experience in threatened species conservation of the person preparing the statement and of any other person who has conducted research or investigations relied on in preparing the statement (Section 110(4)).

9.2 Other approvals required for the development or activity

A list of any approvals that must be obtained under any other Act or law before the action may be lawfully carried out, including details of the conditions of any existing approvals that are relevant to the species or population or ecological community (Sections 110(2)(j) and 110(3)(g)).

In providing a list of other approvals the following shall be included:

- Where a consent is required under Part 4 of the *Environmental Planning and Assessment Act 1979*, the name of the consent authority and the timing of the development application should be included; or
- Where an approval(s) is required under Part 5 of the *Environmental Planning and Assessment Act 1979*, the name of the determining authority or authorities, the basis for the approval and when these approvals are proposed to be obtained should be included; or
- Where an approval(s) is required under *Native Vegetation Act 2003*, the name of the determining authority or authorities, the basis for the approval and when these approvals are proposed to be obtained should be included.

Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

An action will require the approval of the Federal Minister for the Environment (in addition to any State or Local Government approval or determination) if that action will have, or is likely to have, a significant impact on a matter of national environmental significance. Threatened species and communities listed in the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) are considered to be a matter of national environmental significance.

Many of the species and ecological communities listed in the *Threatened Species Conservation Act 1995* (NSW) are also listed in the Commonwealth EPBC Act. Further information regarding the operation of the EPBC Act (including Federally-listed threatened species and communities) may be obtained from the Commonwealth Department of Environment (DOE) website www.environment.gov.au/ or by contacting the DOE on (02) 6274 1111.

9.3 Licensing matters relating to the survey

Persons conducting flora and fauna surveys must have appropriate licences or approvals under relevant legislation. The relevant legislation and associated licences and approvals that may be required are listed below:

National Parks and Wildlife Act 1974:

- General Licence (Section 120) to harm or obtain protected fauna (this may include threatened fauna).
- Licence to pick protected native plants (Section 131).
- Scientific Licence (Section 132C) to authorise the carrying out of actions for scientific, educational or conservation purposes.

Threatened Species Conservation Act 1995:

- Licence to harm threatened animal species, and/or pick threatened plants and/or damage the habitat of a threatened species (Section 91).

Animal Research Act 1985:

- Animal Research Authority to undertake fauna surveys.

Typically you will require a licence under section 132C of the NPW Act to undertake an activity (e.g. survey) for scientific, educational or conservation purposes that is likely to result in one or more of the following:

- harm to any protected fauna, or to an animal that is a threatened species or is part of an endangered population or an endangered ecological community
- harm to any protected native plant, or any plant that is a threatened species or is part of an endangered population or an endangered ecological community. You will need a licence if you plan to collect voucher specimens for identification purposes, pick cuttings or whole plants, or collect seed
- damage to critical habitat
- damage to a habitat of a threatened species, an endangered population or an endangered ecological community.

Information pertaining to section 132C licences can be obtained from the following website:

www.environment.nsw.gov.au/wildlifelicences/ScientificResearchLicences.htm

Section 132C licences came into effect in January 2003 and replaced the previous need for separate licences under other provisions of the NPW Act and the TSC Act.

It is a condition of all licences that you submit a report of the work carried out under the licence, including any results and specific details / locations of all flora and fauna, to the OEH within two months of the expiry of the licence.

Also, be aware of the requirements relating to animal care and ethics when conducting wildlife surveys. The handling and capture of animals is regulated by the NSW *Animal Research Act 1985* and the *NSW Animal Research Regulation 1995*, which are administered by Department of Trade and Investment, Regional Infrastructure and Services. The Act requires that every person undertaking animal research must hold an Animal Research Authority. Under the Act, animal research includes the 'use' (e.g. handling, trapping etc.) of animals in field surveys. Details on animal ethics can be obtained from the following website:

www.animalethics.org.au/home

All surveys must be carried out in accordance with the NSW Department of Trade and Investment, Regional Infrastructure and Service's Guidelines for wildlife surveys located at:

www.animalethics.org.au/policies-and-guidelines/wildlife-research/wildlife-surveys

9.4 Section 110 (5) reports

Section 110(5) of the *Threatened Species Conservation Act 1995* has the effect of requiring the OEH to provide that information regarding the State-wide conservation status of the subject species that it has available, in order to satisfy ss.110(2)&(3) of the Act. These documents are available on the internet at:

www.environment.nsw.gov.au/threatenedspecies/index.htm

This website provides basic profiles for the majority of species listed as threatened, as well as links to the Scientific Committee determinations, more detailed profiles, environmental impact assessment guidelines and recovery plans, where these documents are available. The OEH is unable to provide any further information for section 110(5) reports.

Lord Howe Island Rodent Eradication Project

NSW Species Impact Statement
February 2017
Appendix B - DGR's Checklist

ATTACHMENT B:

CHECKLIST FOR DETERMINING IF AN SIS HAS MET THE REQUIREMENTS OF THE MINISTER ADMINISTERING THE THREATENED SPECIES CONSERVATION ACT 1995

Under the *Environmental Planning and Assessment Act 1979*, where a significant effect on threatened species, populations or ecological communities is likely, a development application must be accompanied by concurrence from the Minister administering the *Threatened Species Conservation Act 1995* (TSC Act). As such a species impact statement prepared in accordance with Division 2 of Part 6 of the TSC Act must accompany the application.

The development is taken not to significantly affect threatened species, populations or ecological communities, or their habitats if:

a) the development is to be carried out on biodiversity certified land (within the meaning of Part 7AA of the TSC Act, or

b) a BioBanking statement has been issued in respect of the development under Part 7A of the TSC Act.

Therefore, before deciding to issue consent or approval and consequently requesting the concurrence of the Minister administering the TSC Act, it is required of the consent or determining authority to determine whether the SIS meets the Director General's requirements (DGRs).

This checklist has been drawn up to assist consent and determining authorities in this matter. A comments column has been included to allow authorities to provide, among other things, reasons for their decisions or comments on whether an omission is significant.

Note that this is a generic checklist and some items may not be relevant to the application being reviewed or the Director General's requirements issued. If the requirements do not specify one of the matters below, then it is recommended that this be noted in the comments column. Consultants preparing an SIS may also use this checklist as a brief guide to preparing the SIS.

Matter	Yes/No	Comments
Has the SIS been signed by both its author and the applicant for consent/approval?	Yes	
Has the description of the proposal included all associated activities and works, such as hazard reduction zones, access roads and road upgrades, utilities, etc?	Yes	
Have all requested plans, maps and aerial photographs been provided? This includes any A1 or A0 sized proper survey plans prepared by a registered surveyor that clearly show the location and boundaries of any proposed offsets.	Yes	
Has the SIS determined the subject species by reviewing the suggested list in the DGRs, other available information and survey results and assessing which species, populations and ecological communities are to be impacted by the development?	Yes	

Matter	Yes/No	Comments
Has the survey undertaken provided sufficient information to determine the likely impacts of the proposal on threatened species, populations and ecological communities?	Yes	Species previously recorded have been included in the SIS and the entire LHI is subject to the proposal
Have surveys been undertaken during the appropriate season(s) for the detection of the species that may possibly occur on site?	Yes	see above
Have surveys been undertaken during appropriate weather conditions?	Yes	see above
Have climatic conditions preceding the surveys (e.g. drought c.f. wet) affected the possibility of subject species being detected?	Yes	see above
Have all specific survey methods, techniques and intensities requested in the DGRs been followed completely?	Yes	see above
Has the documentation of survey effort, locations and techniques provided sufficient information to determine the above?	Yes	see above
Has the assessment of impacts included the impacts of ALL activities associated with the development, including fire hazard reduction requirements, access road upgrades, downstream and downslope impacts, detention basins, severing of fauna movement corridors, etc.	Yes	
Has the SIS discussed the extent, conservation significance and security of other occurrences of the subject species' in the locality (locality is defined in the DGRs)?	Yes	
Has the SIS discussed the significance of the population/remnant to be affected, relative to others within the locality?	Yes	
Has the SIS discussed the extent, conservation significance and security of other occurrences of the subject species in the region (region is defined in the TSC Act).	Yes	
Has the SIS discussed the significance of the population/remnant to be affected, relative to others within the region?	Yes	
Have alternatives to the proposal been discussed? Alternatives may include relocation of infrastructure or, for example, reducing minimum lot size so that a similar number of lots may be realised whilst retaining a larger conservation lot within a subdivision, or changing mining techniques.	Yes	
Has the discussion of alternatives included assessment of the social and economic (not merely financial) aspects of these alternatives (particularly, of not proceeding)?	Yes	
Has the discussion included an assessment of how the project meets the principles of Ecologically Sustainable Development, as defined in section 6(2) of the *Protection of the Environment Administration Act 1991*?	Yes	

Matter	Yes/No	Comments
Have all proposals for compensatory actions (e.g. purchase of similar vegetation / habitat or revegetation of habitat, where appropriate) been discussed with the relevant landowners/manager?	Yes	
Is there documented agreement for sale or revegetation activities?	N/A	
Is there agreement to change zoning or enter into a covenant on title in order to secure the conservation of the properties being purchased or revegetated?	N/A	
If translocation is proposed, has the impact of the translocation on the recipient site(s) been assessed?	N/A	
Is there a 'Plan of Management' or similar titled document?	Yes	
Has the SIS utilised relevant information from published draft and final recovery plans? If no plan has been published, but it is known that one is being prepared, has the SIS utilised advice from the NPWS as to the likely contents of that recovery plan (liaison to obtain this advice may have been specified in the DGRs)? For example, would the proposal result in the loss of a local population or remnant that a recovery plan describes as being of particular importance to the conservation of the species, population or ecological community?	Yes	
If a BioBanking assessment has been done for the proposal have the following been provided: copies of BioBanking Credit reports, copies of field datasheets, and copies of a checklist that includes all data used in the credit calculator and the underlying assumptions, such as how local vegetation communities were assigned to BioMetric vegetation types?	N/A	
Has the SIS discussed the relationship of the proposal to any listed Key Threatening Processes (e.g. does the proposal result in the need for High Frequency Fire as a fire hazard reduction measure, or does it result in the Clearing of Native Vegetation)?	Yes	
Has the SIS discussed the relationship of the proposal to any published Threat Abatement Plan (e.g. does the proposal result in an increased threat in a manner that is specifically at odds with a published plan)?	Yes	
Has a revised Part 5A assessment of significance been included?	Yes	
Has the 'Additional Information' specified in section 9 of the DGRs been provided?	Yes	
Have the qualifications and experience of those involved in the surveys been included?	Yes	
Have other approvals which are required for the development or activity been documented?	Yes	
Any licensing requirements (e.g. s.91 under TSC Act).	Yes	

Lord Howe
ISLAND BOARD

Lord Howe Island Rodent Eradication Project

NSW Species Impact Statement February 2017

Appendix C - Captive Management Package

C.1 Taronga Zoo Captive Management Pilot Study Report

C.2 Taronga Zoo Captive Management Work Procedures

C.3 Taronga Zoo Captive Management Currawong Diet Sheet

C.4 Taronga Zoo Captive Management Woodhen Diet Sheet

C.5 LH Currawong Survey Report

C.6 LHI Woodhen Husbandry Manual

C.7 CM Indicative Facilities

C.8 CM Construction Management Plan

C.9 Woodhen Disease Profile

Captive management for Woodhen and LHI Currawong associated with the Lord Howe Island Rodent Eradication project

March 2014

This report details work that occurred in the provision of captive care of Lord Howe Island Woodhen and Lord Howe Island Currawong between July 22 and October 18 2013. It details some of the preparatory work, but concentrates on recommendations for proposed work an order of magnitude larger in 2017.

1. Executive Summary

The Lord Howe Island Board has been granted approximately $9 million to conduct an eradication program of introduced rats and mice from Lord Howe Island (LHI). This work is jointly funded through the Australian Government's Department of Environment, and the NSW Government's Environmental Trust and was announced on July 15 2012. The eradication will be via the dense distribution of a bait containing brodifacoum in a single 100 day baiting operation.

Ship rats are implicated in the extinction of at least five endemic birds and at least 13 invertebrates. They are also a recognised threat to at least 13 other bird species, 2 reptiles, 51 plant species, 12 vegetation communities and numerous threatened invertebrates[1].

Taronga Conservation Society Australia (Taronga) was contacted in July 2009 about potential involvement in the program. It initially played an advisory role, though with the clear intention of operational involvement should the funding application be successful.

A detailed risk assessment is presented which determines the risks to the environment (including wildlife, freshwater and marine habitats), humans, livestock and pets. Measures to ameliorate any adverse impacts are also detailed. These include the establishment of captive populations of a number of species: LHI woodhen, LHI pied currawong, LHI golden whistler, LHI silvereye and emerald ground-dove.[2]

Advice from the steering committee was that only woodhen and currawong were at such a risk that they required captive management. Ultimately, Taronga entered a Service Agreement with the Lord Howe Island Board, jointly agreed to a Captive Management Project Plan, and successfully submitted a budget predicated upon cost recovery. The project in 2013 was to design and test assumptions around animal husbandry, *in situ*, with both species of birds most at risk during the baiting program scheduled for 2016. Taronga designed enclosures and managed their construction on LHI. Taronga provided animal husbandry staff and veterinary services, and had staff live on LHI for the period of the trial, 22/7/13 - 18/10/13.

Taronga, through its Taronga Education Centre, were engaged to work with students of the Lord Howe Island Central School. Two educators, Paul Maguire and Nikki Bodel visited the Central School May 15 - 17 and commenced work. Unfortunately, some members of the deeply divided community of LHI wrote to the NSW Government and were successful in convincing the Central School to abandon that part of the project.

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[1] Lord Howe Island Board 2009, *Draft Lord Howe Island Rodent Eradication Plan*, Lord Howe Island Board, Lord Howe Island.

[2] *Ibid.*

2. Key Personnel and Contacts

Name, Position, Institution. Summary of role, communication, further contact required

- Paul Andrew, Curator, Taronga Zoo
  - Scientific advice; population management responsibilities
- Simon Duffy, General Manager, Life Sciences Research and Conservation, Taronga Conservation Society Australia
  - Taronga responsibility for project; financial responsibility
- Frances Hulst, Veterinary Officer, Taronga Zoo
  - Veterinary advice; clinical responsibilities on LHI at capture and release; point of contact for keepers on all veterinary matters
- Paul Maguire, Manager Learning and Experience, Taronga Conservation Society Australia
  - Managed school's education component
- Rodd Stapley, Australian Fauna Precinct Manager, Taronga Zoo
  - Responsible for all operational requirements including staffing and enclosure design.
- Erna Walraven, Senior Curator, Taronga Zoo & Taronga Western Plains Zoo
  - Main contact with Taronga Zoo Project Manager (Gary Fry).
- Mark Williams, Media Relations Manager, Taronga Conservation Society Australia
  - Taronga's media and public relations link.
- Hank Bower, Manager Environment/World Heritage, Lord Howe Island Board, hank.bower@lhib.nsw.gov.au
  - Initial primary contact on LHI
- Pete McClelland, Lord Howe Island Rodent Eradication Project Manager, Lord Howe Island Board, pete.mcclelland@lhib.nsw.gov.au
  - Manager, Rodent Eradication project
- Veronica Blazely, Director, National Natural Heritage, Department of the Environment, veronica.blazely@environment.gov.au
  - Australian Government funding
- Peter Dixon, Senior Manager Grants, Environmental Trust, NSW Government, peter.dixon@environment.nsw.gov.au
  - NSW Government funding
- Chia Moan, Partner and Director, Make Stuff Happen, chia.moan@makestuffhappen.com.au
  - Community engagement
- Gary Fry, Bio-logical, gary.fry.biological@gmail.com
  - Taronga Zoo Project manager

3. Reiteration of Goals

The Lord Howe Woodhen and Lord Howe pied Currawong are identified as being at risk from primary and secondary poisoning during the eradication project and a large proportion of the population need to be held in captive management for the duration that bait is expected to persist in the environment. 0.0.22 woodhen and 0.0.10 currawong will be held during a trial period to test assumptions of behaviour of the two species and determine the best methods of housing, maintaining and caring for the birds during the eradication project. Some woodhen will be held on mainland Australia, during at least the period the rodent eradication is underway, as a hedge against a catastrophic event on Lord Howe Island.

The project also becomes part of Taronga's 'Project Insitu' education program where Taronga's education team train and build the capacity within local school students to engage their local community to take action in helping save a locally threatened species. The goal of the project is motivate the students to become a part of the solution and for them to be challenged to create awareness and behaviour change in their local community[3].

The trial program tested a number of aspects of the program, other than the obvious and primary husbandry aspects. These are no less important and the relatively few changes required have been tabulated below.

Managing staffing requirements so that there was appropriate expertise and decision-making ability on LHI, without compromising the daily work at Taronga was important. The numbers of husbandry, veterinary and CWI and project staff who worked on LHI were judged at appropriate levels.

The provision of a house for those staff staying for long periods was appropriate, and for resort accommodation for those staff staying shorter periods, was also appropriate.

4. Outline of Activities/Timeline

Date	Activity	Note
7/2009	Taronga SMT advised of possible role for Taronga on LHI in project involving eradication of rodents.	Announcement of joint funding for this project by Australia and NSW governments was made 15/7/2012.
17 - 21/12/12	Gary Fry and Rodd Stapley visited LHI for site assessment.	
18/2/12	Agreement with OEH on numbers of birds to be brought into captivity.	This was set at 0.0.10 Currawong, and 0.0.20 Woodhen. Woodhen numbers were later lifted to 0.0.22 to avoid the need for a future application should there be deaths. This was unnecessary.
18/3/2013	LHIB in principle agreement of Taronga budget.	
8/4/2013	Commencement of Service Agreement for	

[3] **Error! Main Document Only.**LORD HOWE ISLAND BOARD Project Plan

Date	Activity	Note
	'Captive management for Woodhen and LHI Currawong associated with the Lord Howe Island Rodent Eradication project' between LHIB and Taronga.	
30/4/13	Purchase Order issued by Taronga to aviary manufacturers.	
15-17/5/13	Paul Maguire and Nikki Bodel worked with Central School students on LHI.	
10/6/13	Aviaries transported to and constructed on LHI.	
14/7/13	Three staff and a volunteer to LHI for commencement of captive phase.	
22/7/13	OEH commenced capturing birds and delivering to Taronga staff at aviaries.	Taronga Zoo Veterinarian present for this work.
8/8/13	First and only full communications meeting across all partners (LHIB, OEH, DSEWPaC, Taronga, Make Stuff Happen).	This meeting was facilitated by Taronga.
11/8/13	One staff member leaves LHI once birds settled and routines established.	The balance of 3 staff and 1 volunteer continued for the remainder of the captive phase.
18/10/13	All birds returned to OEH staff for release.	Taronga Zoo Veterinarian present for this work.
25/10/13	Final staff member and volunteer leave LHI having completed all works.	

5. Outcomes and Outputs

The trial program tested a number of aspects of the program, other than the obvious and primary husbandry aspects. These are no less important and the relatively few changes required have been tabulated below.

6. Conclusions and new knowledge / learnings

Project area	Problem / Issue	Solution / Note	Budget implication
Husbandry	Increased numbers of birds in 2017 will increase rubbish produced tenfold.	Access to vehicle twice per week to remove rubbish	Nil - use of LHIB vehicles
	Poor service with animal food delivery	Formal contract as per Taronga protocols with mainland supplier	Nil.
	Initial weight gain by Woodhen	All birds commence on 45g food each.	Nil.
	Currawongs regularly left food.	Reduce currawong diet to 1 cup.	Positive.
	Too much animal food	Experience of 2013 instructive	Positive.

Project area	Problem / Issue	Solution / Note	Budget implication
	ordered initially	for 2017.	
	Inability to medicate currawong	Include pinkies in diet	Negative (minimal)
	Earthworm harvesting time consuming for keepers.	Engage Lord Howe Islanders.	Nil.
	Chick starter too powdery.	Substitute with grain or pellet.	Nil.
	Animals (Currawong) being pre-fed ahead of capture to facilitate capture.	Use elements of captive diet to facilitate adaption to captive diet.	Minimal.
Veterinary	No baseline data on health of LHI currawong population	Conduct basic health assessment and disease screening of currawong prior to 2017, similar to what was done for Woodhen in 2007. Could be tied in with catch up for banding.	Negative. Pathology. Transport.
	Veterinary requirements	The presence of a clinician at the catch up of all birds, and at release, was considered a suitable amount of time on LHI.	Nil
Infrastructure	Restricted airflow in currawong aviaries	Suggest no shade-cloth at ends of aviaries, and shade-cloth in sections rather than full wall	Yes. Modified design.
	Possible dampness on floor of currawong aviary.	No leaf litter on floor of currawong aviary.	No
	Sand on base of currawong aviary.	Access to sand	No.
	Access to leaf-litter during baiting period.	Stockpile of leaf-litter for woodhen. Hand-baiting within period.	No
	Limited taps within aviaries.	Plumbing to more water points within complex	Yes
	Aviary doors unable to be latched closed from inside	Attach fittings to facilitate single person operation	Yes
	Woodhens dig beneath internal dividing walls	Increase depth of walls into ground	Yes
	Currawong aviaries – mesh rusting where welded to frames	Consider other attachment, especially if aviaries not to be single use	Yes
	Currawong aviaries had multiple entry points for mice: around keeper doors, between panels, beneath walls,	Better contract management; more stringent design	Yes
	Tool storage area within domes	Provide	Yes
	Require ability to subdivide	Design	Yes

Project area	Problem / Issue	Solution / Note	Budget implication
	woodhen pen during project if required		
	Domestic freezer space required to freeze leftover food to kill mealworms. Used domestic freezer in office area.	Design / purchase. Won't have access in 2017.	Yes
	Require walk-in cool-room for storage of food stuffs	Used cool-room north of office area	Yes
	Measure site for works for 2017.	Completed by Paul Fittolani, LHI Builder.	No.
School education	LHI Central School abandoned program when some families became strident in opposition.	Re-engage with Central School and determine best strategy to re-engage.	No – allowed for in 2016 budget
Media	Initial engagement with communications managers within other partners late.	Early engagement through LHIB.	No
Human Resources	Transport around LHI	One bike per staff member when on LHI	Yes.
	Confusion within staff group.	Clarity of Taronga delegations manual.	Nil.
	Communication with Taronga	Access to desk at Admin, or internet access at nursery	Yes
	Staffing	Establishment of staffing early to minimise disruption to the core work required at Taronga, and ensuring that the LHI project has the appropriate expertise.	Nil
	Staffing levels	Staffing levels were considered appropriate for this component of the project. Even though there were times that staff had completed work early, communication with LHI confirmed the need to maintain staffing levels should they be required in an emergency.	Nil
Logistics / project management	Current systems within Taronga not designed for management of large remote projects. Consequently, there were a number of procedural breaches within Taronga, especially around purchasing.	Work with Taronga departments to establish systems / protocols that pay heed to remote work on LHI.	Nil

Project area	Problem / Issue	Solution / Note	Budget implication
	Confusion over payment of freight costs.	All freight to be paid by LHIB under contract, and Taronga subsequently invoiced. Procedure established between LHIB and Taronga.	Yes. Expect reduced costs
	Staff rostering created challenges with contact re ordering.	Develop Standard Operating Procedure	Nil.
	Maintain kingfisher and / or emerald doves during baiting period.	Maintain 20:20 individuals sourced from across LHI. Assumption that will be maintained separately, in pairs for kingfisher and group for ground-doves in 50% of currawong aviary (doves and kingfishers)	Yes. Substantial impact.

7. Next steps/follow up

2017

Initial thinking was that the rodent eradication phase would occur in 2015. This is likely to now occur in 2017. It has become apparent that this project is more divisive within the Lord Howe Island community that was previously considered. The LHIB Rodent Eradication Project Manager is aware that Taronga is equally able to undertake this work in 2017 as it is in 2015. It is also understood that costs will be higher due to inflation.

All documentation within Taronga has been stored electronically at ELO Professional. This documentation has been assembled to ensure that future Taronga involvement can proceed making full use of what has been learned during the trial period of 2013. It is especially important that these documents are reviewed by a couple of staff members to ensure that all information required is present, and that the information is assembled in a manner enabling staff involved in 2017 to enter the project confidently.

Kingfishers and ground-doves

The LHIB Rodent Eradication Project Manager, Pete McClelland, has suggested that Taronga may be asked to take on husbandry for Sacred Kingfisher *Todiramphus* sanctus and Emerald Ground-dove *Chalcophaps indica*[4]. Taronga's initial response has been that it is likely to be able to undertake this husbandry.

Advice from Paul Andrew is that 10.10 individuals of both species would be sufficient as an insurance population. The husbandry recommendation from Rodd Stapley's team is that the kingfishers would be housed in pairs. It is suggested that the ground-doves could be housed in groups of 10. Both species would be held in aviaries of the design used for currawongs. The kingfisher pairs would only require 50% of the space that currawongs require.

It was suggested to Pete McClelland, Lord Howe Island Rodent Eradication Project Manager that in order to provide initial and very crude costings, we would house both species in the aviaries designed for the currawongs.

[4] Lord Howe Island Board 2009, Draft Lord Howe Island Rodent Eradication Plan, Lord Howe Island Board, Lord Howe Island.

Species	Double aviary cost 2013	Number of banks	Projected aviary cost 2017 assuming 8% inflation
Sacred Kingfisher	$12 800	2.5	$34 560
Emerald ground-dove	$12 800	1	$13 824

There has been no allowance made for transport of aviaries to Lord Howe Island. There will be about eleven times (11x) the number of aviaries constructed in 2017 than in 2013. It is unlikely that transport costs will be increased by a factor of eleven.

Staffing

It was determined that there was an adequate level of staff on Lord Howe Island in 2013. Indeed due to both species adapting to captivity better than expected, there was capacity within the keepers' working days to assume responsibilities for husbandry of Lord Howe Island Stick Insect during the 2013 trial. It is likely that once the birds are established, that these additional aviaries can be maintained by the 4 keepers budgeted for in initial quotes.

It is suggested however, that an additional keeper be allocated to assist with initial establishment. $4 800 should be allowed.

8. Financial acquittal – income and expenditure

SUMMARY	Budget	Actual to 31 Jan 2014	Interpretation
FUNDING			
Project Funding ex gst	$ 360,000.00	$ 360,000.00	
TOTAL FUNDING	**$ 360,000.00**	**$ 360,000.00**	
EXPENDITURE			
Animal Food	$ 6,500.00	$ 2,060.95	• Currawongs adapted to captive diet earlier than anticipated. Lead to less live food. • Dietary changes due to availability reduced cost.
Consultancy Fee	$ 80,000.00	$ 45,082.70	• Efficiencies and re allocation of tasks reduced the requirement of project manager. • Linked to overspend in salaries and wages
Contract Services	$ 77,000.00	$ 119,168.63	• Cost of bird holding and freight was $40K greater than estimated in the budget.
Laboratory Costs	$ 11,900.00	$ 1,571.20	• This was budgeted on worst case scenario of deaths and potential investigations. • Birds adapted better to captivity than anticipated.
Salaries & Wages	$ 130,600.00	$ 151,425.40	• Requirement for management and administration support was greater than anticipated. • Reallocation of tasks from Project Manager's role.
Travelling - airfare, accommodation,	$ 43,000.00	$ 21,642.14	• Able to place keeping staff on Island longer than anticipated and reduce

sustenance			number of flights. • Staff able to organise food delivery and cost effective options. • Did not send media, education or management staff as per budget.
Ancillary Costs	$ 9,000.00	$ 13,089.37	• Included freight costs that were not anticipated.
TOTAL EXPENDITURE	**$ 358,000.00**	**$ 354,040.39**	
NET RESULT	**$ 2,000.00**	**$ 5,959.61**	

Budget Implications for 2017

It is recommended that staffing, aviary, transport, animal food costs and inflation to be revisited, as detailed in the report, once the plan for 2017 is confirmed. The figures above should not be used as the only tool for 2017 budget projections.

1 Description of Facilities

The Taronga Zoo Lord Howe Island Project team is responsible for the husbandry and maintenance of the Lord Howe Woodhen and Lord Howe Currawong for the duration of the captive trial.

2 Overview of Work Routine

Two Senior keeping staff will be present for the duration of the trial, assisted by two volunteers. An additional keeper, veterinary staff and project manager will be present for the commencement and conclusion of the trial.

Keeping Work Routines

TIME	TASK/ACTIVITY
7:00-7:30	Morning Check – Sight aviaries for sick/injured/dead birds. Perimeter pest inspection
7:30-10:00	Husbandry Duties: AM Feeds Observing Woodhen closely to ensure no birds being denied food. Cleaning Sight animals Exhibit security Report to Aus Fauna Manager Mon-Fri (weekends by exception)
10:00-10:15	Morning Tea
10:15-11:00	Food Prep
11:00-12:00	Miscellaneous tasks where appropriate: Catching birds Browse collection Pest control Aviary maintenance Attending to sick/injured birds Community Education Bird Monitoring and Observations Leaf litter collection
12:00-13:00	Lunch
13:00-14:00	Afternoon feeds
14:00-14:30	Cleaning buckets, dishes, kitchen
14:30-15:00	Records Administrative tasks Afternoon perimeter pest inspection Lock up facility

Volunteer Work Routines (Min. 4 hours)

TIME	TASK/ACTIVITY

7:00-10:00	**Assist keeping staff with husbandry Duties:** **AM Feeds** **Cleaning** **Sight animals – record each bird as it is feeding.**
10:00-10:15	**Morning Tea**
10:15-12:00	**Assist with miscellaneous keeping tasks** **Collect browse** **Facilitate school group worm/food collections** **Assist with general husbandry** **Food prep**
12:00-13:00	**Lunch**
13:00-15:00	**Assist with afternoon feeds** **Clean buckets, dishes, kitchen**

2.1 General Notes

- Volunteers must always initially be supervised by a staff member when carrying out husbandry tasks such as food preparation and browse collection. The volunteer can then undertake the work unsupervised at the mentor's discretion.
- It is important that keepers report to AFP manager on a daily basis via fax or email, outlining the day's activities and any issues that have arisen.
- Staff are required to wear full Taronga uniform in working time. Taronga uniform is not to be worn outside work hours.
- Aviary security is paramount. All staff (keepers and volunteers) must ensure that keys to aviaries are kept in a secure place at all times.
- Staff are required to read MSDS prior to use to ensure all safety measures are in place prior to handling and use of chemicals on section. Personal Protective Equipment (PPE) which must be worn at all times where stated and safe handling procedures adhered to in accordance with HR.10.5 Chemical management policy.
- Staff are required to read the Service Agreement between the LHIB and the TCSA - 'Captive management for Woodhen and LHI Currawong associated with the Lord Howe Island Rodent Eradication project'
- Always check exhibit integrity when servicing animals

2.2 Expected Standards of Conduct

2.2.1 *Be informed*

It is your responsibility to check relevant procedural and daily documentation etc to bring yourself up to date with current animal behaviours, health treatments and other activities. It is your responsibility to ensure appropriate information and messages are effectively communicated to other keeping staff and/or AFP manager so that everyone is aware of what has gone on.

Majority of animals and all enclosures should be checked as soon as possible each morning. Rectify any problems immediately.

Check for signs of ill health (including condition of faeces), moult, aberrant or aggressive behaviour and reproductive activity. Where a specimen cannot be found during any inspection advise workmates immediately and take decisive action. If still not found inform Unit Supervisor/Manager immediately.

Animal Observation Guide (Check the following for signs of good health)

- Feathers bright and sleek (not fluffed up)
- Eyes bright and round
- Locomotion free and without limping
- Obvious intake of food by individuals
- Specimens freely moving around exhibit (not hiding in corners and away from others)
- Wounds or blood on animal
- Droppings well formed and appear normal for species
- No excessive signs of aggression or stress (excessive pacing, panting)
- No signs of stereotypic behaviour

2.2.2 *Movement in enclosures*

When working in enclosures, move slowly and deliberately. Allow the animals to predict where you are going and when moving into the main part of an enclosure move up the sides rather than straight up the middle to allow animals a clear path to avoid you if they want to. If the exhibit or aviary is low roofed keep as low as possible. When more than one person is working in the same exhibit, work in similar parts of the enclosure to allow quiet areas for the animals to escape to.

2.2.3 *Animal Diets*

Animals must be fed in accordance with approved animal diet sheets (located in ELO), including enrichment and browse. Any changes, such as additions/subtractions and substitutions must be raised with the project manager and authorised by the veterinary team before being implemented.

2.2.4 *Occupational Health and Safety Considerations*

It is up to each individual (keeper or volunteer) to be responsible for the health and safety of themselves, other staff, the visitors and the animals. Ensure any breaches of OHS are identified as soon as possible and brought to the appropriate person's attention. Potential risks or incidents should be rectified immediately and reported to AFP Manager

Ensure you are aware of and abide by OHS policy in regard to the use of all chemicals and equipment on your section. PPE must be worn where required.

Personal hygiene is an important factor in regards to transmission of zoonotic diseases. Hand washing facilities are available and should be made full use of both before and after dealing with any animals.

3 Administration

It is the responsibility of the Precinct Manager to oversee the review of all procedures as needed. The Life Sciences Operations Manager should be notified of changes or updates of procedures. All procedures are located in ELO and in hard copy form in the office at the LHI nursery.
Suitable issues may be raised with the LHI Environmental Officer Hank Bower after advice is sought from AFP Manager.

3.1 Reporting

Daily phone reports will be made to the Manager Aus Fauna mon-fri and by exception as required on weekends. Phone numbers can be called in the following order via phone located in the nursery office.

- Rodd Stapley mobile (0459824197)
- Shannon Parker Mobile (0408694689)
- Nick de Vos mobile (0422 024 384)

Bird related health issues will be reported immediately to on site/on call Vet Frances Hulst on 99324 369.
Daily report sheet including ordering requests and animal information and will be faxed through daily to 02 9978 4613.

SPECIES: Lord Howe Pied Currawong (*Strepera graculina crissalis)*

ZOO DIVISION:
Australian Fauna Precinct

GROUP COMPOSITION:
1.1 Housed on Lord Howe Island

NATURAL DIET:
Omnivorous. Take wild variety of fruit and seeds particularly outside breeding season; Invertebrates, mainly insects and small vertebrates, mostly small birds and their and their eggs and nestlings. (Marchant & Higgins 1990).

BODY WEIGHT RANGE FOR WILD MALES AND FEMALES:
Males 320g, Females 280g (Marchant & Higgins 1990).

TARONGA CONSERVATION SOCIETY AUSTRALIA DIET:

FOOD ITEM	MON	TUES	WED	THURS	FRI	SAT	SUN
Insectivore Mix	53g	53g	53g	53g	53g	53g	53g
Carnivore Mix	57g	57g	57g	57g	57g	57g	57g
Frugivore Mix	112.5g	112.5g	112.5g	112.5g	112.5g	112.5g	112.5g
Mealworms	25g	25g	25g	25g	25g	25g	25g
Enrichment							
Crickets	5g			5g			

Diet preparation: Insectivore, carnivore and frugivore mix is prepared as outlined below and placed separately on a shallow metal dish.
Mealworms are fed out live.

Recipe mixes:
Insectivore Mix
760g Vetafarm Insectivore Powder
1.8kg Eggs (33 x 55g eggs, hard-boiled)
715g Fly pupae

Place Insectivore Mix into a bucket. Using 6 hard-boiled eggs at a time, cut eggs in half and blend them in the food processor. Using short bursts of power closely monitor the state of the eggs. Ensure that they are of a rough consistency (not too large, but not stuck together and mushy). Repeat with the rest of the eggs. Place eggs into bucket over Insectivore Mix and then place fly pupae on top. Do not mix together, place in fridge until the next morning.
The following morning, mix all ingredients together. Add enough water enough to get ingredients to bind together without becoming wet and sticky.

Vetafarm Insectivore Powder

Ingredients: wheat, corn, soybean, vegetable oil, fish meal, canthaxanthin, pyridoxine hydrochloride (13.34mg/kg), dicalcium phosphate, salt, choline chloride, DL-methionine, menadione dimethylpyrimidinol bisulphite (vitamin K 7.11mg/kg), thiamine mononitrate (14.66 mg/kg), vitamin A acetate (13.33IU/g), cholecalciferol (vitamin D_3 IU/g), biotin, folic acid (1.29mg/kg), ethoxyquin, zinc oxide, vitamin B_{12} supplement (23.77mcg/g), calcium pantothenate (B_5 40.77mg/kg), riboflavin (B_2 27.25mg/kg), nicotinic acid, ferrous sulphate (174.89mg/kg), copper sulphate (31.15mg/kg), L-lysine, threonine, manganous oxide (124.68mg/kg), zinc sulphate (101.35mg/kg), calcium carbonate, cobalt carbonate, sodium selenite, niacin (B_3 157.91mg/kg), Vitamin C (17.85mg/kg).
Composition: Protein 36%, Fat 5%, Fibre 6%, Salt 0.5%, Calcium 2.88%, Phosphorus 1.33%, Magnesium 0.2%, Potassium 1.14%, Arginine 1.67%, Histidine 0.65%, Linoleic Acid 0.61%, Isoleucine 1.24%, Leucine 2.12%, Methionine 0.76%,
Manufacturer: Vetafarm

Frugivore Mix:
1.1kg Sultanas
1.0kg Currants
910g Apples (diced in ~5mm pieces)
1.2kg Pears (diced in ~5mm pieces)
1.2kg Grapes or Kiwi (if available)
1.5kg Paw Paw (if available)
1.4kg Corn
1.4kg Frozen Berries (optional as a transition)
440g Chopped endive
1.2kg Paradise Pellets (optional)

Place sultanas and currants at the bottom of a bucket and mix together. Cut off ends of apples and pears, and any bruises before finely dicing. Place finely chopped apples, then pears, on top. If pears are slightly mushy, place in a metal tub lined with paper towel, instead of putting them straight into the red bucket. Place the chopped grapes in a paper towel lined tub and place on top of mix – the bucket goes into the fridge.
The following morning mix ingredients from the bucket together in a large plastic tub, and add the chopped fruit including freshly diced pawpaw (this will be chopped by keepers in morning), fine greens, paradise pellets, frozen berries and frozen corn, and mix.

Paradise Pellets
Ingredients: wheat, corn, soybean, vegetable oil, fish meal, canthaxanthin, pyridoxine hydrochloride (B_6 9.66mg/kg), dicalcium phosphate, salt, choline chloride, DL-methionine, menadione dimethylpyrimidinol bisulphite (vitamin K 4.78mg/kg), thiamine mononitrate (11.45mg/kg), vitamin A acetate (10.59 IU/g), cholecalciferol (vitamin D_3 2.24 IU/g), biotin, folic acid (0.35mg/kg), ethoxyquin, zinc oxide (65.2 mg/kg), vitamin B_{12} supplement (0.08mcg/g), calcium pantothenate (B_5 25.93mg/kg), riboflavin (B_2 15.48mg/g), nicotinic acid, ferrous sulphate (Iron 57.52mg/kg), copper sulphate, L-lysine, threonine, manganous oxide (87.48mg/kg), zinc sulphate (64.2mg/kg), calcium carbonate, cobalt carbonate, sodium selenite, niacin (B_3 100.17mg/kg), vitamin C (370.90mg/kg), copper (21.73mg/kg), iron (57.52mg/kg).

Composition: Protein 19.36%, Fibre 2.31%, Fat 10.33%, Ash 3.83%, calcium 1.14%, phosphorus 0.53%, magnesium 0.10%, potassium 0.66%, linoleic acid 1.32%, arginine

0.98%, histidine 0.44%, isoleucine 0.82%, leucine 1.36%, methionine 0.45%, phenylalanine 0.96%, tyrosine 0.39%, tryptophan 0.24%, valine 0.87%.
Manufacturer: Vetafarm

Carnivore Mix

1.7kg Dog Kibble – Pedigree Small Breed
850ml Water
564g Wombaroo Insectivore Powder
1kg Kangaroo Mince

Place dog kibble in bucket and add water, stirring well. Leave to soak for approximately 2 hours, stirring periodically to make sure that all dog kibble is moist. Once thoroughly moist, and water has been totally absorbed, add the Wombaroo Insectivore Powder. Mix the kibble and powder thoroughly and refrigerate overnight.

The following morning, mix the ingredients from the bucket thoroughly in a rectangular plastic tub, and break the kangaroo mince into very small pieces so that it is evenly distributed throughout the rest of the meat mix. Ad-lib small amounts of Wombaroo insectivore powder while mixing the ingredients so it is not too sticky. The Carnivore Diet should be mixed to a consistency that clumps in the hand when squeezed together but breaks apart easily.

Dog Kibble – Pedigree Small Breed
Ingredients: meat and meat byproduct, whole grain sorghum, wheat or barley, wheat bran, glycerol, sunflower oil, beet pulp, salt, minerals, vitamins, preservatives, antioxidants, food coloring.
Composition: Protein 22%, Fat 10%, Omega-6 1.6%, Omega-3 0.1%, NaCl 1.2%, Fibre 3.5%, B_1 0.5mg/100g, B_2 1mg/100g, Vitamin C 5mg/100g, Vitamin E 16mg/100g, Calcium 950mg/100g, Phosphorus 760mg/100g, Magnesium 160mg/100g, Iron 15mg/100g, Zinc 33mg/100g.
Manufacturer: Pedigree Small Breed

Wombaroo Insectivore Powder
Ingredients: whey protein, soy protein, meat meal, fish meal, blood meal, cereal bran, mannan oligosaccharides, Beta-glucans, lysine, methionine, vegetable oils, omega-3 and omega-6 fatty acids, carotenoids, vitamins A, B_1, B_2, B_6, B_{12}, C, D_3, E, K, nicotinamide, pantothenic acid, biotin, folic acid, choline, inositol, calcium, phosphorus, potassium, sodium, magnesium, zinc, iron, manganese, copper, iodine, selenium.
Composition: Protein 52%, Fat 12%, Fibre 5%, Salt 0.8%.
Manufacturer: Wombaroo

Individual animal variations: None

Feed method: The Insectivore, Carnivore and Frugivore Mixes are placed on a shallow metal dish on tray or wire rack in the enclosure. Water is supplied in a metal bowl on the ground or in ponds in the enclosure. Mealworms and occasionally crickets are scattered on the ground and enclosure furniture during afternoon feeds. The halved banana or kiwi is spiked in the enclosure.

Diet Updates:

Date:	Diet change:	Approved by*:

* Precinct Manager or Unit Supervisor **and** a veterinarian

References: Marchant, S & Higgins, P.J. (1990). Handbook of Australian, New Zealand & Antarctic Birds Volume 7A. Oxford University Press. Melbourne.

Date of original diet submission: 08/01/2013 M. Shiels.
Date of last review: 07/02/2012

DIV 3.6 Diet Sheet

SPECIES: Lord Howe Island Woodhen - *Gallirallus sylvestris*

ZOO DIVISION:
Australian Fauna Precinct

GROUP COMPOSITION:
20.20.0 in a 7m x 7m

NATURAL DIET:
Mainly worms insect larvae and crustaceans. They dig into ground up to 10cm and chisel into wood (Marchant & Higgins 1990).

BODY WEIGHT RANGE FOR WILD MALES AND FEMALES:
Males & Females: 220g (Marchant & Higgins 1990).

TARONGA CONSERVATION SOCIETY AUSTRALIA DIET:

FOOD ITEM	MON	TUES	WED	THURS	FRI	SAT	SUN
Insectivore Mix	½ cup	½ cup	½ cup	½ cup	½ cup	½ cup	½ cup
Carnivore Mix	1 cup	1 cup	1 cup	1 cup	43.75g	43.75g	43.75g
Frugivore Mix	¼ cup	¼ cup	¼ cup	¼ cup	1 cup	1 cup	1 cup
Mealworms	10g	10g	10g	10g	10g	10g	10g
Crickets	10g	10g	10g	10g	10g	10g	10g

Diet preparation: Insectivore, carnivore and frugivore mixes are prepared as outlined below, measured out and placed separately on a shallow metal dish.
Mealworms and crickets are fed out live.

Recipe mixes:
Insectivore Mix
760g Vetafarm Insectivore Powder
1.8kg Eggs (33 x 55g eggs, hard-boiled)
715g Fly pupae

Place Insectivore powder into a bucket. Using 6 hard-boiled eggs at a time, cut eggs in half and blend them in the food processor. Using short bursts of power closely monitor the state of the eggs. Ensure that they are of a rough consistency (not too large, but not stuck together and mushy). Repeat with the rest of the eggs. Place eggs into bucket over Insectivore Mix and then place fly pupae on top**.** Do not mix together, place in fridge until the next morning.
The following morning, mix all ingredients together. Add enough water enough to get ingredients to bind together without becoming wet and sticky.

Vetafarm Insectivore Powder
Ingredients: wheat, corn, soybean, vegetable oil, fish meal, canthaxanthin, pyridoxine hydrochloride (13.34mg/kg), dicalcium phosphate, salt, choline chloride, DL-methionine, menadione dimethylpyrimidinol bisulphite (vitamin K 7.11mg/kg), thiamine mononitrate (14.66 mg/kg), vitamin A acetate (13.33IU/g), cholecalciferol (vitamin D_3 IU/g), biotin, folic

acid (1.29mg/kg), ethoxyquin, zinc oxide, vitamin B_{12} supplement (23.77mcg/g), calcium pantothenate (B_5 40.77mg/kg), riboflavin (B_2 27.25mg/kg), nicotinic acid, ferrous sulphate (174.89mg/kg), copper sulphate (31.15mg/kg), L-lysine, threonine, manganous oxide (124.68mg/kg), zinc sulphate (101.35mg/kg), calcium carbonate, cobalt carbonate, sodium selenite, niacin (B_3 157.91mg/kg), Vitamin C (17.85mg/kg).
Composition: Protein 36%, Fat 5%, Fibre 6%, Salt 0.5%, Calcium 2.88%, Phosphorus 1.33%, Magnesium 0.2%, Potassium 1.14%, Arginine 1.67%, Histidine 0.65%, Linoleic Acid 0.61%, Isoleucine 1.24%, Leucine 2.12%, Methionine 0.76%,
Manufacturer: Vetafarm

Frugivore Mix:
1.1kg Sultanas
1.0kg Currants
910g Apples (diced in ~5mm pieces)
1.2kg Pears (diced in ~5mm pieces)
1.2kg Grapes or Kiwi (if available)
1.5kg Paw Paw (if available)
1.4kg Corn
1.4kg Frozen Berries (optional as a transition)
440g Chopped endive
1.2kg Paradise Pellets (optional)

Place sultanas and currants at the bottom of a bucket and mix together. Cut off ends of apples and pears, and any bruises before finely dicing. Place finely chopped apples, then pears, on top. If pears are slightly mushy, place in a metal tub lined with paper towel, instead of putting them straight into the red bucket. Place the chopped grapes in a paper towel lined tub and place on top of mix – the bucket goes into the fridge.
The following morning mix ingredients from the bucket together in a large plastic tub, and add the chopped fruit including freshly diced pawpaw (this will be chopped by keepers in morning), fine greens, paradise pellets, frozen berries and frozen corn, and mix.

Paradise Pellets
Ingredients: wheat, corn, soybean, vegetable oil, fish meal, canthaxanthin, pyridoxine hydrochloride (B_6 9.66mg/kg), dicalcium phosphate, salt, choline chloride, DL-methionine, menadione dimethylpyrimidinol bisulphite (vitamin K 4.78mg/kg), thiamine mononitrate (11.45mg/kg), vitamin A acetate (10.59 IU/g), cholecalciferol (vitamin D_3 2.24 IU/g), biotin, folic acid (0.35mg/kg), ethoxyquin, zinc oxide (65.2 mg/kg), vitamin B_{12} supplement (0.08mcg/g), calcium pantothenate (B_5 25.93mg/kg), riboflavin (B_2 15.48mg/g), nicotinic acid, ferrous sulphate (Iron 57.52mg/kg), copper sulphate, L-lysine, threonine, manganous oxide (87.48mg/kg), zinc sulphate (64.2mg/kg), calcium carbonate, cobalt carbonate, sodium selenite, niacin (B_3 100.17mg/kg), vitamin C (370.90mg/kg), copper (21.73mg/kg), iron (57.52mg/kg).

Composition: Protein 19.36%, Fibre 2.31%, Fat 10.33%, Ash 3.83%, calcium 1.14%, phosphorus 0.53%, magnesium 0.10%, potassium 0.66%, linoleic acid 1.32%, arginine 0.98%, histidine 0.44%, isoleucine 0.82%, leucine 1.36%, methionine 0.45%, phenylalanine 0.96%, tyrosine 0.39%, tryptophan 0.24%, valine 0.87%.
Manufacturer: Vetafarm

Carnivore Mix
1.7kg Dog Kibble – Pedigree Small Breed

DIV 3.6 Diet Sheet

850ml Water
564g Wombaroo Insectivore Powder
1kg Kangaroo Mince

Place dog kibble in bucket and add water, stirring well. Leave to soak for approximately 2 hours, stirring periodically to make sure that all dog kibble is moist. Once thoroughly moist, and water has been totally absorbed, add the Wombaroo Insectivore Powder. Mix the kibble and powder thoroughly and refrigerate overnight.

The following morning, mix the ingredients from the bucket thoroughly in a rectangular plastic tub, and break the kangaroo mince into very small pieces so that it is evenly distributed throughout the rest of the meat mix. Ad-lib small amounts of Wombaroo insectivore powder while mixing the ingredients so it is not too sticky. The Carnivore Diet should be mixed to a consistency that clumps in the hand when squeezed together but breaks apart easily.

Dog Kibble – Pedigree Small Breed
Ingredients: meat and meat byproduct, whole grain sorghum, wheat or barley, wheat bran, glycerol, sunflower oil, beet pulp, salt, minerals, vitamins, preservatives, antioxidants, food coloring.
Composition: Protein 22%, Fat 10%, Omega-6 1.6%, Omega-3 0.1%, NaCl 1.2%, Fibre 3.5%, B_1 0.5mg/100g, B_2 1mg/100g, Vitamin C 5mg/100g, Vitamin E 16mg/100g, Calcium 950mg/100g, Phosphorus 760mg/100g, Magnesium 160mg/100g, Iron 15mg/100g, Zinc 33mg/100g.
Manufacturer: Pedigree Small Breed

Wombaroo Insectivore Powder
Ingredients: whey protein, soy protein, meat meal, fish meal, blood meal, cereal bran, mannan oligosaccharides, Beta-glucans, lysine, methionine, vegetable oils, omega-3 and omega-6 fatty acids, carotenoids, vitamins A, B_1, B_2, B_6, B_{12}, C, D_3, E, K, nicotinamide, pantothenic acid, biotin, folic acid, choline, inositol, calcium, phosphorus, potassium, sodium, magnesium, zinc, iron, manganese, copper, iodine, selenium.
Composition: Protein 52%, Fat 12%, Fibre 5%, Salt 0.8%.
Manufacturer: Wombaroo

Individual animal variations: None

Feed method: The Insectivore, Carnivore and Frugivore Mixes are placed on a shallow metal dish on tray or wire rack in the enclosure. Water is supplied in a metal bowl on the ground or in ponds in the enclosure. Mealworms and occasionally crickets are scattered on the ground and enclosure furniture during afternoon feeds. The halved banana or kiwi is spiked in the enclosure.

Diet Updates:

Date:	Diet change:	Approved by*:

Life Sciences & Environmental Education

Life Sciences Operations

DIV 3.6 Diet Sheet

* Precinct Manager or Unit Supervisor **and** a veterinarian

References: Marchant, S & Higgins, P.J. (1990). Handbook of Australian, New Zealand & Antarctic Birds Volume 7A. Oxford University Press. Melbourne.

Date of original diet submission: 21/12/2012
Date of last review: 21/12/2012

Department of
Environment and Conservation (NSW)

Population size and distribution of the Lord Howe Currawong *Strepera graculina crissalis*

Nicholas Carlile and David Priddel

January 2007

Report prepared for the Lord Howe Island Board
by the Department of Environment and Conservation (NSW)

Executive summary

In October 2005 the Threatened Fauna Ecology Unit of the Department of Environment and Conservation (NSW) commenced an ecological study of the Lord Howe Currawong *Strepera graculina crissalis* on Lord Howe Island. The aim was to gather sufficient ecological information on the Currawong which, in turn, could be used to safeguard the bird from possible risks associated with any rodent eradication program undertaken on Lord Howe Island.

The objectives of the study were to (1) determine the population size and distribution of the Lord Howe Currawong; (2) determine the home range and movement patterns of individual birds; (3) identify threats to, and limiting factors of, the subspecies; (4) provide incidental observations relating to Currawong interactions with other avian species; (5) develop techniques and procedures, including an annual monitoring program, to assess future trends in population size; and (6) examine temporal changes in trappability. Information was also gathered about the breeding and foraging ecology of the subspecies, as well as diagnostic characteristics to distinguish between subspecies, age classes and sexes.

Fieldwork was undertaken during nine visits to the island between October 2005 and July 2006. In all, 190 individuals were captured and individually colour banded. The population size was estimated at 215 ± 11 birds (including 48 juveniles). The probable inaccuracy of previous population estimates makes it uncertain as to whether the apparent increase in population size reflects real population growth.

The Lord Howe Currawong is found only on Lord Howe Island and nearby islets. It occurs throughout the island, but breeds primarily in undisturbed forests. During the breeding season pairs established, occupied and defended a territory of approximately 5.4 ha. Based on the expanse of potential nesting habitat we estimate that Lord Howe Island can support no more than 124 breeding pairs. Outside the breeding season, most birds aggregated into small flocks that were not wide-ranging.

Two hundred and twelve sightings were recorded, of which 72.2% involved observations of birds that were seen at the same locale as they had been recorded previously. A further 9.0% of sightings were within 1 km of their previous recorded location, 10.4% were 1–2 km distant, and 2.4% were 2–3 km distant. Only 13 movements (6.1%) were greater than 3 km away from the previous recorded sighting. The longest movement recorded (by two birds) was between Mount Gower and Middle Beach Road, a distance of approximately 6.4 km. Birds that regularly received food from residents or tourists were never seen more than a few hundred metres from these feeding sites.

Other evidence confirmed the sedentary nature of the Lord Howe Currawong. Of 30 birds banded on Mount Gower during 2000–01, four were trapped or sighted during this current study; all were either on Mount Gower or in nearby Erskine Valley.

The extent of available nesting habitat appears to be the key factor limiting the numbers of Lord Howe Currawong. However, illegal shooting remains a threat to the population. A high number of genetic deformities suggest that inbreeding may also threaten the viability of this particular subspecies.

Observed interactions with other avian species were few. Reported interactions mostly involved predation by Currawongs on White Terns *Gygis alba*. These interactions, while causing the failure of some nesting attempts, have not been sufficient to halt the expansion of the White Tern population on Lord Howe Island.

There is no empirical evidence of a historical decline (or increase) in population size of the Lord Howe Currawong, but accurate data are lacking. Although the estimate of current population size exceeds any previous estimate, past estimates of population size have not been derived with sufficient accuracy to gauge past population trends with any degree of confidence. This study provides a one-off measure of the size of the Currawong population on Lord Howe Island. Further regular monitoring is necessary to determine inter-annual variation in numbers and population trends. An annual monitoring program undertaken in September using mark-recapture analysis of banded birds is recommended.

Adult Currawongs can be trapped in reasonable numbers only during the period July–October. Outside this period they are difficult to trap.

Courtship began in September and nesting commenced in October. Hatching occurred between late October and late December. Fledglings left the nest between late December and late February. Overall, 41% of nests successfully produced at least one fledgling. The mean number of fledglings produced was 0.8 ± 0.3 (range 0–3) per nesting attempt, 1.1 ± 0.4 (range 0–5) per breeding pair, and 2.0 ± 0.3 (range 1–3) per successful nest.

The nest was located 4.5–20.0 m above ground in trees that were 5.5–25.0 m tall. A variety of tree species were used, the most common being Banyan *Ficus macrophylla*, Blackbutt *Cryptocarya triplinervis*, and Scalybark *Syzygium fullagarii*. Median brood size was two.

Typically, the male did not feed the female during incubation. Instead, the female left the nest every 21 minutes during daylight to forage for periods averaging 6.0 minutes. Although both parents fed the chicks, females provided 70% of feeds. Invertebrates (mainly beetle larvae and cicadas) were the most common food item (65.8% by frequency). Vertebrates (most notably the introduced Grass Skink *Lampropholis delicata*) comprised 21.2% of food items delivered to nestlings. The proportion on vertebrates fed to chicks increased with age of the chick. Fruit comprised 12.9% of the food items fed to chicks.

The Lord Howe Currawong has an eye colour that is different to that of the mainland subspecies (orange rather than yellow). The lighter colouration of the lower mandible and the presence of a yellow gape can be used to distinguish juveniles. Sexes can probably be differentiated on the basis of bill (culmen) length. All captured adults known to be male had culmen lengths of at least 66 mm, whereas the culmen length of birds known to be female was less than 66 mm. Males also possess a sex-specific call used in establishing and maintaining their territory.

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Project overview

Background

The Lord Howe Island Board, in partnership with the Foundation for National Parks, commissioned the Threatened Fauna Ecology Unit of the Department of Environment and Conservation (NSW) to undertake ecological research on the Lord Howe Currawong *Strepera graculina crissalis*. The aim was to gather sufficient ecological information on the Currawong which, in turn, could be used to safeguard the bird from possible risks associated with any rodent eradication program undertaken on Lord Howe Island. The Lord Howe Currawong is one of the non-target species on Lord Howe Island that is potentially most at risk from any rodent baiting program (Saunders and Brown 2001).

Findings from this research will be used in the preparation of a Species Impact Statement required as part of the approval process for any rodent eradication program undertaken on Lord Howe Island. Additionally, the findings will add to our understanding of the ecology of the Lord Howe Currawong and enhance the scientific basis for its management and conservation on Lord Howe Island.

The initial contract was extended following the observation that the trappability of the Lord Howe Currawong varied temporally. This report, compiled after the additional component was completed, is the final report for the project. It fulfils the reporting schedule outlined in the contract (and the subsequent extension) between the Department of Environment and Conservation (NSW) and the Lord Howe Island Board. The findings of this study will form the basis of several papers to be published in appropriate peer-reviewed scientific journals.

Project objectives

The objectives of the project, as stated in the contractual brief, were to:

1. Determine the population size and distribution of the Lord Howe Currawong.
2. Determine the home range and movement patterns of individual birds.
3. Identify threats to, and limiting factors of, the subspecies.
4. Provide incidental observations relating to Currawong interactions with other avian species.
5. Develop techniques and procedures, including an annual monitoring program, to assess future trends in population size.

A further objective was subsequently added:

6. Examine temporal changes in trappability.

During the course of the study the opportunity arose to gather additional information about the ecology of the subspecies; information which would be useful for the long-term management of the species on Lord Howe Island. Additional objectives associated with this material were to:

7. Describe nesting sites and document nesting behaviour.
8. Assess breeding success.
9. Investigate the range of food items fed to nestlings.
10. Identify diagnostic characters to distinguish between subspecies, ages and sexes.

Fieldwork schedule

Fieldwork was undertaken during five visits (of approximately 10-days duration) to the island between October 2005 and January 2006 and four shorter visits between February and July 2006. The duration of each trip and the activities undertaken are contained in Appendix 1.

The Lord Howe Currawong

Status and taxonomy

The Lord Howe Currawong is endemic to Lord Howe Island and is generally regarded as a subspecies of the Pied Currawong found on mainland Australia (Mayr and Greenway 1962; Schodde and Mason 1999). However, it has been suggested that the taxonomy be reviewed, especially at the molecular level, to determine if the Lord Howe subspecies warrants recognition as a distinct species (McAllan *et al.* 2004).

The Currawong has persisted on Lord Howe Island despite the introduction of the Black Rat *Rattus rattus* in 1918, although it may have benefited from the ongoing poisoning program for rats (Fullagar and Disney 1975; McAllan *et al.* 2004).

The Lord Howe Currawong is currently listed as *Vulnerable* in New South Wales under the Threatened Species Conservation Act 1995. However, based on IUCN criteria (IUCN 2001), it has been assessed as *Endangered* nationally (Garnett and Crowley 2000). The small size of the population makes it highly vulnerable to decline or extinction through a single threatening process, especially a catastrophic event. The only other threat to have been identified is the illegal shooting of Currawongs by islanders, presumably in retaliation for predatory attacks on other, more charismatic, birds. It is believed that the incidence of shooting has declined since the 1970s due to greater conservation awareness on Lord Howe Island (Hutton 1991; Garnett and Crowley 2000).

No recovery actions have been implemented for the Lord Howe Currawong. The only recovery action to have been proposed is regular monitoring (Garnett and Crowley 2000).

Description

The Lord Howe Currawong is approximately 46 cm in length (Higgins *et al.* 2006), conspicuous, readily detectable because of its loud and distinctive call, and extremely curious, often investigating humans or human activity (Hindwood 1940; Disney and Smithers 1972; Hutton 1991; McFarland 1994). The bird is predominantly glossy black with a small patch of white on each wing, at the base of the primaries. It has a large patch of white around the undertail coverts, a small patch of white at the base of the tail, and a white tip to the tail (Higgins *et al.* 2006). The sexes are alike, but females are typically smaller than males (Schodde and Mason 1999; Higgins *et al.* 2006). Juvenile and immature birds are similar to the adults, but they have a duller and (especially in juveniles) browner plumage. Juvenile birds also exhibit pale markings on the head, neck, upper body, breast and wings, and have a yellow gape (Higgins *et al.* 2006).

Population size and distribution

Current population size

A total of 190 individuals, including 48 immature birds, were captured and banded during the study (October 2005 to July 2006). Ninety-two of these birds were trapped within the southern mountains and 98 in the lowlands, principally within the settlement area.

Captured birds were generally banded with four bands: a coloured band above a numbered metal band on the left leg and two coloured bands on the right leg. Numbered metal bands were supplied by the Australian Bird and Bat Banding Scheme (ABBBS). Coloured bands were powder coated stainless steel bands (ABBBS size 10 blanks).

The three coloured bands, used to identify individuals without recapturing them, were a unique combination of 10 possible colours (pink, yellow, orange, purple, dark green, pale green, black, white, dark blue and sky blue). A list of band combinations used to date is contained in Appendix 2. Seven adults were banded (with two bands) on one leg only because the other leg was malformed. Another two birds, also with malformed legs, were fitted with three bands only. Additionally, 11 juveniles and one adult were banded on only one leg (dark blue or green over metal on left leg) when the supply of other colours was exhausted.

Records of all captures and all subsequent resightings are contained in Appendix 3.

Mark-recapture analyses

In winter 2006, after breeding had ceased and birds were again wide-ranging, a search was made at sites scattered across the island to locate Lord Howe Currawongs. A total of 51 birds were sighted, of which 45 were banded and 6 unbanded. From this information we estimated the proportion of the population that was banded to be 88.2%.

Mark-recapture is a method of estimating population size from recapture data. The simplest mark-recapture estimate of population size is the Petersen Estimate. This method is based on the axiom that the proportion of the population that have certain characteristics (in this case bands) can be estimated from the proportion of individuals with these characteristics within a sample of the population (Caughley 1977). Within the limits of sampling variation

$$M/N = m/n$$

where M animals are marked in a population of size N (N being unknown) and m marked animals are recaptured or resighted in a subsequent sampling of n animals. Manipulation of this equation gives

$$N = Mn/m$$

That is, the population size at the time of marking is estimated by the number marked divided by the proportion of marked animals in a sample taken at a later date. The technique is based on several assumptions: there are no births or deaths during the study period, no immigration or emigration from the population, and marked individuals mix evenly throughout the population.

Although intuitively reasonable, the Petersen Estimate actually produces a biased estimate that, over the long run, results in an overestimation of N (Bailey 1951; Bailey 1952). Bailey suggested that when the number of marked individuals to be recaptured is not decided prior to recapturing, a more satisfactory estimate is

$$N = M(n+1)/(m+1)$$

This estimate has a standard error (SE) of

$$\mathrm{SE} = \sqrt{(M^2(n+1)(n-m)/(m+1)^2(m+2))}$$

Using these formulae we estimate the size of the Lord Howe Currawong population to be 215 (including 48 juveniles) ± 11 birds. In this instance the standard error is about 5% of the population estimate, a relatively high level of precision.

The number of marked animals that must be recaptured to provide a certain level of precision of an estimate of population size is a function of the number marked (M) and population size (N). A SE that is about 10% or less of the population estimate is generally regarded as satisfactory (Caughley 1977). For a population of about 200, the recapture of about 50 marked animals will provide a SE of about 10% or less.

Survival

Between October 2000 and February 2001, when trapping techniques were being trialled, 33 Lord Howe Currawongs were banded. Only five of these birds were trapped or sighted during the current study. Although these data are extremely limited, they are consistent with low adult survivorship, short longevity and a high population turnover.

Of the 48 immature birds banded during this study, 6 were approaching 1 year of age and 42 were recently fledged juveniles. The older of these two cohorts, caught in October and November 2005, were young birds that had survived from the 2004–05 breeding season. These immatures comprised less than 5% of the 129 birds captured during spring 2005, suggesting that the survival of juveniles over winter may be low.

The recently fledged birds, caught between April and July 2006, were progeny from the 2005–06 breeding season. If population monitoring continues (as suggested in *Assessment of population trends*), data from these birds of known-age will provide important information regarding survival and longevity.

Distribution

The Lord Howe Currawong is found only on Lord Howe Island and nearby islets (Garnett 1992; Schodde and Mason 1999; Garnett and Crowley 2000). It occurs throughout the island, but is most numerous in mountainous areas to the south (Cooper 1990; Hutton 1991; McFarland 1994; Garnett and Crowley 2000). It breeds primarily in tall rainforests and palm forests, especially beside creeks or in gullies. Most nests occur in undisturbed forests, but tracts of forest adjacent to pasture land, and patches of remnant forest in settled areas are also occupied (Etheridge 1889; Sharland 1929; Disney and Smithers 1972; Knight 1987; Hutton 1991; McFarland 1994).

The Lord Howe Currawong occurs singly, in pairs and family groups and, in the non-breeding season, in small flocks of up to 15 birds (Disney and Smithers 1972; Lindsey 1986; Knight 1987; Hutton 1991).

During this study, the distribution of the Lord Howe Currawong did not vary from previously published descriptions. Individuals occurred throughout the main island and nested on slopes above creeks or gullies. No Currawongs were observed on Roach Island, but the island was visited only once.

Homerange and movement patterns

Introduction

The Lord Howe Currawong is sedentary (Higgins *et al.* 2006) and resident on Lord Howe Island all year round (McAllan *et al.* 2004). During the breeding season the birds are territorial, each territory being occupied by a breeding pair and its offspring. Territory boundaries appear to expand or contract according to the number of birds within the family group (Knight 1987). Some territories may be defended in both the breeding and non-breeding seasons. The defence of a territory is very aggressive; intruding conspecifics are pursued (Knight 1987), and humans are swooped upon if they approach a nest too closely (Hutton 1991).

The Lord Howe Currawong undertakes local altitudinal movements. In autumn and winter they descend from breeding sites in the hills and mountains to forage within the lowlands, returning to higher altitudes in spring to breed (Hindwood 1940; Disney and Smithers 1972; Fullagar *et al.* 1974).

Homerange

During the nesting season (November to March) adult birds held fixed territories. Close observation of 12 nesting pairs within particular discrete areas of nesting habitat (tall forest) enabled us to delineate the boundaries of each breeding territory. The areas examined included the southern face of Transit Hill adjacent to the airport, the Clear Place and the southern face of the North Hills. Territorial boundaries tended to align with geographical boundaries such as streams or cleared areas. Each territory was then digitally mapped using Arcview, and its size calculated (Table 1).

Table 1. Size of individual breeding territories of the Lord Howe Currawong

Location	*n*	Mean (ha)	SE (ha)	Range (ha)
Transit Hill	4	5.1	0.26	4.4–5.5
Clear Place	3	4.8	0.16	4.5–5.0
North Hills	5	6.0	0.33	5.4–7.3
Combined	12	5.4	0.22	4.4–7.3

Territories were larger in the North Hills than at either Transit Hill or the Clear Place (ANOVA, $F_{2,9} = 4.355$, $P = 0.047$). The reason for this difference is unclear, but it probable reflects differences in the availability of food within each habitat. On average, each breeding pair of Currawongs occupied a territory of 5.4 ± 0.2 ha (mean ± SE).

Based on the extent of forest habitat outside those areas examined (approximately 608 ha) we estimate that the island can support no more than 112 pairs in addition to the 12 pairs whose territories we mapped; a total population of 124 breeding pairs. In this calculation we have assumed that the territory size within the southern mountains is similar to that measured in the North Hills, and that territory size is independent of population size. The validity of each of these assumptions is untested.

Throughout the period of nesting, incubation and chick rearing, males patrolled the boundaries of their territory, reinforcing their presence by vocalising. Male Currawongs uttered a distinctive call not used by the females. This sex-specific call is best described as a harsh, guttural, scolding note with a downward inflection followed immediately by several short stutters. Females would often answer this call with the more familiar call used by both birds.

Movement patterns

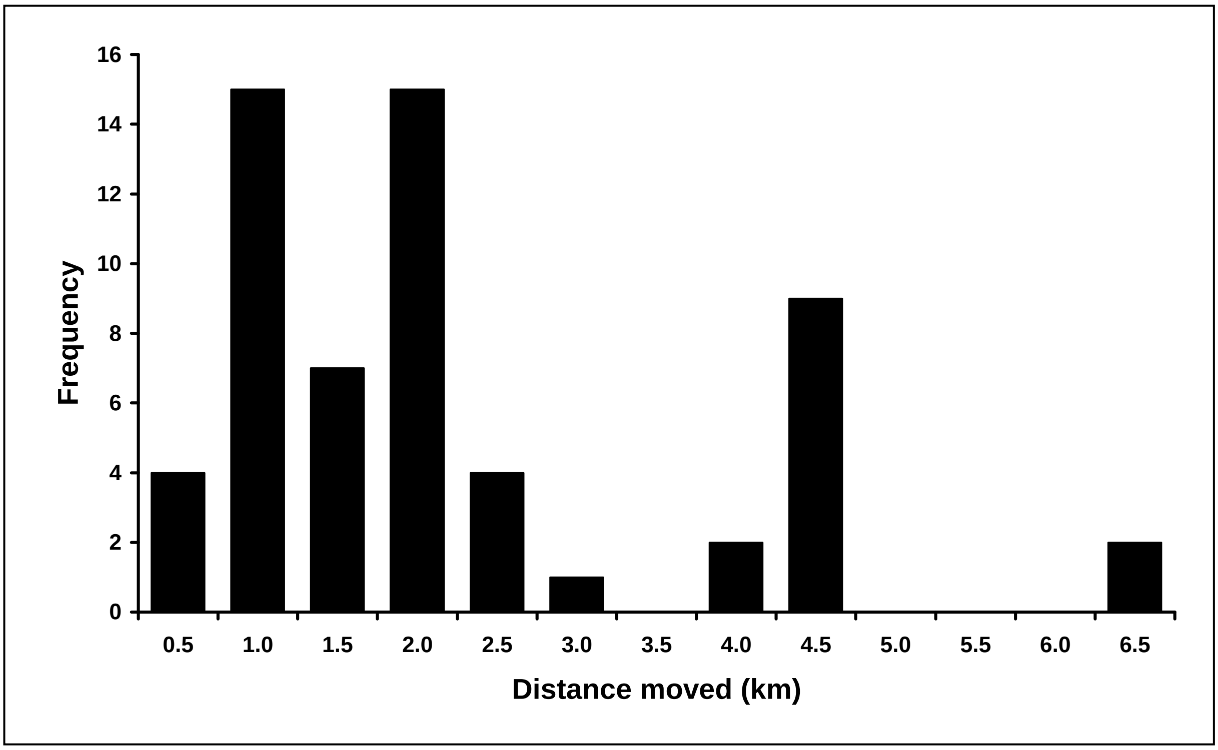
Currawongs on Lord Howe Island undertook local altitudinal movements that were associated with breeding activity. In spring they moved into the forested hills and mountains to breed. In autumn and winter they descended from these breeding sites to forage within the lowlands. These altitudinal movements are similar to those made by the mainland subspecies of Pied Currawong (see Readshaw 1968a), only on a much-reduced scale.

Movements during the nesting season (November to March) were largely restricted to foraging within established territories, whereas outside the breeding season territories were not maintained and individuals aggregated into small flocks that ranged more widely. Of the 169 birds that were trapped and colour banded between October 2005 and May 2006 (and therefore could potentially be resighted during a subsequent survey) 77 (46%) were resighted. In all, 212 sightings were recorded. Of these, 72.2% involved observations of birds that were seen at the same locale (within 100 m or so) of where they had been recorded previously. A further 9.0% of sightings were within 1 km of their previous recorded location, 10.4% were 1–2 km distant, and 2.4% were 2–3 km distant (Figure 1).

Only 13 movements (6.1%) were greater than 3 km distant from the previous recorded sighting. The longest movement recorded (by two birds) was between Mount Gower and Middle Beach Road, a distance of approximately 6.4 km. The most frequently observed movement of more than a kilometre was between Far Flats and the summit of Mount Gower. Birds that regularly received food from residents or tourists were never seen more than a few hundred metres from these feeding sites.

In October 2000, when trapping techniques were being trialled, 30 birds were banded on Mount Gower. Four of these birds were trapped during the current study, and another sighted; all were either on Mount Gower or in nearby Erskine Valley. Although these data are limited, the observations indicate that, over the long-term, Currawongs are relatively sedentary.

Figure 1. The distances moved by colour banded Lord Howe Currawongs
Of the 212 sightings of colour banded birds, 153 (72.2%) were at the same locale as that individual was seen previously. These data have been omitted from this figure.



Threats and limiting factors

Introduction

Settlement of Lord Howe Island has resulted in the loss of some nesting habitat of the Lord Howe Currawong (Pickard 1983; McFarland 1994). This loss does not appear to have affected the subspecies to any significant degree. It remains widespread on the island and occurs throughout the settlement. It may have benefited from the associated introduction of some exotic plants and animals that are now exploited as a food source (Cooper 1990; Hutton 1991; McFarland 1994; Garnett and Crowley 2000).

Threats

This study confirmed that illegal shooting is a potential threat to the Lord Howe Currawong. A single individual was found in an emaciated state near Soldiers Creek with its lower mandible and tongue missing. This individual was euthanased. The injury was consistent with the bird having sustained a shot from a low calibre rifle. The frequency of such occurrences and the severity of this threat are unknown.

Of the 190 birds captured during this study, 12 (6%) had a visible physical abnormality. Four had a malformed left leg, five had a malformed right leg, one had malformed feathers on the right wing, one had an irregular upper mandible and one had a misshapen bill (a crossbill where the upper and lower mandibles do not align). Another bird that could not be caught was flightless. Such a high level of abnormality among the population is probably due to inbreeding, a consequence of a small isolated population.

Limiting factors

Based on 1) the extent of potential Currawong nesting habitat on Lord Howe Island and 2) the size of each territory, we estimate that the island can support no more than 124 breeding pairs (see *Homerange and movement patterns*). As not all forest habitats are likely to support currawongs, actual maximum potential population size may be considerably less. Given that we estimate there are about 215 Currawongs currently on Lord Howe Island (see *Population size and distribution*) it would appear that most, if not all, available habitat is occupied. Thus, it is likely that the factor limiting the numbers of this subspecies is the extent of available habitat.

The low survival of Lord Howe Currawongs during their first year of life (see *Survival*) is consistent with this conclusion. The only territories available to young birds are likely to be those where an adult bird has died. Birds that are unable to establish territories lack a secured food source and are unlikely to survive.

Interaction with other avian species

Introduction

The Lord Howe Currawong preys on the chicks of several native birds including the Providence Petrel *Pterodroma solandri*, Red-tailed Tropicbird *Phaethon rubricauda*, Lord Howe Woodhen *Gallirallus sylvestris*, Sooty Tern *Sterna fuscata*, White Tern *Gygis alba*, Emerald Dove *Chalcophaps indica*, and Golden Whistler *Pachycephala pectoralis*. It also takes the young of some introduced birds including Domestic Fowl *Gallus gallus*, Pacific Black Duck *Anas superciliosa* (or hybrids of these and Mallard *A. platyrhynchos*) and Song Thrush *Turdus philomelos* (reviewed in McAllan *et al.* 2004).

Observed interactions

Despite more than 250 hours of observation, few interactions between Currawongs and other avian species were observed. At nest sites, both male and female Currawongs regularly chased other terrestrial bird species away from the area.

Approximately 50 hours of observations were undertaken within White Tern colonies. Only a single instance of predation was recorded. A Currawong took a White Tern chick (approximately one-week old) from beneath a brooding adult nesting in a Norfolk Island Pine *Araucaria heterophylla* along Lagoon Road. The adult was pushed off the chick, and the chick taken within 15 seconds of the Currawong arriving. The ease at which this foraging sortie was completed suggests that if White Terns were a major component of the Currawong‘s diet, few tern chicks would fledge, which is not the case. The White Tern population on Lord Howe Island has increased over recent years and reproductive output is comparable to that at other colonies (Carlile and Priddel in prep). Predation by Currawongs does not threaten the viability of the White Tern population on Lord Howe Island. Predation by Masked Owls *Tyto novaehollandiae* is likely to be much more frequent, and more focused on adults. On current evidence, however, both Owl and Currawong predation combined is not preventing an expansion of the White Tern population on Lord Howe Island.

The only other interaction between Currawongs and other fauna we observed involved the remains of a freshly killed Flesh-footed Shearwater *Puffinus carneipes* chick found near an active Currawong nest on 24 January 2006. The nestling was approximately one day old.

Reported interactions

Islanders were asked to report any interactions they observed between Lord Howe Currawongs and other fauna. The six instances reported to us all involved predation by Currawongs on White Tern adults, chicks or eggs along Lagoon Road. Three were direct observations of Currawong predation and three were implications based on circumstantial evidence. Ian Hutton observed a Currawong taking two adult White Terns. Cam Wilson observed two instances of Currawongs taking White Tern eggs or chicks. Clive Wilson, Dean Hiscox and Jill Hiscoe all reported suspicious Currawong behaviour within the vicinity of White Tern losses.

Assessment of population trends

Past population trends

There is no empirical evidence of a historical decline in population size of the Lord Howe Currawong, although accurate data are lacking. The species was described as being very plentiful in 1887 (Etheridge 1889) and 1907 (Hull 1910), common in the late 1920s (Sharland 1929), and fairly plentiful in the mid-to late 1930s (Hindwood 1940).

In the 1960s, the population was estimated at 70–100 birds, and was thought to have declined when, in 1971, it was estimated to number only 30–50 birds (Fullagar *et al.* 1974). The population comprised a minimum of 52 birds in 1984 and 55 birds in 1985 (Knight 1987). Based on these counts, and a speculative estimate of the number of birds that occurred in areas that were not surveyed, the total population in 1985 was estimated to comprise of 73 birds (Knight 1987). In 1986, the population was reported to be 30–50 birds (Cooper 1990). Surveys in the southern mountains in 1987, 1989 and 1991 recorded 28, 35 and 37 birds respectively (McFarland 1994). In 2000, the population was reported to comprise 80 adult birds (Garnett and Crowley 2000).

Using mark-recapture techniques, this study estimated population size in 2006 to be 215 birds (see *Current population size*). This result, together with past observations, suggests that the population has increased in recent times. However, past estimates of population size are based on observations of unmarked birds, and, in our opinion, have not been derived with sufficient accuracy to gauge past population trends with any degree of confidence. The difference between the current estimate of population size and previous estimates may be due, at least in part, to a more accurate assessment of population size rather than any real population growth.

On the other hand, local perception is that Currawongs are more numerous today than in decades past. Some older residents suggested that, in the past, Currawongs were seen only within forested areas of Lord Howe Island and rarely within the settlement. Our observations suggest that although Currawongs are common within the settlement during the non-breeding season, they are in much reduced numbers there during the summer. It is possible that the practice of feeding currawongs has ‗lured' them into the settlement in recent times. The provision of supplementary food may have also contributed to raising the carrying capacity of Currawongs on Lord Howe Island.

Future population trends

This study provides a one-off measure of the size of the Currawong population on Lord Howe Island. Further regular monitoring is necessary to determine inter-annual variation in numbers and population trends. Such information is crucial in order to assess the conservation status of the subspecies on Lord Howe Island. Any future monitoring program should straddle the years of the proposed rodent eradication so that the impact of this management initiative on the Currawong population can be assessed.

Magrath *et al*. (2004) recommended appropriate methods to survey all Australian birds. They suggested that the method to survey the Lord Howe Currawong was to conduct area searches or transect surveys in suitable habitat. They noted that the subspecies can readily be detected by sight or by call (Knight 1987) and that individuals are known to respond to the playback of recorded calls of the Lord Howe Woodhen (McFarland 1994). Consequently, they suggested that broadcast surveys (the playback of recorded calls to elicit a response from a bird or birds) could also prove effective. The effort they recommended for conducting area searches or transect surveys in an area of 50 ha or less was eight person hours, spread over a period of four days (Magrath *et al.* 2004). They made no recommendation on the effort required when performing broadcast surveys.

In contrast, McFarland (1994) and Garnett and Crowley (2000) have argued that an accurate census of the Lord Howe Currawong population would only be possible if individuals were banded. We concur with their opinion, and point to the difficulties of interpreting past population estimates made in the absence of banding. We believe that the population size of the Lord Howe Currawong can be determined accurately only through trapping, colour marking and resighting of individuals, as done during this study. Mark-recapture techniques have been used successfully to estimate the size of winter flocks of the mainland subspecies of Pied Currawong, each containing 500–1000 birds (see Readshaw 1968b).

Another advantage of using a mark-recapture technique is that, when undertaken annually, it can also provide data on mortality rates and movements, and facilitate the identification of rogue or problem birds. In addition, accumulated resightings of banded birds of known age can provide data on longevity.

An annual mark-recapture survey would best be carried out in early spring (September) when birds:

1. have not yet commenced nesting (see *Timing of breeding*);
2. are wide-ranging, having not yet established territories (see *Homerange and movement patterns*);
3. readily aggregate in small flocks;
4. are easily trapped (see Figure 2); and
5. after the expected period of high juvenile mortality.

The survey should include a number of widely separated sites that, together, sample virtually the entire Currawong population. Sites should include locations where reasonable numbers of birds aggregate, particularly where they are fed regularly. We recommend the following eight sites:

1. the picnic ground at Old Settlement Beach;
2. the churches along Middle Beach Road;
3. the track leading to the Clear Place;
4. the golf course (particularly the 9th tee);
5. the residence of Barney Nichols;
6. the residence of Ray Shick;
7. the track through Far Flats; and
8. the NE end of Mount Gower (particularly the lookout).

At each survey, all banded birds that visit the site should be identified and recorded. Any unbanded birds should be trapped and banded. To capture the most timid individuals, it may be necessary to deter (or hold temporarily in bags) the more dominant individuals. All birds should be banded with four bands: one numbered metal band and three coloured bands of unique arrangement.

Surveys are best conducted in the early morning or late afternoon, depending on the time of day when the birds are normally fed at that site. Trapping should continue until all birds present have been banded or until all birds become disinterested and disperse (about an hour at all sites other than Mount Gower). Due to the large number of individuals that visit the site, trapping on Mount Gower may take up to four hours. Inclement weather or rain may cause delays, as the birds‘ behaviour in these conditions makes them difficult to trap. Birds become extremely wary in high winds and following rain the birds disperse to feed on invertebrates that emerge in response to the moist conditions. Trapping of all sites should be completed within the shortest possible timeframe, which should not extend beyond two weeks. Weight, sex (based on culmen length measured to the nearest 0.1 mm, see *Sex determination*), age (adult or juvenile see *Age determination*) together with any physical abnormalities should also be recorded for each individual.

Data should be analysed using an appropriate mark-recapture technique. This study used a deterministic model (the Petersen Estimate) to estimate population size because data were derived from one marking and one resighting event only. This technique will need to be repeated during the first year of any monitoring program. For this method to yield an accurate estimate of population size (SE ≤ 10% of the mean) no fewer than 50 individuals should be resighted.

In subsequent years, when banded birds have been captured (or sighted) on two or more occasions, a stochastic model such as the Jolly-Seber Method is more appropriate (Williams *et al.* 2002; Amstrup *et al.* 2006). This analysis, although more complex, can be performed using the computer program MARK (White 2006), available free on the internet.

Data should be stored electronically as an *encounter history* (Cooch and White 2006). This format consists of a contiguous series of ―1"s and ―0"s, where ―1" indicates that the animal was recaptured (or otherwise known to be alive) and ―0" indicates the animal was not captured (or otherwise seen). Other data (known as *covariates*) such as weight, culmen length and age should be recorded in separate columns. Data stored in this format will require minimal manipulation to create the data input file needed to run program MARK.

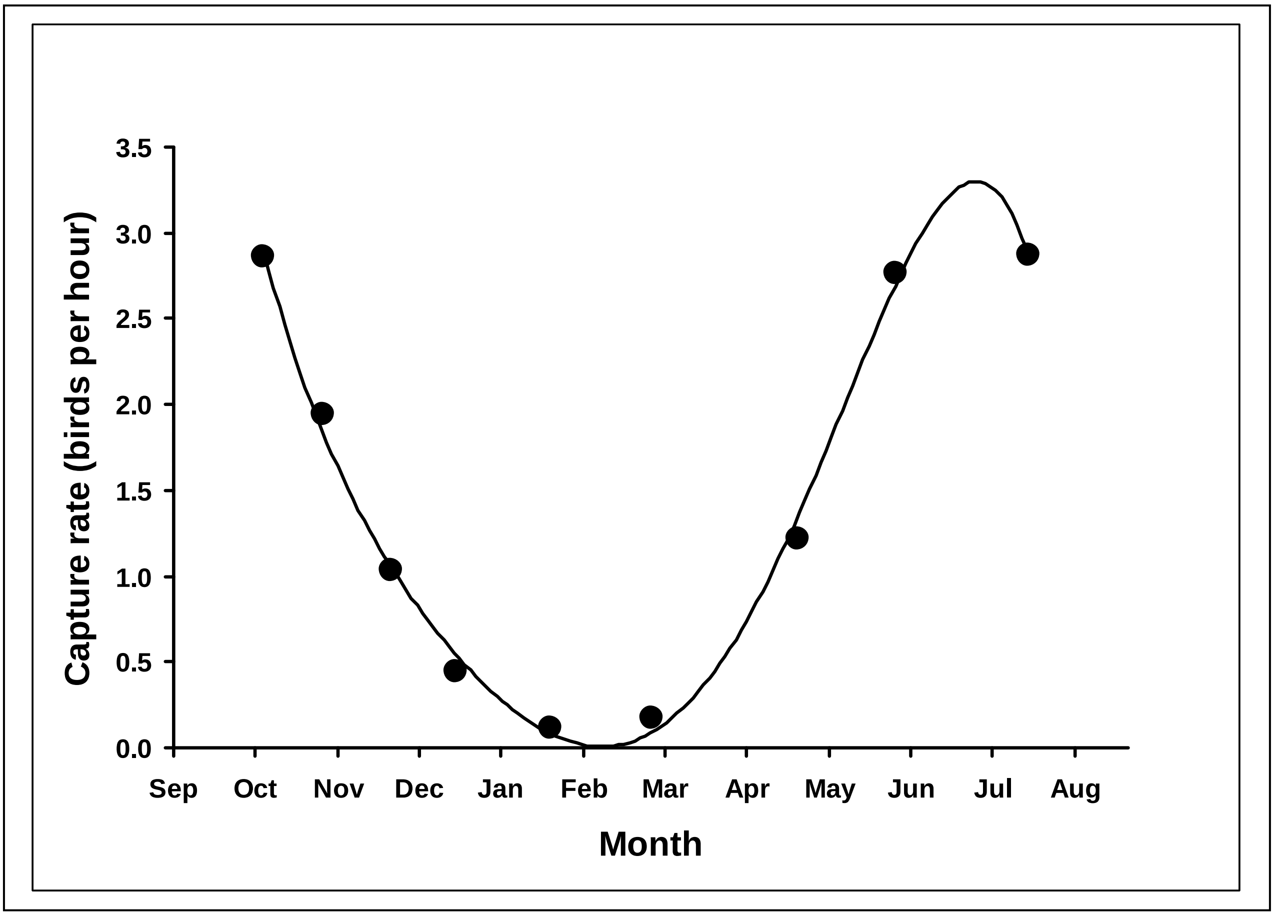
Trappability

Introduction

Understanding the ease with which Currawongs can be trapped and how this trappability varies temporally is crucial to the future management of the subspecies. Any proposal to place the bulk of the population into captivity as a means of protecting the subspecies from a baiting program designed to eradicate rodents requires Currawongs to be trapped. Temporal variability in trappability will dictate when the birds can be trapped and how long they will need to be kept in captivity.

Temporal trends in trappability

Figure 2. The capture rate of Lord Howe Currawongs between October 2005 and July 2006



The capture rate (trappability) of individuals (Figure 2) was high in early October, when the study began, but decreased soon after, coincident with the onset of nesting. It continued to fall over the next few months, remaining low throughout summer and autumn. Trappability began to increase again in April, but most (75%) of birds caught in April and June were juveniles. We conclude that adult Currawongs are difficult to trap between November and June. They can be trapped in reasonable numbers only during the period July–October.

Breeding ecology

Introduction

The Lord Howe Currawong nests from October to December (Hindwood 1940; McFarland 1994). However, it has also been purported to breed in September (McAllan *et al.* 2004) or possibly even as early as July (Hull 1910). It nests in gullies, and close to water, in undisturbed forest on the slopes of hills and mountains (Hull 1910; Hutton 1991; McFarland 1994; Garnett and Crowley 2000).

In other subspecies, the birds spend up to two weeks after courtship building the nest (Recher 1976). Although both sexes gather nesting material, it seems that only the female constructs the nest. On Lord Howe Island, the nest is a cup-shaped bowl of sticks and twigs, and sometimes vines, high above ground in the outer branches of a tree such as Scalybark *Syzygium fullagarii*, Blackbutt *Cryptocarya triplinervis*, Greybark *Drypetes deplanchei*, Banyan *Ficus macrophylla* and Kentia Palm *Howea forsteriana* (Hull 1910; Sharland 1929; Hindwood 1940; Hutton 1991; McFarland 1994; McAllan *et al.* 2004).

Clutches typically consist of three eggs, light-brown to rufous-brown in colour with darker spots and blotches of brown and grey (Hindwood 1940). In other subspecies, the female incubates the eggs for a period of 21 days. The nestlings are fed by both parents, and depart the nest about 30 days after hatching (Recher 1976). No information is available on the period of dependence of young, but most fledglings probably become independent within about seven weeks of leaving the nest (Prawiradilaga 1996; Higgins *et al.* 2006). No quantitative information is available on breeding success for the Lord Howe Currawong, but successful broods usually consist of one or two young and, in some seasons, pairs may not rear a brood at all (Knight 1987).

Nest attributes

Fourteen nest trees were identified: Banyan (*n* = 4), Blackbutt (*n* = 3), Scalybark (*n* = 3), Dogwood *Homalanthus nutans* (*n* = 2), Bloodwood *Baloghia inophylla* (*n* = 1) and Shittenwood *Xylosma maidenii* (*n* = 1). Nests were 4.5–20.0 m above ground (mean 9.0 ± 1.0 m) in trees that were estimated to be 5.5–25.0 m tall (mean 12.5 ± 1.4 m).

Timing of breeding

Hatching occurred between late October and late December. Fledglings left the nest between late December and late February. Although not observed, it is inferred from the timing of hatching that courtship took place during September and October.

Breeding productivity

Clutch size was not assessed. Median brood size was two (range 1–3).

The outcome was ascertained for 17 breeding attempts, involving 13 pairs (four pairs nested twice, one pair successfully raising two broods). Seven nests successfully produced at least one fledgling, a success rate of 41%. The mean number of fledglings produced was 0.8 ± 0.3 (range 0–3) per nesting attempt, 1.1 ± 0.4 (range 0–5) per breeding pair, and 2.0 ± 0.3 (range 1–3) per successful nest.

Few other studies of Pied Currawongs have examined breeding success. The most detailed study, in Canberra, monitored 38 nests (34 first nests and 4 replacements) of which 30 (79%) were successful (Prawiradilaga 1996). A single pair of Currawongs raising two broods within a season (double brooding) has not been documented previously for any subspecies of Pied Currawong.

Foraging ecology

Introduction

The Lord Howe Currawong is omnivorous, consuming a wide variety of food items (Hindwood 1940; Hutton 1991; Garnett and Crowley 2000). Diet includes the fruits and seeds of Stinkwood *Coprosma putida*, Blackbutt, Greybark *Drypetes deplanchei*, Island Apple *Dysoxylum pachyphyllum* and Little Mountain Palm *Lepidorrhachis mooreana*. It takes various insects including beetle larvae and the Lord Howe Cicada *Psaltoda insularis*.

Little published information is available on the feeding behaviour of the Lord Howe Currawong. It picks insects from the bark of trees, and uses its large and robust bill to break apart rotten logs in search of larvae (Hutton 1991). It pursues and captures rats, and attacks and kills young birds (Hutton 1991; Garnett and Crowley 2000).

Feeding frequency

Almost 14 hours of observations were made of a single incubating bird. Unlike the mainland subspecies (Recher 1976), the male did not feed the female during the observation period. Instead, the female left the nest for brief periods to forage. During daylight she left the nest every 21.3 ± 2.0 minutes (range 3–41, n = 30) for periods averaging 6.0 ± 0.4 minutes (range 3–10 min, n = 32).

A further 123 hours of diurnal observations were made of nests containing chicks, during which 734 chick-feeding events were observed. On average, chicks were fed 6.0 times per hour, with females providing 70% of all feeds. Females also undertook most of the nest hygiene duties, removing faecal material in transparent sacs.

During the first week after hatching, chicks were brooded by the female for 35% of the time that the nest was under observation. Males played no part in brooding the chicks.

Foraging behaviour

Foraging Currawongs collected fruits from within the canopy and from the ground. Before being fed to the chicks, large vertebrates were dismembered away from the nest. Snails were removed from their shells by breaking them open on a rock. Food was occasionally cached.

Diet

Food items delivered to Currawong nestlings were identified in 60.4% of observed feeding events (Table 2). Invertebrates were the most common food identified (65.8% by frequency). Beetle larvae and cicadas were the most numerous invertebrate prey identified, although other insects (beetles, cockroaches and crickets), spiders, and spider egg sacs, worms and snails all featured (Table 2). Vertebrates comprised 21.3% of identified food items delivered to nestlings. The introduced Grass Skink *Lampropholis delicata* was the most common vertebrate prey, and it is possible that Currawongs fulfil a useful role in controlling the numbers of this species. Introduced rodents (Black Rats and House Mice *Mus musculus*), nestlings of Blackbird *Turdus merula* and Emerald Dove *Chalcophaps indica* and one Lord Howe Gecko *Christinus guentheri* were also taken. Fruit comprised 12.9% of the identified food items delivered to Currawong nestlings.

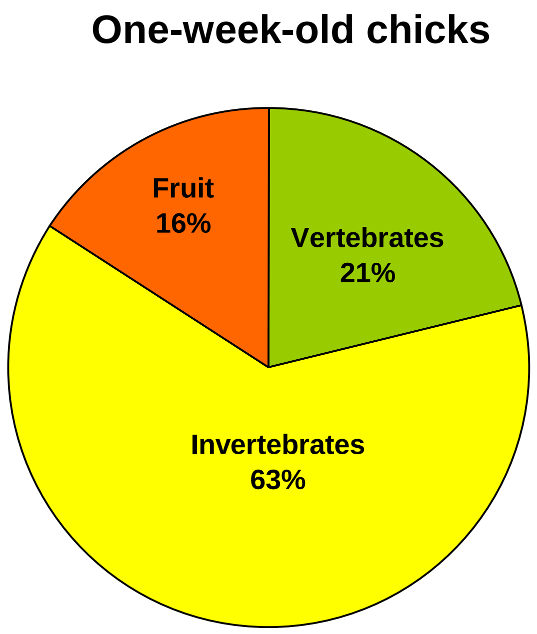
Table 2: Food items fed to Currawong nestlings of different ages

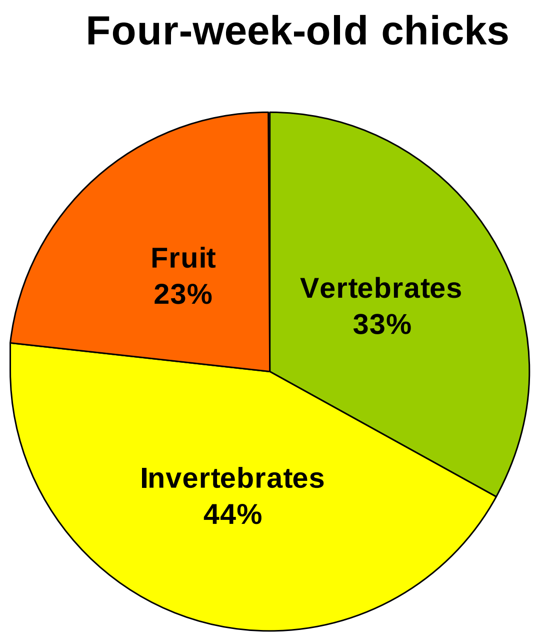
Food item	All ages		1-week old		4-week old	
	n	(%)	*n*	(%)	*n*	(%)
Unknown	291	39.6	45	44.1	113	49.6
Invertebrates						
Beetle larvae	105	14.3	9	8.8	11	4.8
Cicadas	76	10.4	2	2.0	6	2.6
Other insects	45	6.1	12	11.8	13	5.7
Beetles	22	3.0	2	2.0	8	3.5
Worms	21	2.9	3	2.9	6	2.6
Spiders	11	1.5	6	5.9	3	1.3
Spider sacs	3	0.4	2	2.0	0	0.0
Cockroaches	3	0.4	0	0.0	2	0.9
Snails	2	0.3	0	0.0	0	0.0
Cricket	1	0.1	0	0.0	0	0.0
Moth	1	0.1	0	0.0	1	0.4
Vertebrates						
Grass skinks	55	7.5	3	2.9	29	12.7
Unidentified flesh	21	2.9	4	3.9	7	3.1
Mammals	11	1.5	0	0.0	0	0.0
Birds	6	0.8	4	3.9	1	0.4
Gecko	1	0.1	1	1.0	0	0.0
Fruit	57	7.8	9	8.8	26	11.4
Cheese	2	0.3	0	0.0	2	0.8
Total	734	100.0	102	100.0	228	100.0

The composition of the diet changed between the first and fourth week that nestlings were in the nest (Figure 3). The proportions of vertebrates and fruit both increased, whereas the proportion of invertebrates declined. The relative importance of Grass Skinks in the diet increased substantially as the chicks grew older (Table 2). It is not known whether this reflects a change in prey selectivity by the Currawong or a change in the availability of the prey.

Currawongs are lauded by foresters for their appetite for phasmids (Readshaw 1965). The Lord Howe Currawong probably lost a major component of its diet when rats eradicated the large and abundant local species, the Lord Howe Phasmid *Dryococelus australis*.

Figure 3. Known food items fed to Lord Howe Currawong chicks of one week and four weeks of age.





Diagnostic characteristics

Subspecies determination

The eye colour of adult Lord Howe Currawongs differed from that reported for the subspecies and is distinct from that of the mainland Pied Currawong. The Lord Howe subspecies has an orange eye (irides), whereas the mainland subspecies has a yellow eye (Higgins *et al.* 2006). The yellow eye of the mainland subspecies was confirmed by trapping an individual on the mainland and by examining several existing photos.

A sample of blood was taken from a sample of 10 Lord Howe Currawongs. This material was forwarded to Griffith University, Queensland, to be used in a national study examining the genetic relationships of the various Currawongs. The findings of this study will assist in clarifying the taxonomic relationship between the Lord Howe Currawong and the subspecies on the mainland.

Age determination

No information is available on the age to sexual maturity or the life expectancy of Pied Currawongs. However, individuals are probably capable of surviving to more than 20 years of age (Higgins *et al.* 2006)..

Of the 190 individuals banded during this study, 48 were less than one year old. If population monitoring continues, data from these birds of known-age will provide important information regarding survival and longevity. Immature birds (less than one year old) are discernible by two diagnostic features—the lighter colouration of the lower mandible and a yellow gape

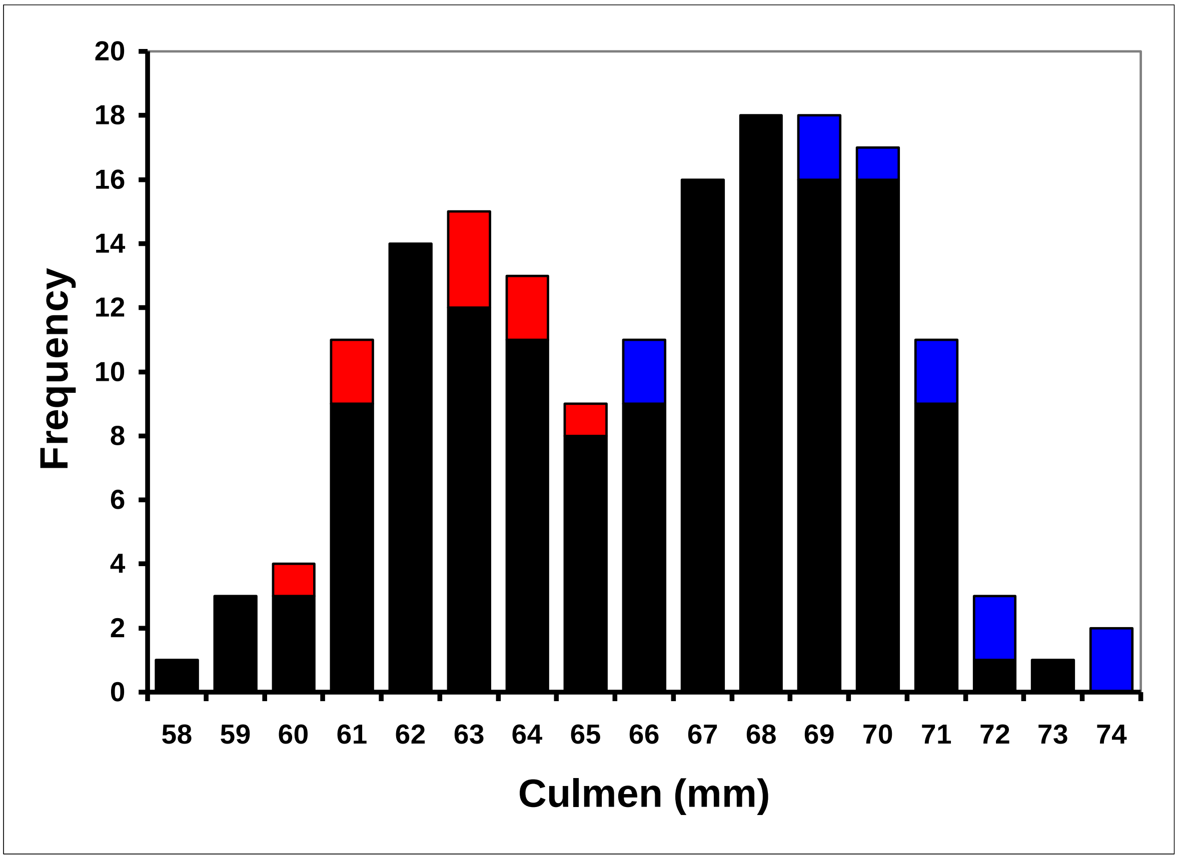
Sex determination

Although females are slightly smaller than males the high degree of overlap precludes sex to be determined from weight alone. Previous workers have suggested that bill size may be a useful sexing criterion (Wimbush 1969; Higgins *et al.* 2006). To examine this possibility, we measured the bill (culmen length, Lowe 1989) of 167 adults, including museum specimens.

Of those individuals that we measured, we were able to ascertain the sex of 20, either by observation of sex specific behaviour or by previous dissection of dead museum specimens. These data, plotted in Figure 4, show that males have a longer bill than females. This preliminary analysis indicates that adults with a culmen length of < 66 mm are females; those with a culmen of ≥ 66 mm are males. Schodde and Mason (1999) examined 12 museum skins and found males to have a culmen length of 67.0–70.0 mm and females 60.0–62.5 mm. This accords with our findings. Details of the extent of the difference between sexes and the degree of overlap will be more fully explored in a scientific paper, once more individuals have been sexed and measured.

Males can also be distinguished from the sex-specific call used in establishing and maintaining territories (see *Homerange*).

Figure 4. Frequency distribution of culmen length for 167 adult Lord Howe Currawongs
Red cells show birds known to be females; blue cells show males.



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Appendix 1. Schedule of fieldwork

Date	Activities
5–14 October 2005	Trapping and colour banding of Currawongs Initial mark-recapture survey Public meeting for community consultation
26 October – 5 November 2005	Trapping and colour banding of Currawongs Attempted mark-recapture survey Mapping of Currawong breeding territories Monitoring of White Tern colonies for intraspecies interactions Discussions with key local residents
19–28 November 2005	Trapping and colour banding of Currawongs Observation of nesting behaviour Monitoring of White Tern colonies for intraspecies interactions Discussions with key local residents
14–23 December 2005	Trapping and colour banding of Currawongs Observation of nesting behaviour Monitoring of White Tern colonies for intraspecies interactions Discussions with key local residents
18–27 January 2006	Trapping and colour banding of Currawongs Observation of nesting behaviour Monitoring of White Tern colonies for intraspecies interactions Discussions with key local residents

Date	Activities
24 February – 01 March 2006	Trapping and colour banding of Currawongs Monitoring of White Tern colonies for intraspecies interactions Discussions with key local residents
20–24 April 2006	Trapping and colour banding of Currawongs Monitoring of White Tern colonies for intraspecies interactions Discussions with key local residents
26–30 May 2006	Trapping and colour banding of Currawongs Discussions with key local residents
15–21 July 2006	Trapping and colour banding of Currawongs Presentation of results to community Discussions with key local residents

Appendix 2. Colour combinations of colour-marked Currawongs

k, pink; y, yellow; o, orange; u, purple; g, dark green; n, black; w, white; b, dark blue; s, sky blue; p, pale green; m, metal.
Notation is LuLdRuRd. Underscore indicates band absent. The combination pmbn has inadvertently been used on two different birds.

kmgn	**omgk**	**nmbs**	**wmbu**	**bmkb**	**ymgk**	**umgk**	**gmbn**	**smbs**	**pmbn**	**__bm**
kmgw	**omgn**	**nmbu**	**wmby**	**bmko**	**ymgn**	**umgn**	**gmbs**	**smpb**	**pmbn**	**__km**
kmng	**omgw**	**nmbw**	**wmog**	**bmky**	**ymgo**	**umgy**	**gmbu**	**smps**	**pmbs**	**__yu**
kmnw	**omgy**	**nmby**	**wmon**	**bmoy**	**ymgw**	**umkg**	**gmbw**	**smsy**	**pmbu**	**_msw**
kmny	**omkg**	**nmgw**	**wmyn**	**bmps**	**ymkg**	**umkn**	**gmby**	**smyn**	**pmnb**	**bm__**
kmog	**omkn**	**nmkb**	**wmyu**	**bmsp**	**ymkn**	**umko**	**gmnw**	**smyp**	**pmnn**	**bm__**
kmon	**omku**	**nmky**	**wmyw**	**bmug**	**ymko**	**umkw**	**gmsn**		**pmns**	**bm__**
kmou	**omkw**	**nmob**		**bmuw**	**ymku**	**umky**	**gmsu**		**pmpn**	**bm__**
kmow	**omky**	**nmow**		**bmwn**	**ymkw**	**umng**	**gmsw**		**pmpp**	**bm__**
kmoy	**omng**	**nmpb**		**bmws**	**ymnb**	**umnk**	**gmun**		**pmps**	**bm__**
kmug	**omnw**	**nmsb**		**bmwu**	**ymnu**	**umnw**	**gmuw**		**pmsn**	**bm__**
kmun	**omug**	**nmsu**		**bmwy**	**ymnw**	**umob**	**gmyb**		**pmsp**	**bm__**
kmuo	**omuk**	**nmsy**		**bmys**	**ymog**	**umog**	**gmyn**		**pmss**	**bm__**
kmuw	**omun**	**nmuw**		**bmyu**	**ymok**	**umon**	**gmys**		**pmub**	**bm__**
kmuy	**omuw**	**nmwu**		**bmyw**	**ymon**	**umow**	**gmyu**		**pmun**	**gm__**
kmwn	**omuy**	**nmys**			**ymou**	**umoy**	**gmyw**		**pmus**	**gm__**
kmwu	**omyg**	**nmyu**			**ymow**	**umwk**	**gwum**		**pmyn**	**k_yu**
kmyg	**omyk**	**nmyw**			**ymub**	**umyg**			**pmyo**	**om__**
kmyn	**omyn**				**ymug**	**umyn**			**pmyp**	**pm__**
kmyo	**omyu**				**ymuk**	**umyo**			**pmyu**	**sm__**
kmyw	**omyw**				**ymun**	**umyw**				**wm__**
					ymuo					
					ymuw					

Appendix 3. Data from trapping and resightings of colour banded Currawongs

BN, band number; R, retrap; SP, species; A, age; HA, how aged; SX, sex; HS, how sexed; LC, locode; M, method; ST, status; W, weight (g); CL, culmen length (mm); TZ, Tarsus length (mm); WL, wing length (mm); CB, colour bands (k, pink; y, yellow; o, orange; u, purple; g, dark green; p, pale green; n, black; w, white; b, dark blue; s, sky blue; m, metal. Notation is LuLdRuRd. Underscore indicates band absent. The combination pmbn has inadvertently been used on two different birds); PR, bander number; Locale, location captured or sighted; DM, distance moved (m). Data notation and codes follow that of the Australian Bird and Bat Banding Scheme (Lowe 1989).

BN	R	SP	A	HA	SX	HS	DATE	LC	TIME	M	ST	W	CL	TZ	WL	CB	PR	LOCALE	DM
091-19301		8017	1+	U	U	U	19/10/2000	801051	0745ES	06	13	270	62.1	50.8	232		801007		
091-19302		8017	1+	U	U	U	23/10/2000	801051	0730ES	06	13	315	65.5	51.8	238		801007		
091-19303		8017	1+	U	U	U	23/10/2000	801051	0730ES	06	13	330	64.8	60.2	249		801007		
091-19304		8017	1+	U	U	U	23/10/2000	801051	0730ES	06	13	335	63.5	57.3	249		801007		
091-19304	R	8017	1+	U	U	U	23/10/2000	801051									801007	GOWER	
091-19304	R	8017	6+	K	U	U	07/10/2005	801051	1230ES	06	13	325				ymon	801007	GOWER	
091-19304	R	8017	6+	K	U	U	09/10/2005	801051								ymon	801007	GOWER	0.0
091-19304	R	8017	6+	K	U	U	22/11/2005	801051								ymon	801007	GOWER	0.0
091-19305		8017	1+	U	U	U	23/10/2000	801051	0730ES	06	13	340	69.1	56.7	266		801007		
091-19305	R	8017	1+	U	U	U	23/10/2000	801051									801007	GOWER	
091-19305	R	8017	6+	U	U	U	08/10/2005	801051	0720ES	06	13	320				umgn	801007	GOWER	
091-19306		8017	1+	U	U	U	23/10/2000	801051	0730ES	06	13	340	70.1	56.8	249		801007		
091-19307		8017	1+	U	U	U	23/10/2000	801051	0730ES	06	13	405	69.7	57.1	258		801007		
091-19308		8017	1+	U	U	U	23/10/2000	801051	0730ES	06	13	355	67.7	54.3	250		801007		
091-19309		8017	1+	U	U	U	23/10/2000	801051	0730ES	06	13	380	68.7	57.5	258		801007	GOWER	
091-19309	R	8017	6+	U	U	U	08/10/2005	801051	0720ES	06	13					umko	801007	GOWER	
091-19309	R	8017	6+	U	U	U	02/11/2005	801051								umko	801007	GOWER	0.0
091-19309	R	8017	6+	U	U	U	22/11/2005	801051								umko	801007	GOWER	0.0
091-19310		8017	1+	U	U	U	23/10/2000	801051	0730ES	06	13	320	62.4	53.9	246		801007		
091-19311		8017	1+	U	U	U	23/10/2000	801051	0730ES	06	13	370	70.1	55.8	262		801007		
091-19312		8017	1+	U	U	U	23/10/2000	801051	0730ES	06	13	345	60.4	51.2	247		801007		
091-19313		8017	1+	U	U	U	23/10/2000	801051	0730ES	06	13	350	67.2	53.4	254		801007		
091-19314		8017	1+	U	U	U	23/10/2000	801051	0730ES	06	13	310	66.4	49.3	244		801007		
091-19315		8017	1+	U	U	U	23/10/2000	801051	0730ES	06	13	350	61.4	55.2	248		801007		
091-19316		8017	1+	U	U	U	23/10/2000	801051	0730ES	06	13	330	67.0	57.2	249		801007		

BN	R	SP	A	HA	SX	HS	DATE	LC	TIME	M	ST	W	CL	TZ	WL	CB	PR	LOCALE	DM
091-19317		8017	1+	U	U	U	23/10/2000	801051	0730ES	06	13	295	59.5	50.5	230		801007		
091-19318		8017	1+	U	U	U	24/10/2000	801051	0730ES	06	13	365	61.6	52.0	266		801007		
091-19319		8017	1+	U	U	U	24/10/2000	801051	0730ES	06	13	330	60.7	51.1	246		801007		
091-19320		8017	1+	U	U	U	24/10/2000	801051	0730ES	06	13	345	59.7	53.9	250		801007		
091-19321		8017	1+	U	U	U	24/10/2000	801051	0730ES	06	13	345	70.9	54.5	252		801007		
091-19322		8017	1+	U	U	U	24/10/2000	801051	0730ES	06	13	340	62.5	52.2	247		801007		
091-19323		8017	1+	U	U	U	24/10/2000	801051	0730ES	06	13	280	59.4	53.1	223		801007		
091-19324		8017	1+	U	U	U	24/10/2000	801051	0730ES	06	13	305	62.6	53.7	246		801007		
091-19325		8017	1+	U	U	U	25/10/2000	801051	0730ES	06	13	335	67.3	54.9	253		801007		
091-19325	R	8017	6+	U	U	U	22/11/2005	801051	0720ES		13					_b_m	801007	ERSKINE VALLEY	
091-19326		8017	1+	U	U	U	25/10/2000	801051	0730ES	06	13	295	62.4	52.4	240		801007		
091-19327		8017	1+	U	U	U	25/10/2000	801051	0730ES	06	13	310	62.1	60.4	242		801007		
091-19328		8017	1+	U	U	U	25/10/2000	801051	0730ES	06	13	355	63.4	55.3	246		801007		
091-19329		8017	1+	U	U	U	25/10/2000	801051	0730ES	06	13	315	61.9	50.8	247		801007		
091-19330		8017	1+	U	U	U	25/10/2000	801051	0730ES	06	13	310	67.5	52.4	257		801007		
091-19331		8017	1+	U	U	U	25/10/2000	801051	0730ES	06	13	360	67.2	55.0	248		801007		
091-19332		8017	1+	U	U	U	31/01/2001	801051	1200ES	06	13	290	69.5	48.3	256		801007		
091-19333		8017	1+	U	U	U	03/02/2001	801051	1200ES	06	13	365	67.1	55.5			801007		
091-19333	R	8017	1+	U	U	U	03/02/2001	801051									801007	GOWER	
091-19333	R	8017	6+	U	U	U	08/10/2005	801051	0720ES	06	13	320				gwum	801007	GOWER	
091-19334		8017	1+	U	U	U	06/10/2005	801051	0700ES	06	13	295	62.7	55.0	245	kmyo	801007	OLD SETTLEMENT BEACH	
091-19335		8017	1+	U	U	U	06/10/2005	801051	0815ES	06	13	295	64.7	53.0	240	kmyg	801007	OLD SETTLEMENT BEACH	
091-19335	R	8017	1+	U	U	U	08/10/2005	801051								kmyg	801007	NORTH HILLS	738.6
091-19335	R	8017	1+	U	U	U	10/10/2005	801051								kmyg	801007	OLD SETTLEMENT BEACH	738.6
091-19335	R	8017	1+	U	U	U	11/10/2005	801051								kmyg	801007	MIDDLE BEACH ROAD	1365.6
091-19335	R	8017	1+	U	U	U	26/10/2005	801051								kmyg	801007	MIDDLE BEACH ROAD	0.0
091-19335	R	8017	1+	U	U	U	04/11/2005	801051								kmyg	801007	MIDDLE BEACH ROAD	0.0
091-19336		8017	1+	U	U	U	06/10/2005	801051	1050ES	06	13	340	70.0	55.3	251	kmyn	801007	AIRPORT	
091-19336	R	8017	1+	U	U	U	26/02/2006	801051								kmyn	801007	AIRPORT	0.0
091-19336	R	8017	1+	U	U	U	22/04/2006	801051								kmyn	801007	AIRPORT	0.0
091-19336	R	8017	1+	U	U	U	16/07/2006	801051								kmyn	801007	AIRPORT	0.0
091-19337		8017	1+	U	U	U	06/10/2005	801051	1410ES	06	13	320	70.8	51.3	255	kmyw	801007	GOLF COURSE	
091-19337	R	8017	1+	U	U	U	14/10/2005	801051								kmyw	801007	GOLF COURSE	0.0
091-19337	R	8017	1+	U	U	U	03/11/2005	801051								kmyw	801007	GOLF COURSE	0.0
091-19337	R	8017	1+	U	U	U	29/05/2006	801051								kmyw	801007	GOLF COURSE	0.0
091-19337	R	8017	1+	U	U	U	16/07/2006	801051								kmyw	801007	GOLF COURSE	0.0

BN	R	SP	A	HA	SX	HS	DATE	LC	TIME	M	ST	W	CL	TZ	WL	CB	PR	LOCALE	DM
091-19338		8017	1+	U	U	U	06/10/2005	801051	1500ES	06	13	315	61.3	52.4	232	kmou	801007	GOLF COURSE	
091-19338	R	8017	1+	U	U	U	30/05/2006	801051								kmou	801007	SOLDIERS CREEK	604.7
091-19338	R	8017	1+	U	U	U	16/07/2006	801051								kmou	801007	SOLDIERS CREEK	0.0
091-19339		8017	1+	U	U	U	06/10/2005	801051	1500ES	06	13	315	63.9	54.8	239	kmog	801007	GOLF COURSE	
091-19339	R	8017	1+	U	U	U	13/10/2005	801051							239	kmog	801007	GOLF COURSE	0.0
091-19339	R	8017	1+	U	U	U	20/11/2005	801051							239	kmog	801007	MIDDLE BEACH ROAD	2325.2
091-19340		8017	1+	U	U	U	06/10/2005	801051	1500ES	06	13	345	67.4	55.7	245	kmon	801007	GOLF COURSE	
091-19340	R	8017	1+	U	U	U	13/10/2005	801051								kmon	801007	GOLF COURSE	0.0
091-19340	R	8017	1+	U	U	U	26/02/2006	801051								kmon	801007	AIRPORT	1207.6
091-19340	R	8017	1+	U	U	U	30/05/2006	801051								kmon	801007	SOLDIERS CREEK	1806.6
091-19341		8017	1+	U	U	U	06/10/2005	801051	1500ES	06	13	315	64.0	50.3	249	kmow	801007	GOLF COURSE	
091-19341	R	8017	1+	U	U	U	26/02/2006	801051								kmow	801007	GOLF COURSE	0.0
091-19341	R	8017	1+	U	U	U	27/02/2006	801051								kmow	801007	AIRPORT	1207.6
091-19342		8017	1+	U	U	U	06/10/2005	801051	1500ES	06	13	365	68.4	56.8	246	kmug	801007	GOLF COURSE	
091-19342	R	8017	1+	U	U	U	13/10/2005	801051								kmug	801007	GOLF COURSE	0.0
091-19342	R	8017	1+	U	U	U	23/11/2005	801051								kmug	801007	NORTH HILLS	4243.3
091-19343		8017	1+	U	U	U	06/10/2005	801051	1500ES	06	13	355	67.4	53.7	243	kmun	801007		
091-19344		8017	1+	U	U	U	06/10/2005	801051	1500ES	06	13	315	65.0	55.3	238	kmuw	801007	GOLF COURSE	
091-19345		8017	1+	U	U	U	06/10/2005	801051	1500ES	06	13	285	61.2	53.4	235	kmgn	801007	GOLF COURSE	
091-19345	R	8017	1+	U	U	U	12/10/2005	801051								kmgn	801007	FAR FLATS	2204.1
091-19345	R	8017	1+	U	U	U	31/10/2005	801051								kmgn	801007	GOWER	1898.7
091-19345	R	8017	1+	U	U	U	22/12/2005	801051								kmgn	801007	GOWER	0.0
091-19345	R	8017	1+	U	U	U	27/05/2006	801051								kmgn	801007	ERSKINE VALLEY	648.1
091-19345	R	8017	1+	U	U	U	30/05/2006	801051								kmgn	801007	SOLDIERS CREEK	2877.5
091-19346		8017	1+	U	U	U	06/10/2005	801051	1500ES	06	13	305	61.7	53.3	236	kmgw	801007	GOLF COURSE	
091-19346	R	8017	1+	U	U	U	23/11/2005	801051								kmgw	801007	NORTH HILLS	4243.3
091-19347		8017	1+	U	U	U	06/10/2005	801051	1500ES	06	13	345	66.4	54.0	251	kmnw	801007	GOLF COURSE	
091-19347	R	8017	1+	U	U	U	06/10/2005	801051								kmnw	801007	GOLF COURSE	0.0
091-19347	R	8017	1+	U	U	U	13/10/2005	801051								kmnw	801007	GOLF COURSE	0.0
091-19348		8017	1+	U	U	U	06/10/2005	801051	1745ES	06	13	370	72.3	56.5	260	omnw	801007	AIRPORT	
091-19348	R	8017	1+	U	U	U	22/10/2005	801051								omnw	801007	AIRPORT	0.0
091-19348	R	8017	1+	U	U	U	19/11/2005	801051								omnw	801007	AIRPORT	0.0
091-19348	R	8017	1+	U	U	U	22/12/2005	801051								omnw	801007	AIRPORT	0.0
091-19348	R	8017	1+	U	U	U	19/01/2006	801051								omnw	801007	AIRPORT	0.0
091-19348	R	8017	1+	U	U	U	22/04/2006	801051								omnw	801007	AIRPORT	0.0
091-19348	R	8017	1+	U	U	U	16/07/2006	801051								omnw	801007	AIRPORT	0.0

BN	R	SP	A	HA	SX	HS	DATE	LC	TIME	M	ST	W	CL	TZ	WL	CB	PR	LOCALE	DM
091-19349		8017	1+	U	U	U	07/10/2005	801051	0810ES	06	13	360	66.7	55.2	258	ymko	801007	FAR FLATS	
091-19349	R	8017	1+	U	U	U	09/10/2005	801051								ymko	801007	FAR FLATS	0.0
091-19349	R	8017	1+	U	U	U	13/10/2005	801051								ymko	801007	FAR FLATS	0.0
091-19350		8017	1+	U	U	U	07/10/2005	801051	0810ES	06	13	325	63.1	54.7	249	ymku	801007	FAR FLATS	
091-19350	R	8017	1+	U	U	U	09/10/2005	801051								ymku	801007	GOWER	1898.7
091-19350	R	8017	1+	U	U	U	02/11/2005	801051								ymku	801007	GOWER	0.0
091-19350	R	8017	1+	U	U	U	22/11/2005	801051								ymku	801007	GOWER	0.0
091-19350	R	8017	1+	U	U	U	20/12/2005	801051								ymku	801007	GOWER	0.0
091-19350	R	8017	1+	U	U	U	24/01/2006	801051								ymku	801007	GOWER	0.0
091-19350	R	8017	1+	U	U	U	16/07/2006	801051								ymku	801007	GOWER	0.0
091-19901		8017	1+	U	U	U	07/10/2005	801051	1230ES	06	13	375	68.4	55.0	252	ymkg	801007	GOWER	
091-19901	R	8017	1+	U	U	U	13/10/2005	801051								ymkg	801007	MIDDLE BEACH ROAD	6316.6
091-19901	R	8017	1+	U	U	U	13/10/2005	801051								ymkg	801007	GOLF COURSE	2325.2
091-19901	R	8017	1+	U	U	U	02/11/2005	801051								ymkg	801007	GOWER	4092.6
091-19901	R	8017	1+	U	U	U	21/04/2006	801051								ymkg	801007	GOWER	0.0
091-19901	R	8017	1+	U	U	U	16/07/2006	801051								ymkg	801007	GOLF COURSE	4092.6
091-19902		8017	1+	U	U	U	07/10/2005	801051	1230ES	06	13	335	66.2	55.2	246	ymkn	801007	GOWER	
091-19902	R	8017	1+	U	U	U	02/11/2005	801051								ymkn	801007	GOWER	0.0
091-19902	R	8017	1+	U	U	U	22/11/2005	801051								ymkn	801007	GOWER	0.0
091-19902	R	8017	1+	U	U	U	20/12/2005	801051								ymkn	801007	GOWER	0.0
091-19902	R	8017	1+	U	U	U	27/02/2006	801051								ymkn	801007	GOWER	0.0
091-19902	R	8017	1+	U	U	U	28/05/2006	801051								ymkn	801007	GOWER	0.0
091-19903		8017	1+	U	U	U	07/10/2005	801051	1230ES	06	13	325	64.0	53.0	242	ymkw	801007	GOWER	
091-19903	R	8017	1+	U	U	U	14/10/2005	801051								ymkw	801007	FAR FLATS	1898.7
091-19904		8017	1+	U	U	U	07/10/2005	801051	1230ES	06	13	365	65.6	52.8	247	ymou	801007	GOWER	
091-19904	R	8017	1+	U	U	U	13/10/2005	801051								ymou	801007	FAR FLATS	1898.7
091-19905		8017	1+	U	U	U	07/10/2005	801051	1230ES	06	13	340	68.0		248	ymog	801007	GOWER	
091-19906		8017	1+	U	U	U	07/10/2005	801051	1230ES	06	13	325	66.8	53.1	251	ymow	801007	GOWER	
091-19907		8017	1+	U	U	U	07/10/2005	801051	1230ES	06	13	350	68.0	55.0	265	ymug	801007	GOWER	
091-19907	R	8017	1+	U	U	U	31/10/2005									ymug	801007	GOWER	0.0
091-19907	R	8017	1+	U	U	U	02/11/2005									ymug	801007	GOWER	0.0
091-19907	R	8017	1+	U	U	U	20/12/2005									ymug	801007	GOWER	0.0
091-19908		8017	1+	U	U	U	07/10/2005	801051	1230ES	06	13	375	70.6	56.4	255	ymun	801007	GOWER	
091-19908	R	8017	1+	U	U	U	02/11/2005	801051								ymun	801007	GOWER	0.0
091-19909		8017	1+	U	U	U	07/10/2005	801051	1415ES	06	13	360	70.0	55.3	254	ymuw	801007	GOWER	
091-19909	R	8017	1+	U	U	U	20/12/2005	801051								ymuw	801007	GOWER	0.0

BN	R	SP	A	HA	SX	HS	DATE	LC	TIME	M	ST	W	CL	TZ	WL	CB	PR	LOCALE	DM
091-19909	R	8017	1+	U	U	U	27/02/2006	801051								ymuw	801007	GOWER	0.0
091-19910		8017	1+	U	U	U	07/10/2005	801051	1525ES	06	13	330	68.4	56.2	255	ymgn	801007	GOWER	
091-19910	R	8017	1+	U	U	U	14/10/2005	801051								ymgn	801007	GOLF COURSE	4092.6
091-19910	R	8017	1+	U	U	U	22/11/2005	801051								ymgn	801007	GOWER	4092.6
091-19910	R	8017	1+	U	U	U	28/05/2006	801051								ymgn	801007	GOWER	0.0
091-19910	R	8017	1+	U	U	U	19/07/2006	801051								ymgn	801007	GOWER	0.0
091-19911		8017	1+	U	U	U	07/10/2005	801051	1525ES	06	13	350	70.1	55.0	255	wm__	801007	GOWER	
091-19911	R	8017	1+	U	U	U	24/01/2006	801051								wm__	801007	GOWER	0.0
091-19912		8017	1+	U	U	U	07/10/2005	801051	1620ES	06	13	320	70.0	54.2	256	ymgw	801007	GOWER	
091-19912	R	8017	1+	U	U	U	22/11/2005	801051								ymgw	801007	GOWER	0.0
091-19913		8017	1+	U	U	U	07/10/2005	801051	1640ES	06	13	300	63.0	53.5	240	ymnw	801007	GOWER	
091-19913	R	8017	1+	U	U	U	07/10/2005	801051								ymnw	801007	FAR FLATS	1898.7
091-19913	R	8017	1+	U	U	U	27/02/2006	801051								ymnw	801007	SADDLE	1767.4
091-19914		8017	1+	U	U	U	07/10/2005	801051	1740ES	06	13	330	68.2	51.6	246	umky	801007	GOWER	
091-19914	R	8017	1+	U	U	U	13/10/2005	801051								umky	801007	FAR FLATS	1898.7
091-19915		8017	1+	U	U	U	08/10/2005	801051	0720ES	06	13	325	67.4	53.9	244	umkg	801007	GOWER	
091-19915	R	8017	1+	U	U	U	22/04/2006	801051								umkg	801007	GOLF COURSE	4092.6
091-19916		8017	1	G	U	U	08/10/2005	801051	0720ES	06	13	310	65.8	50.2	231	umkn	801007	GOWER	
091-19916	R	8017	1	G	U	U	24/01/2006	801051								umkn	801007	GOWER	0.0
091-19917		8017	1+	U	U	U	08/10/2005	801051	0720ES	06	13	360	70.3	55.6	255	umkw	801007	GOWER	
091-19917	R	8017	1+	U	U	U	14/10/2005	801051								umkw	801007	FAR FLATS	1898.7
091-19917	R	8017	1+	U	U	U	02/11/2005	801051								umkw	801007	GOWER	1898.7
091-19917	R	8017	1+	U	U	U	22/11/2005	801051								umkw	801007	GOWER	0.0
091-19917	R	8017	1+	U	U	U	20/12/2005	801051								umkw	801007	GOWER	0.0
091-19917	R	8017	1+	U	U	U	24/01/2006	801051								umkw	801007	GOWER	0.0
091-19917	R	8017	1+	U	U	U	27/02/2006	801051								umkw	801007	GOWER	0.0
091-19917	R	8017	1+	U	U	U	21/04/2006	801051								umkw	801007	GOWER	0.0
091-19917	R	8017	1+	U	U	U	27/05/2006	801051								umkw	801007	GOWER	0.0
091-19917	R	8017	1+	U	U	U	19/07/2006	801051								umkw	801007	GOWER	0.0
091-19918		8017	1+	U	U	U	08/10/2005	801051	0720ES	06	13	320	64.8	53.5	246	umyo	801007	GOWER	
091-19918	R	8017	1+	U	U	U	09/10/2005	801051	0720ES	06	13					umyo	801007	GOWER	0.0
091-19919		8017	1+	U	U	U	08/10/2005	801051	0720ES	06	13	325	70.4	53.7	256	umyg	801007	GOWER	
091-19920		8017	1+	U	U	U	08/10/2005	801051	0720ES	06	13	350	68.3	54.2	265	umyn	801007	GOWER	
091-19921		8017	1+	U	U	U	08/10/2005	801051	0720ES	06	13	340	73.2	52.9	255	umyw	801007	GOWER	
091-19922		8017	1+	U	U	U	08/10/2005	801051	0720ES	06	13	370	69.6	56.5	256	umog	801007	GOWER	
091-19922	R	8017	1+	U	U	U	02/11/2005	801051								umog	801007	GOWER	0.0

BN	R	SP	A	HA	SX	HS	DATE	LC	TIME	M	ST	W	CL	TZ	WL	CB	PR	LOCALE	DM
091-19923		8017	1+	U	U	U	08/10/2005	801051	0720ES	06	13	370	70.1	54.0	261	umon	801007	GOWER	
091-19923	R	8017	1+	U	U	U	02/11/2005	801051								umon	801007	GOWER	0.0
091-19924		8017	1+	U	U	U	08/10/2005	801051	0720ES	06	13	390	71.3	56.1	253	umow	801007	GOWER	
091-19924	R	8017	1+	U	U	U	14/10/2005	801051								umow	801007	FAR FLATS	1898.7
091-19924	R	8017	1+	U	U	U	16/07/2006	801051								umow	801007	FAR FLATS	0.0
091-19925		8017	1+	U	U	U	08/10/2005	801051	0720ES	06	13	320	71.0	52.6	254	umnw	801007	GOWER	
091-19926		8017	1+	U	U	U	08/10/2005	801051	0720ES	06	13	335	69.1	57.2	261	gmby	801007	GOWER	
091-19927		8017	1+	U	U	U	08/10/2005	801051	0720ES	06	13	325	61.7	51.2	249	gmbs	801007	GOWER	
091-19927	R	8017	1+	U	U	U	02/11/2005	801051								gmbs	801007	GOWER	0.0
091-19927	R	8017	1+	U	U	U	22/11/2005	801051								gmbs	801007	GOWER	0.0
091-19927	R	8017	1+	U	U	U	20/12/2005	801051								gmbs	801007	GOWER	0.0
091-19927	R	8017	1+	U	U	U	19/07/2006	801051								gmbs	801007	GOWER	0.0
091-19928		8017	1+	U	U	U	08/10/2005	801051	0720ES	06	13	300	71.0	52.5	256	gmbu	801007	GOWER	
091-19928	R	8017	1+	U	U	U	02/11/2005	801051								gmbu	801007	GOWER	0.0
091-19928	R	8017	1+	U	U	U	22/11/2005	801051								gmbu	801007	GOWER	0.0
091-19928	R	8017	1+	U	U	U	27/02/2006	801051								gmbu	801007	SADDLE	499.5
091-19929		8017	1+	U	U	U	08/10/2005	801051	0720ES	06	13	330	69.8	52.0	262	gmbn	801007	GOWER	
091-19929	R	8017	1+	U	U	U	20/12/2005	801051								gmbn	801007	GOWER	0.0
091-19930		8017	1+	U	U	U	08/10/2005	801051	0720ES	06	13	350	72.1	56.7	261	gmbw	801007	GOWER	
091-19930	R	8017	1+	U	U	U	22/11/2005	801051								gmbw	801007	GOWER	0.0
091-19931		8017	1+	U	U	U	08/10/2005	801051	0720ES	06	13	290	70.7	54.4	256	gmys	801007	GOWER	
091-19931	R	8017	1+	U	U	U	12/10/2005	801051								gmys	801007	FAR FLATS	1898.7
091-19932		8017	1+	U	U	U	08/10/2005	801051	0720ES	06	13	345	63.4	54.0	244	gmyu	801007	GOWER	
091-19932	R	8017	1+	U	U	U	21/04/2006	801051								gmyu	801007	SADDLE	499.5
091-19933		8017	1+	U	U	U	08/10/2005	801051	0720ES	06	13	315	66.0	54.3	245	gmyn	801007	GOWER	
091-19934		8017	1+	U	U	U	08/10/2005	801051	0720ES	06	13	370	68.0	56.0	259	gmyw	801007	GOWER	
091-19935		8017	1+	U	U	U	08/10/2005	801051	0720ES	06	13	335	66.9	56.0	252	gmsu	801007	GOWER	
091-19936		8017	1+	U	U	U	08/10/2005	801051	1200ES	06	13	330	68.4	57.0	255	gmsn	801007	GOWER	
091-19936	R	8017	1+	U	U	U	22/11/2005	801051								gmsn	801007	GOWER	0.0
091-19937		8017	1+	U	U	U	08/10/2005	801051	1510ES	06	13	325	68.9	55.4	256	gmsw	801007	GOWER	
091-19937	R	8017	1+	U	U	U	08/10/2005	801051								gmsw	801007	GOWER	0.0
091-19937	R	8017	1+	U	U	U	23/11/2005	801051								gmsw	801007	SOLDIERS CREEK	3524.6
091-19937	R	8017	1+	U	U	U	20/12/2005	801051								gmsw	801007	GOWER	3524.6
091-19938		8017	1+	U	U	U	08/10/2005	801051	1620ES	06	13	320	68.0	55.0	250	gmun	801007	GOWER	
091-19939		8017	1+	U	U	U	09/10/2005	801051	0650ES	06	13	335	69.5	57.0	260	gmuw	801007	GOWER	
091-19939	R	8017	1+	U	U	U	02/11/2005	801051								gmuw	801007	GOWER	0.0

BN	R	SP	A	HA	SX	HS	DATE	LC	TIME	M	ST	W	CL	TZ	WL	CB	PR	LOCALE	DM
091-19939	R	8017	1+	U	U	U	22/11/2005	801051								gmuw	801007	GOWER	0.0
091-19939	R	8017	1+	U	U	U	20/12/2005	801051								gmuw	801007	GOWER	0.0
091-19940		8017	1+	U	U	U	09/10/2005	801051	0725ES	06	13	315	58.3	53.0	249	gmnw	801007	GOWER	
091-19940	R	8017	1+	U	U	U	31/10/2005	801051								gmnw	801007	GOWER	0.0
091-19940	R	8017	1+	U	U	U	02/11/2005	801051								gmnw	801007	GOWER	0.0
091-19941		8017	1+	U	U	U	09/10/2005	801051	1030ES	06	13	370	71.9	57.4	256	nmby	801007	GOWER	
091-19942		8017	1+	U	U	U	10/10/2005	801051	1430ES	06	13	345	64.1	55.0	252	omky	801007	CLEAR PLACE	
091-19942	R	8017	1+	U	U	U	13/10/2005	801051								omky	801007	CLEAR PLACE	0.0
091-19942	R	8017	1+	U	U	U	03/11/2005	801051								omky	801007	CLEAR PLACE	0.0
091-19942	R	8017	1+	U	U	U	21/11/2005	801051								omky	801007	CLEAR PLACE	0.0
091-19943		8017	1+	U	U	U	10/10/2005	801051	1430ES	06	13	300	71.1	54.4	266	omku	801007	CLEAR PLACE	
091-19943	R	8017	1+	U	U	U	27/10/2005	801051								omku	801007	CLEAR PLACE	0.0
091-19943	R	8017	1+	U	U	U	21/11/2005	801051								omku	801007	CLEAR PLACE	0.0
091-19943	R	8017	1+	U	U	U	27/05/2006	801051								omku	801007	CLEAR PLACE	0.0
091-19944		8017	1+	U	U	U	10/10/2005	801051	1430ES	06	13	310	70.4	56.3	257	omkg	801007	CLEAR PLACE	
091-19944	R	8017	1+	U	U	U	14/10/2005	801051								omkg	801007	CLEAR PLACE	0.0
091-19944	R	8017	1+	U	U	U	27/10/2005	801051								omkg	801007	CLEAR PLACE	0.0
091-19944	R	8017	1+	U	U	U	30/10/2005	801051								omkg	801007	PINETREES	675.7
091-19944	R	8017	1+	U	U	U	20/11/2005	801051								omkg	801007	CLEAR PLACE	675.7
091-19944	R	8017	1+	U	U	U	22/12/2005	801051								omkg	801007	CLEAR PLACE	0.0
091-19944	R	8017	1+	U	U	U	19/01/2006	801051								omkg	801007	CLEAR PLACE	0.0
091-19944	R	8017	1+	U	U	U	22/04/2006	801051								omkg	801007	CLEAR PLACE	0.0
091-19944	R	8017	1+	U	U	U	27/05/2006	801051								omkg	801007	CLEAR PLACE	0.0
091-19945		8017	1+	U	U	U	11/10/2005	801051	0630ES	06	13	260	65.4	53.0	235	omkn	801007	MIDDLE BEACH ROAD	
091-19945	R	8017	1+	U	U	U	30/10/2005	801051								omkn	801007	PINETREES	469.0
091-19946		8017	1+	U	U	U	11/10/2005	801051	0630ES	06	13	285	62.6	56.2	227	omkw	801007	MIDDLE BEACH ROAD	
091-19947		8017	1+	U	U	U	11/10/2005	801051	0650ES	06	13	285	61.9		239	omyu	801007	MIDDLE BEACH ROAD	
091-19948		8017	1+	U	U	U	11/10/2005	801051	0810ES	06	13	315	61.9	51.6	246	omyg	801007	CLEAR PLACE	
091-19948	R	8017	1+	U	U	U	13/10/2005	801051								omyg	801007	CLEAR PLACE	0.0
091-19948	R	8017	1+	U	U	U	27/10/2005	801051								omyg	801007	CLEAR PLACE	0.0
091-19948	R	8017	1+	U	U	U	20/11/2005	801051								omyg	801007	CLEAR PLACE	0.0
091-19948	R	8017	1+	U	U	U	22/12/2005	801051								omyg	801007	CLEAR PLACE	0.0
091-19948	R	8017	1+	U	U	U	19/01/2006	801051								omyg	801007	CLEAR PLACE	0.0
091-19948	R	8017	1+	U	U	U	22/04/2006	801051								omyg	801007	CLEAR PLACE	0.0
091-19948	R	8017	1+	U	U	U	27/05/2006	801051								omyg	801007	CLEAR PLACE	0.0
091-19949		8017	1+	U	U	U	11/10/2005	801051	1050ES	06	13	350	68.2	54.7	240	omyn	801007	GOLF COURSE	

BN	R	SP	A	HA	SX	HS	DATE	LC	TIME	M	ST	W	CL	TZ	WL	CB	PR	LOCALE	DM
091-19950		8017	1+	U	U	U	11/10/2005	801051	1050ES	06	13	350	68.0	53.0	256	om__	801007	GOLF COURSE	
091-19950	R	8017	1+	U	U	U	23/11/2005	801051								om__	801007	GOLF COURSE	0.0
091-19951		8017	J	P	U	U	16/07/2006	801051	0805ES	06	13	365	69.8	54.6	256	bm__	801007	GOLF COURSE	
091-19952		8017	J	P	U	U	16/07/2006	801051	0805ES	06	13	335	64.6	52.0	239	bm__	801007	GOLF COURSE	
091-19953		8017	J	P	U	U	16/07/2006	801051	0805ES	06	13	380	68.2	55.8	246	bm__	801007	GOLF COURSE	
091-19954		8017	1+	U	U	U	16/07/2006	801051	0845ES	06	13	330	69.4	55.0	260	bm__	801007	GOLF COURSE	
091-19955		8017	J	P	U	U	16/07/2006	801051	0900ES	06	13	365	69.0	52.0	247	bm__	801007	GOLF COURSE	
091-19956		8017	J	P	U	U	18/07/2006	801051	0910ES	06	13	330	68.0	55.0	247	bm__	801007	GOLF COURSE	
091-19957		8017	J	P	U	U	19/07/2006	801051	1115ES	06	13	400	67.0	55.1	249	umgk	801007	GOWER	
091-19958		8017	J	P	U	U	19/07/2006	801051	1000ES	06	13	365	69.4	54.5	255	gm__	801007	GOWER	
091-19959		8017	1+	U	U	U	19/07/2006	801051	1115ES	06	13	365	65.0	51.9	244	ymub	801007	GOWER	
091-19960		8017	J	P	U	U	19/07/2006	801051	1115ES	06	13	335	61.0	53.7	239	gm__	801007	GOWER	
091-19961		8017	1+	U	U	U	19/07/2006	801051	1115ES	06	13	340	63.5	54.5	244	ymnu	801007	GOWER	
091-19962		8017	1+	U	U	U	19/07/2006	801051	1115ES	06	13	420	70.4	52.5	260	umob	801007	GOWER	
091-19963		8017	1+	U	U	U	19/07/2006	801051	1115ES	06	13	405	71.0	55.3	260	umnk	801007	GOWER	
091-19964		8017	1+	U	U	U	19/07/2006	801051	1115ES	06	13	455	71.9	57.0	263	umwk	801007	GOWER	
091-19965		8017	1+	U	U	U	19/07/2006	801051	1115ES	06	13	380	64.3	54.1	248	umoy	801007	GOWER	
091-19966		8017	J	P	U	U	19/07/2006	801051	1115ES	06	13	400	67.0	54.4	245	umgy	801007	GOWER	
091-19967		8017	J	P	U	U	19/07/2006	801051	1315ES	06	13	365	67.7	55.3	255	umng	801007	GOWER	
091-44301		8017	1+	U	U	U	11/10/2005	801051	1200ES	06	13	335	69.1	55.7	256	omuw	801007	AIRPORT	
091-44301	R	8017	1+	U	U	U	11/10/2005	801051								omuw	801007	AIRPORT	0.0
091-44301	R	8017	1+	U	U	U	23/11/2005	801051								omuw	801007	AIRPORT	0.0
091-44301	R	8017	1+	U	U	U	19/01/2006	801051								omuw	801007	AIRPORT	0.0
091-44301	R	8017	1+	U	U	U	16/07/2006	801051								omuw	801007	AIRPORT	0.0
091-44302		8017	1+	U	U	U	11/10/2005	801051	1350ES	06	13	370	63.7	53.3	250	omyw	801007	GOLF COURSE	
091-44302	R	8017	1+	U	U	U	13/10/2005	801051								omyw	801007	GOLF COURSE	0.0
091-44302	R	8017	1+	U	U	U	27/11/2005	801051								omyw	801007	GOLF COURSE	0.0
091-44302	R	8017	1+	U	U	U	22/04/2006	801051								omyw	801007	AIRPORT	1207.6
091-44303		8017	1+	U	U	U	11/10/2005	801051	1350ES	06	13	290	61.9		235	omug	801007	GOLF COURSE	
091-44303	R	8017	1+	U	U	U	14/10/2005	801051								omug	801007	SOLDIERS CREEK	604.7
091-44303	R	8017	1+	U	U	U	27/11/2005	801051								omug	801007	GOLF COURSE	604.7
091-44303	R	8017	1+	U	U	U	16/07/2006	801051								omug	801007	AIRPORT	1207.6
091-44304		8017	1+	U	U	U	11/10/2005	801051	1450ES	06	13	350	71.4	55.8	259	omgn	801007	GOLF COURSE	
091-44304	R	8017	1+	U	U	U	20/11/2005	801051								omgn	801007	SOLDIERS CREEK	604.7
091-44305		8017	1+	U	U	U	12/10/2005	801051	0635ES	06	13	300	63.2	54.4	249	omgw	801007	GOLF COURSE	
091-44305	R	8017	1+	U	U	U	13/10/2005	801051								omgw	801007	GOLF COURSE	0.0

BN	R	SP	A	HA	SX	HS	DATE	LC	TIME	M	ST	W	CL	TZ	WL	CB	PR	LOCALE	DM
091-44305	R	8017	1+	U	U	U	22/04/2006	801051								omgw	801007	GOLF COURSE	0.0
091-44305	R	8017	1+	U	U	U	29/05/2006	801051								omgw	801007	GOLF COURSE	0.0
091-44306		8017	1+	U	U	U	12/10/2005	801051	0715ES	06	13	345	68.6	56.3	254	__km	801007	GOLF COURSE	
091-44307		8017	1+	U	U	U	12/10/2005	801051	0715ES	06	13	320	69.5	55.2	255	__bm	801007	GOLF COURSE	
091-44308		8017	1+	U	U	U	12/10/2005	801051	0800ES	06	13	360	65.5	53.3	259	nmbs	801007	FAR FLATS	
091-44308	R	8017	1+	U	U	U	21/04/2006	801051								nmbs	801007	ERSKINE VALLEY	1253.7
091-44309		8017	1+	U	U	U	12/10/2005	801051	0800ES	06	13	370	64.3	53.7	244	nmbu	801007	FAR FLATS	
091-44309	R	8017	1+	U	U	U	03/11/2005	801051								nmbu	801007	FAR FLATS	0.0
091-44309	R	8017	1+	U	U	U	25/02/2006	801051								nmbu	801007	FAR FLATS	0.0
091-44309	R	8017	1+	U	U	U	27/05/2006	801051								nmbu	801007	FAR FLATS	0.0
091-44310		8017	1+	U	U	U	12/10/2005	801051	0800ES	06	13	340	68.2	50.8	246	nmbw	801007	FAR FLATS	
091-44310	R	8017	1+	U	U	U	14/10/2005	801051								nmbw	801007	FAR FLATS	0.0
091-44310	R	8017	1+	U	U	U	22/11/2005	801051								nmbw	801007	GOWER	1898.7
091-44310	R	8017	1+	U	U	U	22/04/2006	801051								nmbw	801007	GOLF COURSE	4092.6
091-44310	R	8017	1+	U	U	U	28/05/2006	801051								nmbw	801007	GOWER	4092.6
091-44310	R	8017	1+	U	U	U	19/07/2006	801051								nmbw	801007	GOWER	0.0
091-44311		8017	1+	U	U	U	12/10/2005	801051	0800ES	06	13	285		51.0	234	nmys	801007	FAR FLATS	
091-44311	R	8017	1+	U	U	U	13/10/2005	801051								nmys	801007	FAR FLATS	0.0
091-44312		8017	1+	U	U	U	12/10/2005	801051	0800ES	06	13	350	66.7	53.1	256	nmyu	801007	FAR FLATS	
091-44313		8017	1+	U	U	U	12/10/2005	801051	0800ES	06	13	380	70.0	55.0	251	nmyw	801007	FAR FLATS	
091-44314		8017	1+	U	U	U	12/10/2005	801051	0930ES	06	13	330	66.3	53.2	243	nmsu	801007	FAR FLATS	
091-44314	R	8017	1+	U	U	U	13/10/2005	801051								nmsu	801007	FAR FLATS	0.0
091-44314	R	8017	1+	U	U	U	30/05/2006	801051								nmsu	801007	SOLDIERS CREEK	1660.7
091-44315		8017	1+	U	U	U	12/10/2005	801051	0945ES	06	13	330	69.2	53.7	255	_msw	801007	FAR FLATS	
091-44315	R	8017	1+	U	U	U	16/10/2005	801051		28	98					_msw	801007	SOLDIERS CREEK	1660.7
091-44316		8017	1+	U	U	U	12/10/2005	801051	0945ES	06	13	340	62.9	51.2	254	nmuw	801007	FAR FLATS	
091-44317		8017	1+	U	U	U	12/10/2005	801051	1500ES	06	13	350	67.3	51.9	255	nmgw	801007	GOLF COURSE	
091-44318		8017	1+	U	U	U	28/10/2005	801051	0745ES	06	13	365	60.7	50.0	228	wmby	801007	MIDDLE BEACH ROAD	
091-44318	R	8017	1+	U	U	U	16/07/2006	801051								wmby	801007	GOLF COURSE	2325.2
091-44319		8017	1+	U	U	U	28/10/2005	801051	1200ES	06	13	340	72.7	54.4	256	wmbu	801007	CLEAR PLACE	
091-44319	R	8017	1+	U	U	U	03/11/2005	801051								wmbu	801007	CLEAR PLACE	0.0
091-44319	R	8017	1+	U	U	U	21/11/2005	801051								wmbu	801007	CLEAR PLACE	0.0
091-44320		8017	1+	U	U	U	29/10/2005	801051	0800ES	06	13	355	74.9	54.4	260	wmyn	801007	AIRPORT	
091-44320	R	8017	1+	U	U	U	23/11/2005	801051								wmyn	801007	AIRPORT	0.0
091-44320	R	8017	1+	U	U	U	19/01/2006	801051								wmyn	801007	AIRPORT	0.0
091-44320	R	8017	1+	U	U	U	27/02/2006	801051								wmyn	801007	AIRPORT	0.0

BN	R	SP	A	HA	SX	HS	DATE	LC	TIME	M	ST	W	CL	TZ	WL	CB	PR	LOCALE	DM
091-44321		8017	1+	U	U	U	29/10/2005	801051	0850ES	06	13	325	71.7	52.6	261	wmyu	801007	PINETREES	
091-44321	R	8017	1+	U	U	U	26/11/2005	801051								wmyu	801007	PINETREES	0.0
091-44321	R	8017	1+	U	U	U	16/07/2006	801051								wmyu	801007	AIRPORT	730.9
091-44322		8017	1+	U	U	U	29/10/2005	801051	0940ES	06	13	330	64.9	53.4	251	bmys	801007	PINETREES	
091-44322	R	8017	1+	U	U	U	26/11/2005	801051								bmys	801007	PINETREES	0.0
091-44323		8017	1+	U	U	U	30/10/2005	801051	0740ED	06	13	320	66.3	55.0	255	bmyu	801007	NORTH HILLS	
091-44323	R	8017	1+	U	U	U	23/11/2005	801051								bmyu	801007	NORTH HILLS	0.0
091-44323	R	8017	1+	U	U	U	19/01/2006	801051								bmyu	801007	NORTH HILLS	0.0
091-44323	R	8017	1+	U	U	U	28/02/2006	801051								bmyu	801007	NORTH HILLS	0.0
091-44323	R	8017	1+	U	U	U	29/05/2006	801051								bmyu	801007	NORTH HILLS	0.0
091-44323	R	8017	1+	U	U	U	15/07/2006	801051								bmyu	801007	NORTH HILLS	0.0
091-44324		8017	1+	U	U	U	31/10/2005	801051	0750ED	06	13	335	69.6	53.6	261	pmyo	801007	FAR FLATS	
091-44324	R	8017	1+	U	U	U	03/11/2005	801051								pmyo	801007	FAR FLATS	0.0
091-44324	R	8017	1+	U	U	U	20/11/2005	801051								pmyo	801007	FAR FLATS	0.0
091-44324	R	8017	1+	U	U	U	25/02/2006	801051								pmyo	801007	FAR FLATS	0.0
091-44324	R	8017	1+	U	U	U	22/04/2006	801051								pmyo	801007	FAR FLATS	0.0
091-44324	R	8017	1+	U	U	U	27/05/2006	801051								pmyo	801007	FAR FLATS	0.0
091-44324	R	8017	1+	U	U	U	15/07/2006	801051								pmyo	801007	FAR FLATS	0.0
091-44325		8017	1+	U	U	U	31/10/2005	801051	1135ED	06	13	340	67.0	55.0	240	pmyu	801007	GOWER	
091-44325	R	8017	1+	U	U	U	02/11/2005	801051								pmyu	801007	GOWER	0.0
091-44325	R	8017	1+	U	U	U	22/11/2005	801051								pmyu	801007	GOWER	0.0
091-44325	R	8017	1+	U	U	U	27/02/2006	801051								pmyu	801007	GOWER	0.0
091-44325	R	8017	1+	U	U	U	27/05/2006	801051								pmyu	801007	GOWER	0.0
091-44325	R	8017	1+	U	U	U	19/07/2006	801051								pmyu	801007	GOWER	0.0
091-44326		8017	1+	U	U	U	31/10/2005	801051	1200ED	06	13		65.4	53.8	243	pmyn	801007	GOWER	
091-44327		8017	1+	U	U	U	31/10/2005	801051	1350ED	06	13	340	63.7	55.3	246	pmbu	801007	GOWER	
091-44327	R	8017	1+	U	U	U	02/11/2005	801051								pmbu	801007	GOWER	0.0
091-44327	R	8017	1+	U	U	U	22/11/2005	801051								pmbu	801007	GOWER	0.0
091-44328		8017	1	G	U	U	31/10/2005	801051	1350ED	06	13	355	65.8	54.2	249	pmbn	801007	GOWER	
091-44328	R	8017	1	G	U	U	02/11/2005	801051								pmbn	801007	GOWER	0.0
091-44328	R	8017	1	G	U	U	22/11/2005	801051								pmbn	801007	SADDLE	499.5
091-44329		8017	1+	U	U	U	31/10/2005	801051	1350ED	06	13	320	71.7	54.5	254	pmbs	801007	GOWER	
091-44330		8017	1	G	U	U	31/10/2005	801051	1350ED	06	13	300	64.6	51.8	231	pmun	801007	GOWER	
091-44330	R	8017	1	G	U	U	21/04/2006	801051								pmun	801007	ERSKINE VALLEY	648.1
091-44331		8017	1+	U	U	U	31/10/2005	801051	1350ED	06	13	320	64.3	55.0	252	pm__	801007	GOWER	
091-44332		8017	1	G	U	U	31/10/2005	801051	1350ED	06	13	315	65.4	54.0	240	pmub	801007	GOWER	

BN	R	SP	A	HA	SX	HS	DATE	LC	TIME	M	ST	W	CL	TZ	WL	CB	PR	LOCALE	DM
091-44333		8017	1	G	U	U	31/10/2005	801051	1350ED	06	13	350	67.4	57.0	245	pmus	801007	GOWER	
091-44333	R	8017	1	G	U	U	02/11/2005	801051								pmus	801007	GOWER	0.0
091-44334		8017	1+	U	U	U	31/10/2005	801051	1350ED	06	13	325	67.5	54.4	257	pmnb	801007	GOWER	
091-44335		8017	1+	U	U	U	31/10/2005	801051	1715ED	06	13	330	70.5	53.3	256	pmns	801007	GOWER	
091-44336		8017	1+	U	U	U	01/11/2005	801051	0845ED	06	13	355	69.7	55.2	257	pmpn	801007	GOWER	
091-44337		8017	1+	U	U	U	01/11/2005	801051	0845ED	06	13	305	62.2	52.8	243	pmsn	801007	GOWER	
091-44337	R	8017	1+	U	U	U	03/11/2005	801051								pmsn	801007	MIDDLE BEACH ROAD	6316.6
091-44338		8017	1+	U	U	U	01/11/2005	801051	0845ED	06	13	315	63.4	53.4	234	pmbn	801007	GOWER	
091-44338	R	8017	1+	U	U	U	02/11/2005	801051								pmbn	801007	GOWER	0.0
091-44339		8017	1+	U	U	U	01/11/2005	801051	0845ED	06	13	300	69.6	54.0	260	pmnn	801007	GOWER	
091-44340		8017	1+	U	U	U	01/11/2005	801051	0845ED	06	13	325	64.5	55.5	249	pmps	801007	GOWER	
091-44341		8017	1+	U	U	U	01/11/2005	801051	0845ED	06	13	325	67.4	53.7	258	pmsp	801007	GOWER	
091-44342		8017	1+	U	U	U	01/11/2005	801051	0845ED	06	13	380	63.3	55.6	251	pmpp	801007	GOWER	
091-44343		8017	1+	U	U	U	01/11/2005	801051	0845ED	06	13	280	63.0	52.9	240	pmss	801007	GOWER	
091-44344		8017	1+	U	U	U	01/11/2005	801051	1155ED	06	13	350	68.8	56.6	261	pmyp	801007	GOWER	
091-44345	R	8017	1+	U	U	U	01/11/2005	801051								smyn	801007	GOWER	0.0
091-44345		8017	1+	U	U	U	02/11/2005	801051	1345ED	06	13	335	67.1	54.6	247	smyn	801007	GOWER	
091-44345	R	8017	1+	U	U	U	22/11/2005	801051								smyn	801007	GOWER	0.0
091-44346		8017	1+	U	U	U	02/11/2005	801051	0645ED	06	13	315	69.7	56.1	256	smyp	801007	GOWER	
091-44346	R	8017	1+	U	U	U	22/12/2005	801051								smyp	801007	GOWER	0.0
091-44347		8017	1+	U	U	U	02/11/2005	801051	0645ED	06	13	315	67.2	49.0	257	smps	801007	GOWER	
091-44348		8017	1+	U	U	U	02/11/2005	801051	0645ED	06	13	325	69.0	54.7	266	smpb	801007	GOWER	
091-44349		8017	1+	U	U	U	02/11/2005	801051	0730ED	06	13	295	65.3	52.5	243	smsy	801007	GOWER	
091-44350		8017	1+	U	U	U	22/11/2005	801051	1004ED	06	13	335	71.4	54.2	260	bmps	801007	GOWER	
091-44350	R	8017	1+	U	U	U	20/12/2005	801051								bmps	801007	ERSKINE VALLEY	648.1
091-44351		8017	1+	U	U	U	22/11/2005	801051	1338ED	06	13	325	71.2	56.0	252	bmsp	801007	GOWER	
091-44351	R	8017	1+	U	U	U	20/12/2005	801051								bmsp	801007	ERSKINE VALLEY	648.1
091-44352		8017	1	G	U	U	23/11/2005	801051	0630ED	06	13	320	64.2	53.1	245	nmpb	801007	SOLDIERS CREEK	
091-44353		8017	1+	U	U	U	23/11/2005	801051	0835ED	06	13	300	62.0	50.0	251	nmsb	801007	GOLF COURSE	
091-44353	R	8017	1+	U	U	U	22/04/2006	801051								nmsb	801007	GOLF COURSE	0.0
091-44354		8017	1+	U	U	U	23/11/2005	801051	0835ED	06	13	325	63.6	53.9	245	nmsy	801007	GOLF COURSE	
091-44355		8017	1+	U	U	U	25/11/2005	801051	1535ED	06	13	285	63.4	52.4	248	bmyw	801007	AIRPORT	
091-44356		8017	1+	U	U	U	25/11/2005	801051	1625ED	06	13	335	74.3	56.9	260	bmuw	801007	GOLF COURSE	
091-44357		8017	1+	U	U	U	16/12/2005	801051	0730ED	06	13	310	63.1	53.0	253	bmws	801007	CLEAR PLACE	
091-44357	R	8017	1+	U	U	U	27/05/2006	801051								bmws	801007	CLEAR PLACE	0.0
091-44357	R	8017	1+	U	U	U	15/07/2006	801051								bmws	801007	CLEAR PLACE	0.0

BN	R	SP	A	HA	SX	HS	DATE	LC	TIME	M	ST	W	CL	TZ	WL	CB	PR	LOCALE	DM
091-44358		8017	1+	U	U	U	20/12/2005	801051	1125ED	06	13		69.1	54.5	258	smbs	801007	GOWER	
091-44359		8017	J	P	U	U	20/01/2006	801051	1700ED	06	13	320	65.0	53.5	254	bmwn	801007	AIRPORT	
091-44360		8017	1+	U	U	U	28/02/2006	801051	1720ED	06	13	310	64.5	54.1	249	omgk	801007	AIRPORT	
091-44360	R	8017	1+	U	U	U	21/04/2006	801051								omgk	801007	AIRPORT	0.0
091-44361		8017	1+	U	U	U	21/04/2006	801051	0930ES	06	13	320	69.1	56.0	254	ymok	801007	GOWER	
091-44362		8017	J	P	U	U	22/04/2006	801051	0650ES	06	13	315	67.3	54.9	239	bmoy	801007	GOLF COURSE	
091-44363		8017	J	P	U	U	22/04/2006	801051	0650ES	06	13	290	62.3	54.2	239	bmwy	801007	GOLF COURSE	
091-44364		8017	J	P	U	U	22/04/2006	801051	0650ES	06	13	275	59.4	52.3	237	bmug	801007	GOLF COURSE	
091-44365		8017	J	P	U	U	22/04/2006	801051	0805ES	06	13	335	66.5	55.7	245	bmkb	801007	GOLF COURSE	
091-44365	R	8017	J	P	U	U	16/07/2006	801051								bmkb	801007	GOLF COURSE	0.0
091-44366		8017	J	P	U	U	22/04/2006	801051	1715ES	06	13	265	59.1	51.8	244	bmwu	801007	AIRPORT	
091-44367		8017	J	P	U	U	27/05/2006	801051	1610ES	06	13	290	64.5	53.2	240	bmky	801007	AIRPORT	
091-44367	R	8017	J	P	U	U	16/07/2006	801051								bmky	801007	GOLF COURSE	1207.6
091-44368		8017	J	P	U	U	27/05/2006	801051	1610ES	06	13	290	60.8	53.9	240	bmko	801007	AIRPORT	
091-44368	R	8017	J	P	U	U	16/07/2006	801051								bmko	801007	AIRPORT	0.0
091-44369		8017	1+	U	U	U	28/05/2006	801051	1045ES	06	13	365	70.0	55.4	265	ymuk	801007	GOWER	
091-44370		8017	J	P	U	U	28/05/2006	801051	1130ES	06	13	305	61.2	53.4	245	ymgk	801007	GOWER	
091-44371		8017	J	P	U	U	28/05/2006	801051	1130ES	06	13	340	60.0	53.4	241	ymuo	801007	GOWER	
091-44372		8017	J	P	U	U	28/05/2006	801051	1130ES	06	13	295	59.7	50.4	244	gmyb	801007	GOWER	
091-44373		8017	J	P	U	U	28/05/2006	801051	1130ES	06	13	320	67.0	52.8	243	ymgo	801007	GOWER	
091-44374		8017	1+	U	U	U	28/05/2006	801051	1330ES	06	13	345	62.1	51.5	248	ymnb	801007	GOWER	
091-44375		8017	J	P	U	U	29/05/2006	801051	0700ES	06	13	280	61.6	53.3	242	kmng	801007	GOLF COURSE	
091-44376		8017	J	P	U	U	29/05/2006	801051	0800ES	06	13	345	67.5	55.8	248	kmuy	801007	GOLF COURSE	
091-44376	R	8017	J	P	U	U	30/05/2006	801051								kmuy	801007	SOLDIERS CREEK	604.7
091-44377		8017	J	P	U	U	29/05/2006	801051	0830ES	06	13	425	64.6	53.2	247	wmyw	801007	FAR FLATS	
091-44378		8017	1+	U	U	U	29/05/2006	801051	1100ES	06	13	285	64.3	51.4	247	sm__	801007	AIRPORT	
091-44379		8017	J	P	U	U	29/05/2006	801051	1100ES	06	13	275	64.2	51.8	236	omun	801007	AIRPORT	
091-44379	R	8017	J	P	U	U	16/07/2006	801051								omun	801007	AIRPORT	0.0
091-44380		8017	J	P	U	U	29/05/2006	801051	1145ES	06	13	285	61.7	54.1	245	omyk	801007	AIRPORT	
091-44381		8017	J	P	U	U	29/05/2006	801051	1515ES	06	13	385	70.5	56.4	245	wmog	801007	CLEAR PLACE	
091-44382		8017	J	P	U	U	29/05/2006	801051	1600ES	06	13	280	60.2	49.0	241	wmon	801007	CLEAR PLACE	
091-44383		8017	J	P	U	U	29/05/2006	801051	1615ES	06	13	285	60.0	53.4	239	omuk	801007	AIRPORT	
091-44383	R	8017	J	P	U	U	16/07/2006	801051								omuk	801007	AIRPORT	0.0
091-44384		8017	J	P	U	U	29/05/2006	801051	1715ES	06	13	280	61.9	53.2	235	omuy	801007	AIRPORT	
091-44385		8017	1+	U	U	U	30/05/2006	801051	0715ES	06	13	345	64.7	52.7	245	kmoy	801007	SOLDIERS CREEK	
091-44386		8017	J	P	U	U	30/05/2006	801051	0715ES	06	13	300	65.0	54.2	251	omgy	801007	SOLDIERS CREEK	

BN	R	SP	A	HA	SX	HS	DATE	LC	TIME	M	ST	W	CL	TZ	WL	CB	PR	LOCALE	DM
091-44387		8017	1+	U	U	U	30/05/2006	801051	0715ES	06	13	350	71.6	54.4	262	kmwu	801007	SOLDIERS CREEK	
091-44388		8017	J	P	U	U	30/05/2006	801051	0715ES	06	13	370	64.3	52.6	238	omng	801007	SOLDIERS CREEK	
091-44389		8017	1+	U	U	U	30/05/2006	801051	0715ES	06	13	335	62.8	51.1	253	kmny	801007	SOLDIERS CREEK	
091-44390		8017	J	P	U	U	30/05/2006	801051	0715ES	06	13	325	65.2	55.0	240	nmky	801007	SOLDIERS CREEK	
091-44391		8017	J	P	U	U	30/05/2006	801051	0715ES	06	13	345	66.5	54.7	252	nmow	801007	SOLDIERS CREEK	
091-44392		8017	1+	U	U	U	30/05/2006	801051	0715ES	06	13	295	65.0	52.7	254	kmwn	801007	SOLDIERS CREEK	
091-44393		8017	J	P	U	U	30/05/2006	801051	0715ES	06	13	335	68.0	51.0	243	nmob	801007	SOLDIERS CREEK	
091-44394		8017	J	P	U	U	30/05/2006	801051	0715ES	06	13	345	65.6	54.4	253	nmwu	801007	SOLDIERS CREEK	
091-44395		8017	J	P	U	U	30/05/2006	801051	0715ES	06	13	315	61.6	52.6	238	nmkb	801007	SOLDIERS CREEK	
091-44396		8017	1+	U	U	U	30/05/2006	801051	0915ES	06	13	370	68.8	55.2	261	kmuo	801007	SOLDIERS CREEK	
091-44397		8017	J	P	U	U	16/07/2006	801051	0635ES	06	13	335	70.9	54.0	247	bm__	801007	MIDDLE BEACH ROAD	
091-44398		8017	J	P	U	U	16/07/2006	801051	0715ES	06	13	300	60.9	51.8	235	bm__	801007	GOLF COURSE	
091-44399		8017	J	P	U	U	16/07/2006	801051	0715ES	06	13	300	68.3	56.0	251	bm__	801007	GOLF COURSE	
091-44400		8017	J	P	U	U	16/07/2006	801051	0715ES	06	13	360	66.2	54.6	252	bm__	801007	GOLF COURSE	
NOBAND		8017	1+	U	U	U	06/10/2005	801051	0730ES	06	13	335	69.8	54.7	253	k_yu	801007	OLD SETTLEMENT BEACH	
NOBAND	R	8017	1+	U	U	U	27/10/2005	801051								k_yu	801007	NORTH HILLS	738.6
NOBAND		8017	1+	U	U	U	01/11/2005	801051	1315ED	06	13	295	62.5	56.3	246	__yu	801007	GOWER	
NOBAND	R	8017	1+	U	U	U	27/02/2006	801051								k_yu	801007	GOWER	0.0

AVIAN HUSBANDRY NOTES

GUIDELINES

THE LORD HOWE ISLAND WOODHEN

Gallirallus sylvestris

Prepared and submitted by Judith Gillespie
Bird Division Taronga Zoo,
P.O Box 20 Mosman 2088
July 1993.

Contents

AVIAN HUSBANDRY NOTES

THE LORD HOWE ISLAND WOODHEN

Gallirallus sylvestris

GENERAL INFORMATION

COMMON NAME - Lord Howe Island Woodhen

IUCN CAT: E
CITES: I
Taronga OH&S CAT: unclassified

Banding Size and Special Banding Requirements

No. 10 size Australian Bird Banding Scheme aluminium band.
" plastic colour band.

SEXING METHODS

Adult males are larger than adult females in length of exposed culmen, tarsus, mid-toe and wing chord. A discriminant function to determine sex has been formulated (measurements in mm) :

1.7 tarsus length + exposed culmen length = 141, females less, males more. Care should be taken in using the function on non-adult birds (Fullagar & Disney 1981).

The male also has a more upright stance (Miller & Mullette 1985). Vent sexing, surgical sexing (laparotomy).

AGING METHODS

Adults usually have red eyes.

Juveniles and immatures have pale brown eyes darkening to orange in sub-adults (Fullagar & Disney 1981). Harden (pers.comm.) has observed known age adults with intermediate eye colour.

First year birds have pointed juvenile primaries compared with square ended primary feathers found in adults (Fullagar & Disney 1981). This feather change occurs in the second autumn moult and first complete moult after hatching.

Formula for aging birds up to 70 days old regardless of sex:
Age (days) = 11.7 + 0.065 wt + 1.838 culmen - 1.322 tarsus
measurements in mm (Harden & Robertshaw 1988).

Height - 20cm, in upright stance
Weight (grams) - Ranges: Male 380 - 690 Av.= 530
Female 330 - 640 Av.= 463
Winter weights are approximately 50g lighter than summer ones.
(From weights taken in November 1988, Harden & Robertshaw 1988).
Length - 38cm (culmen, wing, tail, tarsus, middle toe, claw) (Fullagar & Disney 1975).

NATURAL HISTORY

1.0 Distribution

Endemic to Lord Howe Island (Lat.31.33'S Long.159.04'E), a small Pacific island (12 x 2 km long), 700 km NE of Sydney, Australia (Fullagar & Disney 1975).

1.1 Habitat

Mainly closed forest vegetation where the principal plant species are Kentia Palm (*Howea forsteriana*), Banyan Fig (*Ficus columnaris*) and Blackbutt (*Cryptocaria triplinervis*), (Recher & Clark 1974). The birds show a preference for the palm habitats (Harden & Robertshaw 1988).

Lord Howe Island has a high annual rainfall (mean 1611mm) evenly distributed over the year (Miller & Mullette 1985).

1.2 Habits

Adults are sedentary, spending most of their day searching for food and staying close together (Fullagar & Disney 1975). Birds may roost at night in abandonded petrel burrows on Mt Gower and in clumps of vegetation (Miller & Mullette 1985).

(See also Behavioural Notes - 4.2)

1.3 Wild Diet and Feeding Behaviour

The main food is earthworms. Other foods include insect larvae, crustaceans, land snails, spiders, lichen, fungus, blossoms of the green plum (*Randia stipulosa*), cicadas and Providence petrel (*Pterodroma solandri*) chicks (Disney 1974, Miller & Mullette 1985).

Woodhens drink water from pools and water droplets on moss (Miller & Mullette 1985).

Woodhens use their long, sturdy bill to probe up to 10cm into the leaf litter and soil for invertebrates. In addition, tree stumps, logs, rocks and vegetation are turned over and investigated. The feet are not used in the foraging process (Disney 1974).

1.4 Breeding (see also 6.0 Breeding season)

Breeding occurs from August to January (Miller & Mullette 1985). The nest is a simple depression among leaves on the ground, sheltered by low vegetation (Hindwood 1940). On Mt Gower they also use petrel burrows lined with stems of ferns, palm fronds and moss (Fullagar & Disney 1975, Miller & Mullette 1985).

Pairs display very secretive behaviour and nests are difficult to locate. Males usually initiate nest building and copulation. Both birds assist in nest building and incubation (Fraser 1985). On average two eggs are laid and they hatch after 20 days.

Pairs will have multiple broods during the breeding season, forming extended family groups. Different nests are built for each clutch. Juveniles from earlier clutches will assist in collecting food and in feeding the chicks (Fraser, unpubl.)

CAPTIVE HUSBANDRY

PREFERED HOUSING REQUIREMENTS

2.0 Shelter

Use shrubs as natural shelter. Protect feeding and nesting areas in climates of extremes.

Plant adequate vegetation to provide cover for the birds. Orientate aviaries away from prevailing winter and bad weather.

Substrate: 40 cm of soil, fine dry leaf litter over the floor.

2.1 Water

Fresh water in a drinking and washing pond, large enough in which a woodhen can bathe, approximately ten to fifteen centimetres deep and sixty centimetres in diameter.

2.2 Furnishings

Extensive plantings of shrubs and palms for cover, replicating their habitat. Ideally include Lord Howe Island hibiscus, Kentia palms and appropriate ferns and grasses which can be utilised for nesting material. Shade cloth over the roof will protect ferns and palms from scorching and promote growth. Small logs and rocks provide suitable sites to encourage production of invertebrates in the leaf litter as well as recesses for nesting sites.

Fraser (1985) provided artificial nest boxes covered with logs and vegetation but noted that older pairs of birds new to captivity preferred to build their own nests.

A watering system for plants is recommended, especially for the palms and ferns during summertime and for fostering of soil invertebrates. Substrate maintenance including turning and topping up should be done regularly.

2.3 Spatial Requirements - including state regulations e.g EAPA in N.S.W; possible display/off-limit differentiation.

These are ground dwelling birds with strong legs - adequate area for exercise is essential. Minimum housing area per pair - 4 x 4 metres. Breeding occured at the captive breeding centre in aviaries with a surface area of aproximately 100sq.metres (Fraser 1985).

Enclosures must be rat proof, made of wire mesh 1.25cm x 1.25cm.

Birds should be kept as bonded pairs, separate from other pairs. If new or unrelated birds are to be introduced or housed together it is essential that the birds are able to be physically separated from each other, particularly overnight. Males can be very aggressive and kill females or subordinates. Introduce birds slowly and monitor at all times.

HEALTH REQUIREMENTS

3.0 Routine Worming

For most worms : treat with Panacur 2.5, 25 milligrams /kilogram bird, administered once directly to the crop. For Capillaria treat with Ivomectin, 200-400 micrograms/kilogram of bird, as a starting dose. For cestodes treat with droncit, working on one tablet/5 kilograms of bird (pers.comm. Taronga Veterinary staff). Faecal floatation tests performed twice yearly.

3.1 Heat

Lord Howe Island has a mild climate with humid summers and temperate winters (summer min. 20 degrees Celcius, max.25.4C ; winter min. 13.3C, max. 18.4C) (Miller & Mullette 1985). Provide artificial heating and cooling if extreme minumum winter tempreratures and maximum summer temperatures are regularly experienced.

3.2 Cleaning

Replace leaf litter twice a year and maintain regularly. Refurbish before the breeding season commences.

3.3 Nest Hygiene n/a

3.4 Known Health Problems

Obesity. Woodhens overeat in the non-breeding season so foods high in fat must be limited (Fraser 1985).

3.5 Routine Vaccinations

Not applicable

3.6 Routine Quarantine Treatments

Three faecal floatation tests taken over a three week period.

3.7 Vet Procedures

Sexing of birds using a laparoscope to view the reproductive organs while the specimen is anaesthetized may be undertaken.

BEHAVIOURAL NOTES

4.0 Social Structure

Pairs form strong bonds and maintain definite, year-round territories of two to three hectares, maintained by calling. Young birds stay with their parents for three and a half to four and a half months whereafter they are forced into occupied or marginal territories (Fullagar & Disney 1975).

Pairs will multiple brood and form extended family groups. The unit remains close until chicks show signs of independence and become engaged in minor altercations with the parents. The amount of time taken by juveniles to severe parental ties and finally disperse varies with individuals - from a few days to a few weeks (Fraser, unpubl.).

In the wild survival of juveniles is dictated by their ability to hold a breeding territory and this must be achieved by the breeding season following their own hatching. Most juveniles which enter the breeding population are paired before they have adult plumage (Harden & Robertshaw 1988).

4.1 Aggression

Woodhens are territorial. They will aggressively attack any intruders including their own species, using their long bills (Fullagar & Disney 1975). A new bird can be killed. Attacking birds may contiue to hunt for the intruder. Resident birds whether they be male, female, lone or paired are usually dominant and will instigate attacks. Parent birds vigorously defend their chicks (Fraser 1985). Adult femles may be less tolerant of juvenile females than adult males are of juvenile males (Fraser, unpubl.).

4.2 Habits

Birds are inquisitive and will investigate unfamiliar sounds. When alarmed they make a loud, piercing call which they repeat when communicating with other birds. Adult pairs have a "low , resonant 'bomp, bomp' contact call. They use it very regularly when out of visual contact with each other (Fraser 1985, Miller & Mullette 1985). Lone females in captivity sometimes give high-pitched plaintive calls in the evening (Fraser,unpubl. reports to NPWS).

Woodhens are flightless but walk and run swiftly. When pressed they can launch into the air , flapping their wings, over distances of about three metres. They can jump vertically up to 1.5 metres using only their legs (Fraser 1985).

Birds moult in January - February.

4.3 Courtship

See also 1.4 Breeding

Usually males initiate nest building and copulation. (see also 1.4 Breeding). A simple courtship proceeds with the male calling to the female and then offering her food. Copulation takes approximately fifteen seconds. Mutual preening or nest-building may follow (Fraser 1985).

4.4 Bathing

see 2.1 Water

4.5 Drinking

Birds drink by sucking up water.

4.6 Common Captive Behavioural Problems

Obesity is the major problem during the winter and breeding periods. A pair may have to be separated if one has a weight problem, then eating habits can be individually monitored. Male birds should be kept below 600 grams, (Fraser 1985).

4.7 Handling

Birds are easily caught with normal butterfly-style nets. Once caught they are best secured around the upper thighs, close in under the body.

4.8 Transportation

For short journeys birds can be safely carried in large calico bags without fear of injury to the bird. For longer periods of restraint and travel large sturdy, ventilated cardboard or wooden boxes are necessary. For major travel, sturdy, transport boxes are required with adequate padding (to protect the bill), ventilation and insulation from noise.

IATA Regulations : Container requirement 40G (IATA 1992).

4.9 Mixed Species Compatibilities e.g including mammals and reptiles.

Care must be taken in selection of potential exhibit co-habitants on account of the Woodhens' aggressiveness. Predominantly large arboreal species e.g fruit-pigeons and larger passerines have potential. Avoid species of equal and lesser size, including reptiles and mammals. Woodhens have been reported to have killed blackbirds and rats (Fraser, Disney per.comm).

4.10 Behavioural Enrichment Activities

Natural foraging activity can be encouraged with a supply of rotten logs and leaf litter.

FEEDING REQUIREMENTS

5.0 Diets and Supplements

Diets used by (a) Fraser (1985) & (b) Taronga Zoo are listed below:

(a) poultry layer pellets
`Whiskettes' cat food (dry biscuit form)
matured cheddar cheese (grated)
cottage cheese
madiera cake
complete raw egg, occasionally
new-born mice (laboratory bred *Mus musculus*)
mealworms *Tenebrio molitor*
woodgrubs (family Cerambycidai)
other invertebrates

Daily basic diet & approx. amounts per bird were:
Non-breeding season - poultry pellets 5gms (blended to a powder and water added to form a paste)
grated cheese 5gms
mealworms 5gms
`Whiskettes' 20gms
Breeding season - poultry pellets 5gms
grated chees 5gms
mealworms 10 gms
`Whiskettes' 20 gms
cottage cheese 10 gms
raw egg 1 x week per pair
baby mice 2 every 3 days
2-3 woodgrubs per bird 2 x day for 8-10 days before laying.

(b) `Paradise mix' - grated boiled egg
grated cheese
diced greens (lettuce, spinach, celery)
diced apple, paw paw, pear
currants
grated carrot
Zeigler Paradise pellets or Turkey crumble
Calcium powder
Petvite

`Lyre mix' - `Luv Tender Chunks' dog food
grated boiled egg

mealworms *Tenebrio molitor*
earthworms

Daily diet: amount per adult bird approx. half a level tablespoon of each mix, plus half a dozen mealworms.

5.1 Presentation of food

A simple tray or shallow dish.

BREEDING

6.0 Season

See also 1.4 Breeding

Birds usually lay in August until February. Fraser (unpubl) has recorded eggs and chicks in all seasons - this condition being attributed to an abundant food supply. Unusually mild , warm weather and dry autumn weather may prompt early nesting. By manipulating conditions in captivity, mainly diet, birds can be stimulated to start early nesting . This can occur in May to early July with copulation and laying following later in July or early in August (Fraser, unpubl.reports to NPWS).

6.1 Nesting Requirements

Dark, concealed sites for nesting - usually in thick clumps of vegetation (e.g ferns). Fine, dry leaf litter for nest construction; (nest dimensions : 100mm -120mm in diameter, approx. 25mm deep, base of nest bowl 75 mm above the ground (Fraser 1985).

6.2 Diet Changes Prior to Breeding e.g trigger diets

Strict diets can be commenced in June to encourage birds to come into pre-breeding condition. From the second week in July food should be increased in preparation for the breeding season (Fraser 1985).

(See 5.0 for Breeding season diet).

6.3 Diet Changes while Breeding

Winter weights of birds are approximately 50 grams lighter than summer weights. Control over-eating in the non-breeding season by restricting fatty foods (eggs, cheese and grubs) (Fraser 1985).

6.4 Incubation

20 day incubation period starts with the laying of the last egg. In captivity pairs incubate alternately for twenty minutes to two and a half hours (Fraser 1985). Failure to maintain the first eggs at a luke warm temperature is fatal to the developing embryo. Disturbed and frightened parents can predate their eggs (Fraser, unpubl. reports to NPWS).

6.5 Clutch Size

Average clutch size 2 eggs , range 1 - 4 eggs.

Eggs are coloured `dull white with minute dots and large irregular-shaped markings of light chestnut-red, more or less scattered over the surface of the shell ' (Hindwood 1940).

Eggs are laid on alternate days. Daily laying has been recorded. More infertile eggs occur with an increase in clutch number and majority of infertile eggs are laid in later clutches. In captivity the most clutches laid by a pair in the six month breeding period was seven (Fraser, unpubl. reports to NPWS).

Hatching: The precocial chicks are fed by both parents until proficient at capturing their own food at around three weeks of age. Chicks can continue to take food from parents or older siblings up to four months of age (Fraser, unpubl.)

6.6 Fledgling Period

Independent at three weeks.

6.7 Egg weights and measurements and species specific co-efficient

Dimensions: Av. 46.7mm x 36mm (Hindwood 1940, Fraser 1985).

Average freshweight = 28.7g (Fraser 1985).

6.8 Developmental weights, measurements, notes and photos.

All information displayed is from Fraser (1985).

Average chick weights (grams)

Day	0	7	14	21	28	56	100-106
Weight	20	38.2	82.4	131.9	191.2	433	507
min	17.1	28.8	62	105.8	138.7	340	410
max	21.5	49.8	103.9	156.5	235	510	620

Average measurements of exposed culmen (mm)

Day	0	7	14	21	28	56	100-106	Mature
Length	12.6	16.6	21.9	27.2	32.2	46.1	46.9	48.2

Average measurements of tarsus (mm)

Day	0	7	14	21	28	56	100-106	Mature
Length	18.2	24.7	32.5	38.1	41.6	45.8	46	44.5

Development observations

Average hatch weight is 20 grams. Average weight loss during day 1 (due to reabsorption of yolk sac, dessication & first defaecation) is 1.2 gms. Hatchlings are black with dark irises and legs.

Chicks start drinking water on day 4.

Pecking at artificial food and mealworms on day 6.

Pin feathers start emerging around day 12.

Breaking into feather on day 16.

Fully feathered and preening using oil gland on day 18.

Chicks feeding independently by day 21.

Chicks almost fully grown at two months. Iris turning from grey to light red.

Iris fully red at 100 days. Some sexually distinguishing behaviour i.e males fighting among themselves.

Apparently the first hand-raised chicks tended to develop tarsuses shorter than those of wild birds. This problem was addressed in the next season by increasing the quantity of earth-worms fed over the first two weeks. In addition calcium imbalance occurred when cheese and fresh eggs were not included in the diet of the chicks (Fraser, unpubl.reports to NPWS).

6.9 Age of removal from parents

When chicks can feed independently they can be removed from the parents, providing there is adequate warmth and shelter. Juveniles can stay with the parents until signs of aggression arise.

6.10 Use of foster species

Fraser (unpubl.reports to NPWS) successfully fostered eggs under different Woodhen pairs but to date no other species have been used. Other rail species such as the Weka *Gallirallus australis,* Dusky Moorhen *Gallinula tenebrosa,* Eurasian Coot *Fulica atra* and Black-tailed Native-hen *Gallinula ventralis* are worthy of consideration.

ARTIFICIAL INCUBATION

(see Fraser, 1985)

7.0 Incubator type - still air/fan forced, auto/manual turn, brand and model.

Domex `forced draft' incubator and Onslow `still air' incubator.
Eggs placed on sides and rolled alternatively 180 degrees every six hours.

7.1 Incubator temperature and humidity (dry and wet bulb readings)
Air temp : 98.5 deg.Fahr. (36.9 deg. Celcius),
Humidity : 70%

7.2 Desired weight loss
15.3% (stand.dev.1.5%)

7.3 Hatching temperature and humidity
Humidity raised to maximum when eggs have pipped.

7.4 Normal pip to hatch interval

ARTIFICIAL REARING

8.0 Brooder types/design

No specific model. Fraser (1985) used brooders heated with light bulbs for the first ten days, with small boxes or tunnels to hide in. As chicks grow they can be moved into larger indoor pens until ready to be acclimatised outside at about four weeks.

8.1 Brooder temp.

Air temp : provide a heat source e.g light bulbs which chicks can move to and away from, allowing them to regulate their own temperature. Initially a maximum temperature approximating their incubation temperature is desirable.

8.2 Diets

Chicks are fed only on insects for the first week, then artificial food is gradually added. They are fed hourly, from 6am to 10pm, for the first two weeks (with tweezers) on grubs, worms, arthropods from leaf litter. Water should be provided in a very shallow dish.

They start drinking at four days. Artificial food is started on day six and birds are encouraged to feed themselves (Fraser 1985).

8.3 Species special requirements e.g nest substrate

Provide places for chicks to shelter in e.g tunnels or bushy branches placed upside down. Use textured substrate e.g rough papertowel to assist footing. Avoid smooth subtrates. At approximately two weeks of age place chicks on natural substrate to further promote toe and leg development and foraging behaviour.

8.4 Marking methods

Chicks can be marked with nail polish on toes.

8.5Growth charts / developmental notes

see 6.8

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APPENDIX

'Whiskettes' cat food: man. by Uncle Bens of Australia, Parra matta, New South Wales.
'Luv Tender Chunks' dog food: man. by Friskies Pet Care, Bankstown, New South Wales.
Zeigler Paradise pellet: man. by Zeigler Bros. Inc. P.O. Box 95 Gardners, PA 17324, USA.

Domex 'forced draft' Incubator and Onslow 'still air' Incubator : Dominion Incubators Ltd, P.O. Box 566 Hamilton, New Zealand.

ACKNOWLEDGEMENTS
In preparing this work I am indebted to Glen Lourie-Fraser, Graeme Phipps and John de Disney for their inspiration, guidance and advice.

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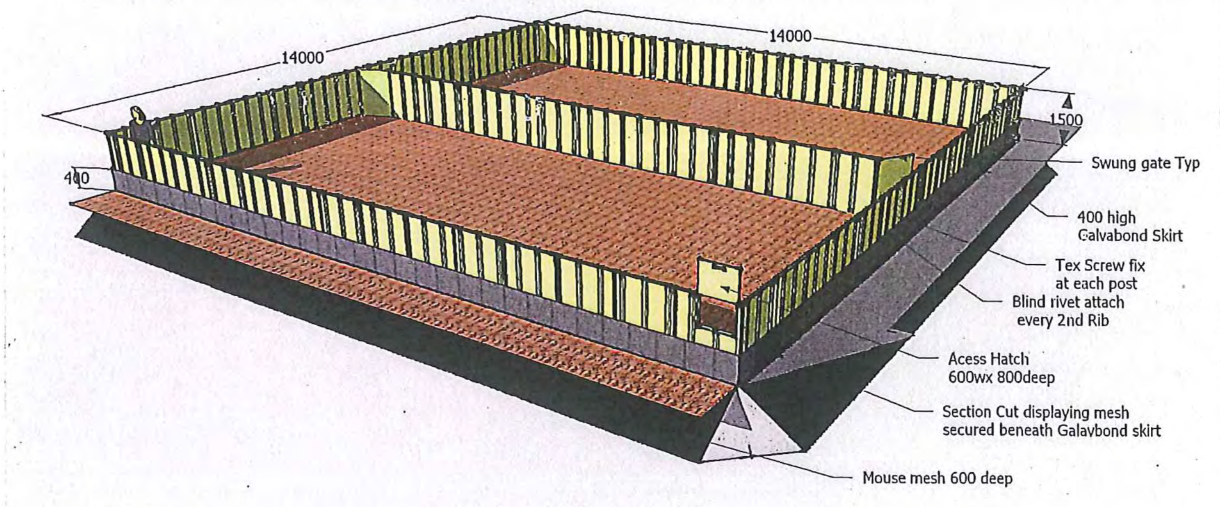

Figure 1: Enclosure design for the Lord Howe Woodhen

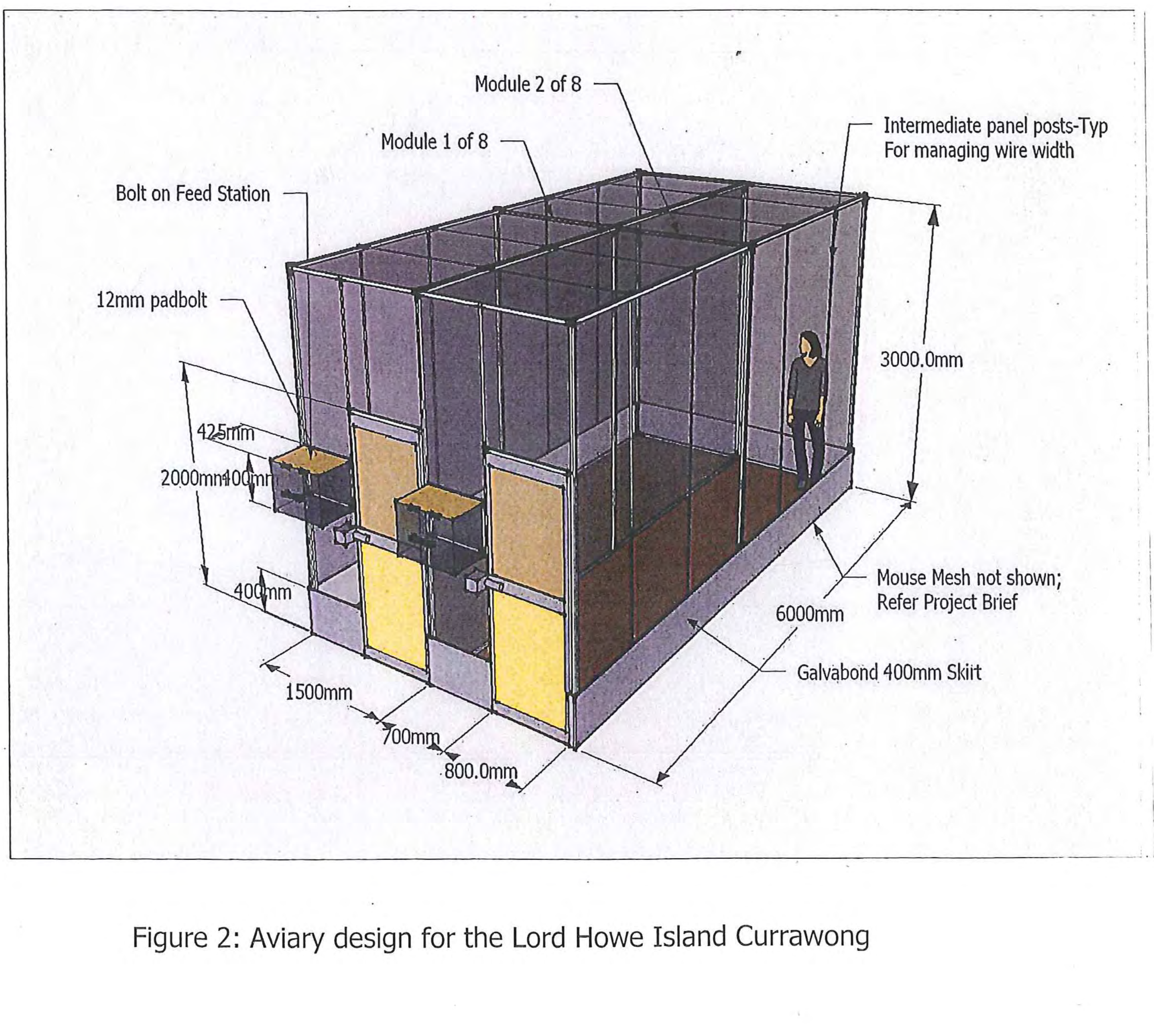

Figure 2: Aviary design for the Lord Howe Island Currawong

Construction of Aviaries and Pens to Conduct Captive Management Trials on Lord Howe Island 2013

Lord Howe Island
Construction and Waste
Management Plan

June 2013

Approved:

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Hank Bower MEWH LHIB

_____/_____/_________

TABLE OF CONTENTS

Introduction

The purpose of this document is to provide detailed information on the construction of captive management facilities for a trial on holding Lord Howe Woodhen and Lord Howe Island Currawong in captivity to inform on the most appropriate husbandry methods to use during a rodent eradication project scheduled for 2015. It includes actions to deal with waste management.

The plan outlines the project delivery methodology, conditions of consent applicable to the works, the construction program and site operations plan.

The document is a controlled document that can only be varied by approval of MEWH LHIB. The document will be reviewed periodically throughout the project and revised as necessary.

Background

The Lord Howe Island Board (LHIB) is implementing a rodent eradication project with baiting scheduled for August 2015. Research has informed that two conservation dependant species of birds (the endemic Lord Howe Woodhen *Gallirallus sylvestris* and Lord Howe Island Currawong *Strepera graculina crissalis*) will be at risk of primary or secondary poisoning during the baiting operation and will need to be held in captivity for the duration that baits are present (up to 100 days). Taronga Zoo has been engaged to design, construct and implement the captive management project. A key aspect of this project is to refine the most appropriate husbandry techniques for both species in a trial in the winter of 2013 prior to undertaking a large scale captive management project for both species in the winter of 2015.

Development Consent was granted on 21 May 2013.

The Construction and Waste Management Plan (CMWP) has been prepared to guide the construction of pens and aviaries and management of waste to meet two conditions of consent associated with the Development Consent for DA 2013-11.

Description of Works

The project involves the construction of aviaries and pens within an existing nursery shade house to hold 22 Lord Howe Woodhen and 10 Lord Howe Island Currawong during trials on husbandry methods. The proposal will require some adjustments to existing infrastructure including but not limited to raising the height of some roofing structures, removal of shade clothe and replacing with bird netting, setting of concrete footings for the aviaries and establishing a food preparation and quarantine area within the potting shed located near the office.

Associated works include:

- Establishment of a site equipment compound;
- Stockpiling building materials; and
- Stockpiling waste to be transferred to the Waste Management Facility.

Below are the plans (figures 1 and 2) for the holding pens for each species as prepared by an experienced aviculturist from Taronga Zoo. Aviary sizes may vary slightly from the plans. The design benefited from knowledge gained from previous facilities built to house woodhen (both at Taronga Zoo and on LHI (Lourie-Fraser 1985)) as well as advice from New Zealand where the Weka *Gallirallus australis*, a species similar to the woodhen, had been kept in captivity during rodent eradication operations undertaken in that country. Birds in the captive facility will be under the full care and responsibility of Taronga Zoo. Experienced bird keepers from Taronga Zoo will be resident on LHI for the entire period that birds are in captivity. If the holding facilities are found to be inadequate after birds have been taken, attempts will be made to rectify any problems. As a last resort, should the welfare of the birds be at serious risk, the birds can be released back into the wild until deficiencies in the procedure are rectified.

A husbandry manual for woodhen is available (Gillespie 1993).

The holding facilities will be located in the palm nursery which is situated in the settlement.

Guiding principles used in the design and location of aviaries have included:

- Locating the aviaries away from areas frequented by people;
- Providing adequate shade and protection from inclement weather;
- Ensuring the birds feel secure by the provision, if need be, of screens between pens containing antagonistic co-specifics;
- Providing cover within pens in which the birds can shelter;
- Ensuring the pens can be effectively cleaned;
- Ensuring drainage is adequate;
- Ensuring internal structures are without sharp surfaces and pointed edges; and
- Encasing the pens in mesh of a size that will exclude rodents and the introduced predator Masked Owl *Tyto novaehollandiae*.

Not withstanding these precautions, a small number of birds (~ 3) are likely to die in captivity due to natural mortality (e.g., due to old age) because birds captured for the trial may reflect the age structure and general health of birds on LHI. All deceased birds will be autopsied to determine cause of death.

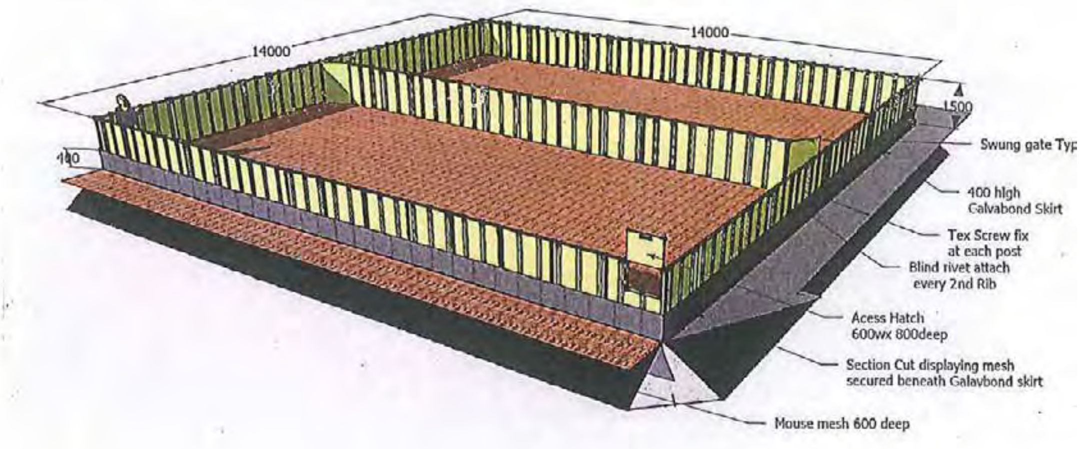

Figure 1: Enclosure design for the Lord Howe Woodhen

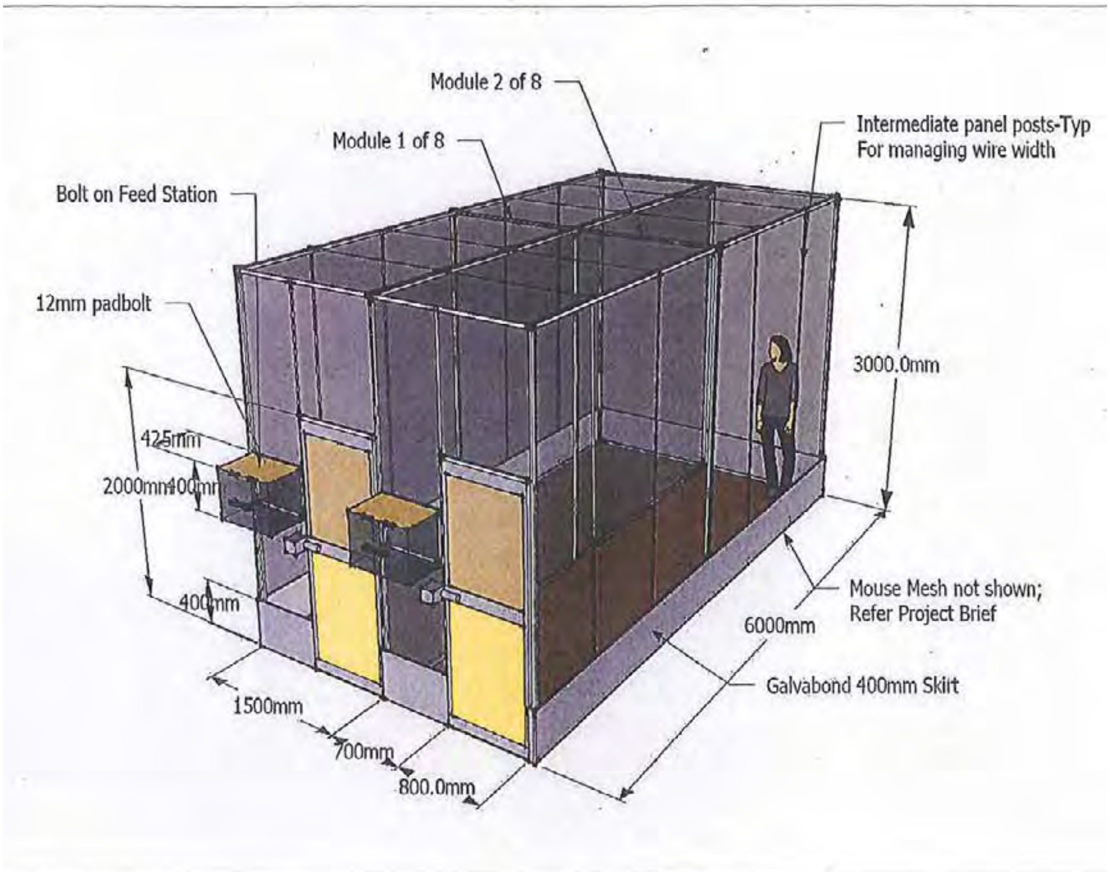

Figure 2: Aviary design for the Lord Howe Island Currawong

Project Delivery Methodology

The project will be managed by LHIB Manager Environment/World Heritage with the assistance of LHIB Rodent Eradication Project Manager.

Construction Program

Construction of works is expected to commence 11 June 2013 with Possession of site to be given on consent of the Development Application.

The following is a summary of the project program:

11 -19 June 2013

- Site Induction and establishment - Initial activities will consist of installation of construction signage, and site amenities, followed by:
  - Removal of unwanted shade clothe from shade house framing and stock piling for later re-use.
  - Construction of aviaries and pens within an existing nursery shade house, construction of a food preparation area and quarantine holding room in an existing shed near the office and transporting of building waste to the Waste Management Facility in accordance with directions listed below.
  - Site clean up.

Construction Site Operations

There are several controls in place to manage the day to day operations of the site. These controls are detailed below.

All construction activities including storage of stock piled will be undertaken under the supervision of the Taronga Zoo Construction Manager. All tools and construction equipment will be stored within the black shade house and the compound will be locked at the end of each day's work.

A motion activated infra red camera will be installed within the shade house for security purposes and will be sign posted.

Hours of operation

The proposed hours of operation of the construction site are specified as follows:

Monday to Friday 7am to 6pm

Saturday & Sunday 8am to 3pm if required.

Hours may need to be extended if adverse weather is encountered as construction will be undertaken by contractors engaged over a set period.

Construction Plans

All relevant site and construction plans will be kept with the Taronga Zoo Construction Manager. The Taronga Zoo Construction Manager is responsible for the management of construction plans.

Currawong aviaries have been prefabricated and erected and inspected on the mainland by the Taronga Zoo Construction Manager prior to transporting to LHI. Designs are as per diagrams in Figures 1 and 2 above and all construction will be contained within the black shade house. The construction area will extend approximately 5 metres beyond the shade house.

Traffic Management

Construction site access

The primary construction site access is through the nursery off Middle Beach Road and is not accessible to through traffic.

Changes to traffic conditions

There are no projected changes to traffic conditions. Access to the construction site will be restricted.

Site management

A prime management responsibility of the site rests with the Taronga Zoo Construction Manager. Daily site meetings will be held between the construction manager and equipment operators on-site to discuss progress and issues including site safety.

Site Safety & OHS

The Taronga Construction Manager will ensure the site is secure and safe at all times. The construction site will be sign posted and fenced off with adequate signage to ensure no unauthorised access. All visitors must have a valid reason to enter the site and approval must be obtained from the Taronga Construction Manager. All unauthorised visitors will be refused access and directed to the LHIB administration building.

Site Induction to be carried out for each worker on site including visitors, Board personnel and contractors, induction log must be signed and dated by each individual prior to commencement on site.

The Taronga Construction Manager or nominated site supervisor will ensure all visitors; contractors and employees who enter the site are inducted prior to entry onto the site.

The Project Manager, Taronga Construction Manager and nominated site supervisor is delegated to refuse entry to site those employees not equipped with the standard PPE which includes Hat, High Visibility Vest/Jacket and Safety Boots, Eye and Ear protection and additional job specific PPE as required.

The Project Manager, Taronga Construction Manager and nominated site supervisor is delegated to refuse entry to site those visitors not equipped with the minimum PPE requirements of Hat, Vest and appropriate enclosed footwear.

No alcohol or drugs are to be consumed on site. The site will be a smoke free workplace.

Daily toolbox meetings will be undertaken by all on-site personnel.

Site Emergency Procedures

Details of the site emergency procedures including a site plan detailing muster points will be available at the site or from the construction manager.

The site will contain a stocked first aid kit.

A copy of the emergency plan is attached. The following are the contact numbers in an emergency:

000	in an emergency
Local contacts	
LHI Hospital	6563 2000
	6563 2460
Doctor radio page	6563 2252
LHI Police	6563 2199
LHIB - Business	6563 2066
–(After hours)	6563 2093

Communications

The site office has a telephone. However, a vhf radio will also be provided as a backup.

Site Amenities

The site has existing toilet facilities and a lunch room.

The site office will contain at a minimum the following equipment and documentation:

- Approved copies of construction drawings
- Copy of DA Consent Conditions
- Copies of all Safe Work Method Statements, CM plans
- Emergency evacuation procedures
- Communications – 2-way radio
- First aid kit

Key Project Personnel

Project Manager: Hank Bower Holt ph 6563 2066 ext 23 (after hours 6563 2225)

Taronga Construction Manager: Stephen Bedford at nursery office ph 6563 2161 (after hours Somerset - 65632061).

Impacts of Earthworks

Footings will be dug within the shade house 600mm x 600mm maximum. All overburden will be spread on site for use within the pens/aviaries.

Biosecurity measures

All imported materials and equipment will be checked for biosecurity hazards at the jetty hardstand prior to transport to the construction site.

Waste Management

All building waste is to be contained at a designated and secured site during the construction period and will then be transported to the LHIB Waste Management Facility (WMF) weekly for recycling or disposal in the appropriate disposal area as instructed by the WMF Manager. No building waste shall be placed in any location or in any manner that would allow it to fall, descend, blow, wash, percolate or otherwise escape from the site.

Some materials on existing infrastructure will be removed during construction and will be stock piled for reuse following the captive management project in 2015. These materials include but are not limited to: shelving, shade clothe, plastic sheeting and irrigation fittings. A designated area will be allocated for stock piling of materials for reuse.

All food waste generated during the captive trials will be collected daily by zoo staff and stored in a sealed plastic bucket and will then be transported to the LHIB Waste Management Facility (WMF) as required (minimum weekly) for composting in the Vertical Compost unit as instructed by the WMF Manager.

Lord Howe Island Woodhen Bio-Security Management Plan

Health assessment of the Lord Howe Woodhen (Gallirallus sylvestris) population on Lord Howe Island NSW, and assessment of disease risks from resident and migratory avian species

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Abstract

In May 2007 a survey was conducted to assess the health of the wild population of the endangered Lord Howe Woodhen (*Gallirallus sylvestris*) on Lord Howe Island (LHI), 700 kms north-east of Sydney, NSW Australia. This included physical examination and health screening of LH Woodhen from two distinct habitat zones on the island, the disturbed settlement area (n = 25) and isolated mountain area (n = 13). Other domestic and wild avian species were assessed to determine their health status and potential disease threat to the Woodhen. This included domestic poultry (*Gallus domesticus*, n = 17), Flesh-footed Shearwater (*Puffinus carneipes*, n = 12), Providence Petrel (*Pterodroma solandri*, n = 11), Masked Booby (*Sula dactylatra*, n = 6) and Emerald Dove (*Chalcophaps indica*, n = 2). For the Woodhen, diagnostic tests included complete blood count, plasma biochemical analysis and examination for haemaprotozoa. Faeces were selected from all species for testing or examination by IFA for Chlamydia, by microscopy for Mycobacterium species and megabacteria, cultured for enteric pathogens (Salmonella, Campylobacter and Shigella) and by flotation for intestinal parasites. Blood samples were selected from all birds to test for exposure to Avian Influenza virus by c-ELISA, to Newcastle Disease Virus (NDV) by Haemagglutination Inhibition, and to arboviruses by c-ELISA. Cloacal swabs were taken from all Woodhens and most other birds to test for viral pathogens, specifically, Avian Influenza virus and NDV by egg inoculation and for Avian Influenza by PCR.

All birds examined were in good health with no sign of apparent disease. Clinical signs of leg mite were found in domestic poultry, however there were no signs of external parasitism in all other species. Results from complete blood count and biochemistry testing of Woodhens were used to establish normal reference ranges for this species. None of the blood parameter results were suggestive of disease. There was no evidence of haemaprotozoa from blood smears taken from 38 Woodhens. Results of faecal culture isolated *Campylobacter sp.* in 8/35 (22%) of Woodhens, 4/17 (23%) poultry and 0/9 for other species. From two of these positive cultures, *Campylobacter coli* were isolated. The isolation of *C. coli* is not unexpected given that it is often found in a wide variety of wild healthy birds (MacKenzie 1988). No other enteric pathogens were isolated. Examination of faeces for Chlamydia by IFA found 5/19 (26%) Woodhens positive and 0/15 in other species. There was no apparent disease in test positive birds and blood parameters were within normal range. Wild birds are often asymptomatic carriers of Chlamydia and disease is more prevalent in caged birds. All other faecal tests did not find any evidence of Mycobacteria (0/56), megabacteria (0/56) and internal parasites (0/61).

The results from testing 84 sera found no evidence of exposure to Avian Influenza virus and Newcastle disease virus and the testing of 86 cloacal swabs did not detect AIV genetic material or any other potentially pathogenic viral agent. Arbovirus testing of sera found antibodies to Kunjin virus in two wild birds.
The findings from this survey and assessment of potential disease risks were used to formulate a biosecurity and avian health monitoring program to incorporate into the Lord Howe Woodhen Recovery Plan. In summary this includes routine monitoring of wild bird health by investigating sick or dead birds at veterinary pathology labs, general health inspection during annual LHIB Woodhen surveys and prospective health surveys timed when other migratory species not sampled in May 2007 are present. Measures to cull existing and newly arrived feral waterfowl and pigeons should be considered, as their health status is unclear from this survey, and potentially these species could carry viral or bacterial pathogens from the mainland. Although there are no immediate disease threats from imported poultry and pet birds, avian imports should be restricted to day old chickens and pet birds that are health screened prior to arrival and securely housed on LHI. The NSW Department of Primary Industries would provide property of origin health assurances for poultry imports.

The clinical and diagnostic health findings of this survey and absence of avian disease in historical records, provide reassurance for the health status of the Woodhen and other wild birds on Lord Howe. Although the relative isolation of Lord Howe provides an important geographic barrier to the spread of avian disease, the recent pandemic of Highly Pathogenic Avian Influenza highlights the need to monitor the health status of migratory birds that seasonally return to breed. The refinement of a LHI Biosecurity program that includes routine health monitoring, avian import policy, feral bird control and emergency response plans, should provide important health safeguards to protect the endangered Woodhen and migratory wild birds on LHI.

Introduction

The Lord Howe Woodhen (*Gallirallus sylvestris*) is a flightless bird endemic to Lord Howe Island, located about 700 km north-east of Sydney in the south-west Pacific Ocean. The species is listed as Endangered under the NSW Threatened Species Convention Act 1995, and vulnerable under the Commonwealth EPBC Act 1999. It is also protected under the Lord Howe Island Act 1953.

The Woodhen was considered common in early settlement years. However the impact of introduced pigs, cats and dogs decimated the population to about 37 individuals confined to the Mt Gower area by the late 1970's. A major rehabilitation program commenced in 1978 with a captive breeding and release program and eradication of all pigs from the island. The program is considered to be extremely successful with about 250 free living Woodhens on Lord Howe today. In 2002 the *Recovery Plan for the Lord Howe Woodhen* was implemented, with objectives that maintain and increase the population of Woodhens, consolidate and extend the significant biodiversity benefits derived from protection of the Woodhen.

The recovery action plan recommends developing a health management plan to provide early warning against the impact of incursion of avian disease. The project outputs include:

- Health screening of Woodhen and other species that interact or have close contact such as poultry, resident and migratory birds
- Establish baseline disease profile of Woodhen and other species as a benchmark for future monitoring of health
- Develop LHI bio-security policy that includes assessment of disease threats and measures to mitigate risk, quarantine and import procedures and health monitoring regime

A review of historical disease records for the Woodhen and a small scale virology survey were undertaken by Dr Alan Jackson in 1987 (unpublished report). Dr Jackson found no historical records of disease and no internal or external parasite records including the captive breeding period of 1978-1983. The 1987 disease survey examined 50 LH Woodhen from both the settlement and mountain areas and found all birds in good health. Cloacal swabs were tested for NDV and Avian Influenza by virus isolation. All samples were negative for both viruses. In 2005 faecal samples from 18 Woodhens were tested for internal parasites at Taronga Zoo. Parasitism was found at higher levels in the Settlement area compared with the Mt Gower population.

There are no known historical records of pathology or disease in the LH Woodhen (Australian Registry of Wildlife Health (ARWN), Taronga NSW). A search of pathology records for the Rallidae family at ARWN, found Aspergillosis, a fungal respiratory disease, as the cause of mortality in a captive rail at Taronga Zoo. Aspergillosis is more likely to be a problem in captive birds.

Disease surveys have also been done on other related species including the captive Guam Rail (*Gallirallus owstoni*) population on Guam Island. The findings included detection of Mycobacterium from faecal culture, however there was no evidence of pathology or active disease (Fontenot et al 2006). In the north island of NZ, declines of the Western Weka (*Gallirallus australis australis*) due to disease have been

reported. In 1996 a rapid decline in numbers over a 6 week period was attributed to a viral disease, however there was no confirmed diagnosis provided (Beauchamp et al 1999). Other diseases have been reported in the Weka including a fungal disease and Avian Pox in an aviary Weka and tick infestation has been detected (Beauchamp et al 1999).
Lord Howe Island is also occupied by resident terrestrial birds (about 30 species) and a seasonally abundant number of migratory seabirds (14 species) that breed on LHI. Other vagrant species such as Pacific Black Duck and feral pigeons have also arrived on the island over the last 30 years. Poultry and pet birds have been introduced to LHI from the mainland and are housed securely. An outline of species that have interaction potential with the Woodhen is included below (see 2.2).

Insert LHI map

Material and methods

Wild bird and poultry

Over a five day period in May 2007 samples were collected from Woodhen and other wild birds and poultry to assess health status. Permits to sample wild birds were obtained by scientific license under the NSW National Parks and Wildlife Act 1974 (License number: S12222) and existing animal ethics approvals for LHIB.

The population size of the LH Woodhen is based on data collected from annual surveys undertaken by LHIB. From the 2006 count, 170 birds were counted and LHIB estimate that there are currently about 250-300 Woodhens. The May 2007 health survey design did not anticipate sampling a statistical size for 95% confidence of disease detection at various prevalence levels due to time, resource and logistical issues. The spatial separation of the Woodhens into two discrete populations would also have been a factor to consider in any statistical sampling exercise.

During the survey, LHIB rangers found Woodhens by listening for a response call to loud audio signalling, such as loud tapping of the vehicle panels or use of a bourbon whistle. Once found Woodhens were then captured with modified butterfly nets. All other wild birds except Emerald Dove were caught by hand near nesting sites. Domestic backyard poultry were sampled from a number of locations in the settlement area. Sampling details are shown in Table 1.

Table 1: Numbers of birds sampled at various locations on LHI

Bird	**Settlement**	**Mt Gower**	**Muttonbird Is.**	**Species total**
Woodhen	25	13	0	38
Poultry	17	0	0	17
Flesh-footed Shearwater	12	0	0	12
Providence Petrel	0	11	0	11
Masked Booby	0	0	6	6
Emerald Dove	2	0	0	2
Total	**56**	**24**	**6**	**86**

Sampling procedures

Blood samples were collected from the brachial vein in all species with the exception of the medial metatarsal vein in the Masked Booby. Blood samples were collected into either 1.1cc microtubes (Sarstedt serum gel S/1.1) or 5cc serum clotting activator tubes (Sarstedt Serum Z/5ml) for serology, and into 1.3cc microtubes (Sarstedt Li-Heparin LH/1.3) for blood count and biochemistry (Woodhens only). Two air dried blood smears were made immediately after collection for differential blood count and microscopic haemaprotozoa screening. Cloacal swabs (Eurotubo collection swab, Deltalab Spain) were taken from each bird and placed into 1cc of viral transport media and stored at 5^0C pending virology testing. Faecal samples were collected into Ames transport media swabs for bacteriology and fresh faecal smears made for Chlamydia and AFB screening. Fresh faeces were also collected into vials and chilled to 5^0C for parasitology. Woodhens were examined for external parasites at several body sites including the crown, inter-scapular, leg and sternal areas.

Laboratory testing

Details of laboratory test procedures to be included from Symbion, DPI Victoria and Sydney Health.

Results

Blood count and biochemistry (Table 2)

Total white and differential cell counts were done on 38 Woodhen with mean and reference range values summarised in Table 2. The WCC values were not adjusted for PCV variability due to clot formation in some lithium heparin tubes. The small narrow brachial vein resulted in difficulty in ensuring rapid blood collection in many Woodhens sampled. It is suggested that heparin treated syringes could be useful in future surveys. Physiological reference values were calculated with both sexes and all ages combined. Raw values were plotted using frequency distribution to confirm that data was normally distributed. Following removal of outliers (≥ 3SD) considered healthy normal birds, the reference range for each parameter were calculated from the mean ±2SD. Values are to be compared with reference values compiled for the Guam Rail (I.S.I.S 2002).

Although some blood results were outside the reference range, given all birds appeared healthy, these values are considered acceptable variations in a population. The results do not suggest the presence of disease.

Table 2: Reference Ranges for Physiological Data Values

Test	Units	Mean	St. Dev.	Reference range
WCC	*10^9/L	8.17	3.17	1.83-14.51
Heterophils	%	49.58	23.35	2.89-96.27
Lymphocytes	%	46.03	22.41	1.20-90.85
Monocytes	%	2.08	2.10	0-6.27
Eosinophils	%	1.32	1.53	0-4.38
Basophils	%	0.00	0.00	0
Urate	mmol/L	0.69	0.35	0-1.38
Glucose	mmol/L	13.52	3.57	6.38-20.67
AST	U/L	348.83	75.05	198.73-498.94
ALP	U/L	34.03	22.05	0-79.13
Protein	g/L	39.84	4.80	31.24-49.44
Albumin	g/L	17.69	1.50	14.88-20.49
Globulin	g/L	22.38	3.23	15.91-28.84
A:G		0.80	0.10	0.6-1.00
CK	U/L	734.63	329.57	75.49-1393.76
Amylase	U/L	1758.85	1001.34	0-3761.43
Bile acids	umol/L	25.77	16.29	0-58.36

Bacteriology (Table 3)

Faecal samples were cultured for enteric pathogens with *Campylobacter sp.* isolated from 8/35 (22%) Woodhens, 4/17 (23%) poultry and 0/9 other species. From two of these positive cultures, *Campylobacter coli* were isolated. Faecal smears were also examined for Mycobacteria, megabacteria and Chlamydia. There was no evidence of Mycobacteria or megabacteria from 56 samples. Examination of faeces for Chlamydia by IFA found 5/19 (26%) of Woodhens positive and 0/15 in other species.

None of the five IFA positives had blood results that would suggest clinical Chlamydia, such as marked leucocytosis, monocytosis and elevated AST.

Parasitology (Table 3)

Fresh faeces collected from 61 birds were examined for internal parasites with no sign of internal parasites or coccidial infection.

Blood smears from 38 Woodhen were examined for haemaprotozoa, however there were no parasites found.

Table 3: Bacteriology and parasitology results

Bird	**Mycobacteria and megabacteria**	**Chlamydia**	**Internal parasites**	**Faecal culture isolation**	**Haemaprotozoa**
Woodhen	0/30	5/19	0/35	8/35	0/38
Poultry	0/17	0/13	0/17	4/17	ND
Flesh-footed Shearwater	0/7	ND	0/7	0/7	ND
Providence Petrel	ND	ND	ND	ND	ND
Masked Booby	ND	ND	ND	ND	ND
Emerald Dove	0/2	0/2	0/2	0/2	ND
Total	**0/56**	**5/34**	**0/61**	**12/61**	**0/38**

Serology and virology (Table 4)

All 84 sera tested negative for antibodies to Avian Influenza and Newcastle disease virus. Three of the sera tested positive for flavivirus by ELISA and two (Providence Petrel and Masked Booby) of these positives had antibodies to Kunjin virus, and endemic virus in parts of Australia which can cause encephalitis in people.

All 86 cloacal swabs were negative for viral pathogens by virus isolation including AI and NDV. Swabs were also screened for AI genetic material by PCR and all 86 were negative by this test.

Table 4: Serology and virology results

Bird	**AI and NDV sera**	**AIV PCR**	**Virus isolation**	**Flavivirus serology#**
Woodhen	0/37	0/38	0/38	
Poultry	0/17	0/17	0/17	1/
Flesh-footed Shearwater	0/11	0/12	0/12	
Providence Petrel	0/11	0/11	0/11	1/
Masked Booby	0/6	0/6	0/6	1/
Emerald Dove	0/2	0/2	0/2	
Total	**84**	**86**	**86**	

Final report pending

Discussion

The objectives of this NHT funded survey were to assess the health status of the LH Woodhen testing for significant avian disease and to establish a baseline health profile for this species. In-contact resident and migratory birds on LHI were also health screened to assess their health status and disease risk to the Woodhen. A number of bacterial and viral diseases were targeted for screening based on perceived risk, impact and test capability, internal and external parasite burdens assessed, and physiological parameters measured to assess clinical health status and compile reference ranges for this species.

The findings from this health survey support historical records that suggest freedom from significant avian disease. A search of pathology records for the Woodhen at the Pathology register at Taronga Zoo found no report of disease. A further search of pathology records since 1999 in captive members of the Rallidae family records the fungal disease, Aspergillosis in several cases, and no other significant disease detections (J Hall, Pathology register Taronga).

For the May 2007 survey, all Woodhen and wild birds were in apparent good health with no clinical signs of disease. There was no evidence of exposure to Avian Influenza and Newcastle disease from serological antibody testing. Further testing for Avian Influenza was done by PCR and virus isolation on cloacal swabs with all samples negative. There was also no evidence of pathogenic viruses by virus isolation on cloacal swabs.

Other positive test results are not considered conclusive for disease. The IFA test for Chlamydia is a screen test which is not validated in wild birds and is not highly specific. Chlamydia is commonly shed in the faeces of healthy wild birds. The isolation of Campylobacter coli from Woodhen and poultry faeces is not considered to be a significant finding, given that this genus is often found in healthy wild birds.

The sampling of LH Woodhen (~13% of known population) and from two spatially discrete populations is considered a representative sample for assessment of health status. Limited testing of in-contact species also suggests freedom from active disease, and a number of migratory species not present at the time should be assessed in prospective avian health surveys.

The survey provides valuable baseline data for the LH Woodhen. Physiological reference ranges allow diagnostic evaluation of prospective clinical cases of disease. The survey findings provide currency on disease status for developing risk assessment and biosecurity policy, and stored serum samples provide ability for retrospective disease testing.

Qualitative risk assessment

- ***Disease risks***

Disease agent	**Nearest location found**	**Susceptible species**	**Disease pathways**	**LHI avian disease risk**	**Comment**
Highly pathogenic avian influenza (HPAI): currently caused by H5N1	Indonesia – epizootic status Last outbreak in Australia: NSW 1997 H7N7	Primarily intensively farmed poultry and ducks. All birds susceptible	Infected poultry and migratory waterfowl	Low	Current HPAI pandemic primarily in poultry. No reported clinical cases or HPAI virus recovery from species that migrate to LHI.
Newcastle disease	Indonesia. Last outbreak in Australia: NSW 2002	Primarily poultry. Also found in other avian hosts	Infected poultry and waterfowl	Low	Infected carrier waterfowl shed virus in faeces into dams. LHI has few waterfowl movements, and Australia currently free of disease
Avian tuberculosis	Australia: uncommon finding in wild and captive birds	Wide avian host range: significant disease in captive exotic birds	Infected birds - shed in faeces	Low	More significant in captive birds under stress.
Avian chlamydiosis	Australia - caged birds and pigeons, carrier wild birds	Caged birds and pigeons, outbreaks recorded in domestic poultry and ducks	Aerosol from faeces and respiration	Low	Wild birds often act as asymptomatic carriers, important disease in caged birds, esp. psittacine and columbiforms.
Avian viral diseases such adenovirus, pox, herpes, paramyxovirus	Australia and overseas	Poultry, pigeons, psittacines and many wild birds	Imported birds Vectors	Not known	Impact not known if introduced, some viral strains species specific, numerous reports in pigeons and psittacines

Disease agent	**Nearest location found**	**Susceptible species**	**Disease pathways**	**LHI avian disease risk**	**Comment**
West Nile virus	USA	Wild birds	Migratory birds	Not known	Unlikely introduction to LHI, require vector
Psittacine Beak and Feather Disease	Mainland	Psittacine birds	Imported psittacine	Low	Only reported in psittacines
Haemaprotozoa	Ubiquitous	All species	Wild birds Vector	Low	Health impact low or not clearly understood
Internal parasites – coccidia, cestodes, nematodes etc External parasites – lice, mites and ticks	Lice are ubiquitous Ticks on the mainland include the Paralysis tick	All species	Poultry and wild birds ticks-animal and people?	Low	Parasitism generally has only low grade affect on health of wild birds. Captive birds may experience heavier burdens. Ticks reported on related species in NZ (Beauchamp et al 1999). Paralysis tick on coastal NSW would be a concern if introduced.
Megabacteria	Australia	Psittacine birds	Imported pet birds	Not known	Considered to be associated with birds under stress such as caged birds. Impact in wild birds unclear
Enteric pathogens: Salmonella, E coli, Shigella, Campylobacter	Australia	All species	Feral pigeons	Low	Campylobacter widespread – minimal impact wild birds, although sporadic outbreaks have been reported in wild birds
Aspergillosis	Widespread fungal pathogen	All species		Low	Opportunistic pathogen seen usually in debilitated birds
Botulism	Not uncommon disease in mainland birds	All species	Environ issue	Low	Not previously recorded at LHI

Disease agent	Nearest location found	Susceptible species	Disease pathways	LHI avian disease risk	Comment
Other poultry diseases: Infectious bronchitis, coryza, Infectious Laryngotracheitis, Fowl cholera, Fowl pox, Fowl typhoid, Infectious bursal disease, Marek's, Pullorum, Avian leukosis, Infectious Mycoplasmosis	Various – some endemic to Australia, others exotic	Primarily diseases of poultry and game birds.	Poultry import	Low or not known	Scientific evidence suggests these have narrow host range, if not specific to domestic production birds. Potential hazard to wild birds not known. No reports of these diseases in wild birds.

- ***Interaction potential between Woodhens and other domestic and wild birds on LHI***

Settlement area	Contact species	LHI status	Population size	Migratory range or origin	Disease threat
Landbirds	Domestic poultry	Caged and free-ranging	200	Imported from NSW	Low-moderate
	Feral pigeons	Feral	20	Introduced from mainland?	Low-moderate
	Feral ducks	Feral	50	Vagrant	Low-moderate
	Aviary pet birds	Caged	<20	Ex mainland	Low
	Shorebirds	Winter visitors	1000+	From Siberia, Mongolia	Low
Seabirds	Black winged Petrel	Dec-Apr		Tasman Sea and central Pacific	Low
	Flesh-footed Shearwater	Dec-May		Northern Pacific	Low
	Wedge-tailed Shearwater	Oct-May		South West Pacific	Low

Settlement area	**Contact species**	**LHI status**	**Population size**	**Migratory range or origin**	**Disease threat**
Seabirds	Masked Booby	Resident		Non-migratory but travel widely for food	Low
	Red-tailed Tropicbirds	Nov-Feb		Extensively through Western Pacific	Low
	Sooty Tern	Sept-Dec		Widely over Pacific, Indian and Atlantic Oceans	Low
	Common Noddy	Aug - May		Widespread over Pacific and Indian Oceans	Low
	White Tern	Sept-June	200		Low
	Providence Petrel	May-Nov		N Pacific east to California, south to Tasmania	Low
	Wedge-tailed Shearwater	Oct-May		South West Pacific	Low
	Black Noddy	Sept-April		Pacific region	Low

Avian biosecurity guidelines for LHI

Developing a LH Biosecurity Plan is an important strategic policy measure to minimise the risk of introducing infectious or emerging diseases into the unique wild bird populations of LHI. The impact of potential disease incursion is difficult to anticipate and may be more dramatic than expected given the relative isolation of LHI from many diseases that circulate in larger and more interactive mainland wild bird populations. A significant number of avian diseases also primarily affect domestic production birds, suggesting either host specific relationships or environmental (high production) factors predispose to disease. Vulnerability of the LH Woodhen to new or emerging diseases is not known and may be influenced by the genetic diversity of the species.

1. Response strategy to disease outbreaks

A number of avian diseases are listed as notifiable under NSW Dept of Primary Industries legislation. Although these are primarily diseases of poultry, there is a requirement to notify NSW DPI if there is suspicion of any listed disease. The DPI operates a disease hotline (1800 675 888). The list of notifiable diseases includes:

Exotic diseases
Avian Influenza
Newcastle disease (virulent)
Infectious Bursal disease (hypervirulent)
Fowl Typhoid
Duck virus enteritis
Duck virus hepatitis
Japanese Encephalitis
West Nile Virus infection

Endemic or sporadic diseases (found in NSW)
Chlamydiosis
Egg Drop Syndrome 76
Infectious Laryngotracheitis
Pullorum disease
Salmonella enteritidis

In the event of an outbreak of avian disease on Lord Howe Island, NSW DPI must be notified. DPI would provide a diagnostic response team to investigate the disease and advise appropriate control measures.

If an outbreak of notifiable disease is reported on mainland NSW, DPI will depending on the situation, generally declare intrastate quarantine and movement restrictions. Depending on its severity, the movement of birds or bird products may be prohibited from NSW to other areas of Australia. With this scenario, LHIB should, with support from NSW DPI also enforce an additional level of security to limit the movement of birds from the mainland.

Recommendation: To engage NSW DPI in LHIB policy on avian disease monitoring and response strategies, seeking formal agreement on assistance as required.

2. Avian health monitoring strategy (see Table 5)

Provision of on-going monitoring of the health of all avian species on LHI includes the endangered Woodhen, migratory and vagrant species, domestic birds and poultry. Any report of disease or mortality in Woodhens needs thorough investigation at a NSW veterinary diagnostic laboratory. Poultry health should be monitored as they are convenient indicators or sentinels of new or emergent disease in the settlement areas of LHI. Any unusual disease or deaths in flocks of birds should be investigated.

In summary the following procedures should be adopted:

- Diagnostic investigation of disease or death in individual Woodhens
- Diagnostic investigation of unusual disease or mortality in other wild birds
- Encourage public reporting of unusual disease and dead birds
- Health inspection of Woodhens during annual surveys including physical inspection and monitoring of body weight
- Prospective health surveys of Woodhen and other birds

Recommendation: Implement an early warning program for detection of new or emerging disease through routine monitoring of unusual disease or death in all bird species

3. Avian import and quarantine policy

Current LHIB policy only allows import of day old chickens, however very few poultry have been imported in recent years. There are legislative controls to enforce this policy?

There are no immediate disease threats that would support a total ban on poultry and pet bird imports from mainland Australia. With the exception of notifiable diseases such as avian influenza and NDV, many of the known poultry diseases are not known to cause disease in wild birds.

However in view of the endangered status and biodiversity value of the Woodhen, it is advisable to have a conservative import policy. LHIB should limit poultry imports to day old chickens and fertile eggs only from properties certified disease free by NSW DPI. Fertile eggs can be incubated readily with a number of cheap incubators available (eg Bellsouth incubator). This policy would be very low risk for introduction of disease.

For exotic pet birds there is potential for pest and disease introduction especially in psittacine species with a number of viral diseases of concern. Although quarantine tests and treatments could be done, there are few reliable diagnostic screening tests to detect carrier birds for a number of these viral diseases. LHIB would also need to consider separate biodiversity threat issues relating to import policy for breeding pairs and assessment of the cage security of these premises.

In the event of a major avian disease outbreak on the mainland, LHIB should also review biosecurity policy and enforce more stringent controls.

There are very few vector borne diseases that clinically affect birds, for example West Nile virus in New York. The risk of this disease is a mitigated by AQIS pre-border treatments on all incoming flights. Pox virus can be transmitted by mosquito vectors, however there is probably insufficient justification to introduce vector control treatments on aircraft arrivals from the mainland.

Recommendation: Avian imports limited to day old chickens and fertile eggs from DPI certified disease free properties. Import policy reviewed in consultation with NSW DPI in response to any notifiable disease outbreak on the mainland.

4. Control of introduced species

Although no immediate disease threat is apparent, feral pigeons and ducks could potentially introduce new diseases to LHI. These could include a number of bacterial and viral diseases with significant impact. Some vagrant species may not be effectively controlled such as the Pacific Black Duck, a dispersive species. LHIB should also consider the biodiversity preservation issues of feral birds as justification for control of introduced species. Is the Black duck considered feral to LHI?? Mallards present?

Recommendation: LHIB to consider options to control feral populations of introduced birds such as feral pigeons and ducks.

5. Environmental health

Maintaining a healthy ecosystem for wild birds in the disturbed settlement area is an important strategy to minimise disease risk from contaminants, chemicals or toxins. This would include water courses, wetlands and waste disposal areas. For example Botulism (although never reported at LHI?) is often associated with stagnant waterways, high temperatures and rotting vegetation. Excessive run-off of fertilisers can lead to a flush of growth followed by plant death, and if conditions suit, botulinum toxin can be produced in rotting vegetation. It is important that wetlands are properly managed in the settlement area and that any wild bird disease or mortality near these wetlands be investigated.

The LH Woodhen and other rails may be at higher risk from exposure to bacteria and fungi in soil and faeces due to their ground foraging habits. However any incidence of disease resulting from ecosystem disturbance is only likely to be localised, affecting individual birds and not be a major biodiversity threat.

Recommendation: LHIB to review threats to ecosystem health and monitor ecosystem health as indicated.

References

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Table 5: Avian health monitoring protocol

Incident	Action required	Rationale	Samples	Contact
Sick or dead wild birds	Investigate cause	On-going monitoring of avian health	Chilled (not frozen) whole bird	NSW DPI EMAI
Sick or dead poultry	Investigate cause	On-going monitoring of avian health	Chilled (not frozen) whole bird	NSW DPI EMAI
Notifiable disease or high numbers sick or dead birds (poultry or wild birds)	Request emergency response team from NSW DPI	Diagnose, treat and control spread and impact of disease		NSW DPI Animal Health
Notifiable avian disease on the mainland	Ban import of live birds until further notice. Seek advice from CVO NSW re disease risk	Minimise risk of disease incursion	N/A	CVO NSW DPI
Report of notifiable disease in species that migrates to LHI	Seek advice from DPI to assess disease threat. Monitor the health of affected species	Provide early warning of disease incursion	N/A	CVO NSW DPI
Vagrant wild bird arrival	Investigate options for control of existing populations and new arrivals	Limit potential for disease introduction	N/A	N/A

Lord Howe

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Lord Howe Island Rodent Eradication Project

NSW Species Impact Statement
February 2017
Appendix D - LHI Trials Package

D.1 LHI Non Toxic Bait Trial Report

D.2 LHI Bait Uptake Trial Report

D.3 LHI Placostylus Trial Report

D.4 LHI Bait Efficacy Trail Report

D.5 Efficacy of Pestoff 20R on LHI Mice

Report on non-toxic bait trials
Lord Howe Island – August 2007

Department of Environment and Climate Change
(Primary Author Dr Ian Wilkinson)

Executive Summary

In August 2007 a non-toxic bait trial was conducted at Lord Howe Island to support preparations for a planned eradication of ship rats (*Rattus rattus*) and mice (*Mus musculus*) that are widespread on the island and have significant averse impacts. The study examined palatability of bait to rodents, risks posed to non-target species, bait longevity in the environment, and trialed the use of aerial bating methodology which will be critical for an eradication attempt.

Palatability of baits to rodents was tested by baiting large (23 and 34 ha) areas with baits of two sizes (5.5 mm and 10 mm diameter pellets) at a rate of 13 and 9 kg/ha and then trapping animals over a 7 days period commencing 2 days after the bait drops. Baits were non-toxic and contained a biomarker which fluoresces under ultra violet light. Bait ingestion was confirmed by the presence of fluorescence in trapped rats and mice. Prior to baiting, each area was trapped for between 3 and 7 days and live captured rodents were ear marked and released. Residency of rodents on the trapping grids and thus access to bait prior to capture was assumed if trapped animals were ear marked. 83.9% of mice, and 87.5% of marked rats in the 5.5 mm bait area had eaten bait, and 100% of animals in the 10 mm bait area consumed bait. Robust comparison of the two rates of uptake was prevented by low capture rates with only 1 mouse and 9 rats were captured on the 10 mm grid areas. While results on bait uptake are equivocal, circumstances relating to those animals not consuming bait in the 5.5 mm suggest that bait palatability may not necessarily have been the reason for no observed uptake.

Non-target species were assessed for uptake by baiting a 30 ha area adjacent to the islands golf course with 5.5 mm bait at a rate of 10.1 kg/ha and capturing animals over the following 9 days.

Four bird species were shown to be at risk from the baiting, and would therefore be at risk during a poison drop. Of these, woodhens were the only threatened island endemic to test positive for bait uptake, and confirmed the view that they would be vulnerable during a bait drop. The threat posed to woodhens from a poison bait drop will necessitate the capture and holding of a significant proportion of the population in captivity for the duration of any eradication operation. The period of captivity will be determined by the time it takes for baits remaining in the environment after rodent deaths to breakdown to a stage where they are no longer a risk to non-target species.

Other threatened island endemics; currawongs, golden whistlers and silvereyes did not appear to ingest bait, notwithstanding the findings, currawongs are at high risk of secondary poisoning during any operation as they would prey on dead and moribund rats ands mice. Consequently they would also be captive managed along with woodhens.

Several invertebrate species were observed either fluorescing under UV light indicating bait ingestion, or feeding on baits.

Condition of baits placed in cages in three habitat types was monitored over 55 days and indicated that the smaller 5.5 mm baits disintegrated at a faster rate than the 10 mm which would reduce the period any at risk non-target species were held in captivity during an eradication, and livestock in confined holding facilities.

Aerial baiting was shown to be an effective technique that could be utilised in an operation on Lord Howe Island. The trial provided an opportunity to establish the correct flight configuration: air speed and aperture ring size to produce the required flow rate of bait during operations. Methodologies for loading procedures, and determination of bait usage on flight runs were developed for use in future baiting operations.

Introduction

In common with many oceanic islands Lord Howe Island has unique faunal and floral assemblages, with high degrees of endemism. The introduction of house mice (*Mus musculus*) in 1860, and ship rats (*Rattus rattus*) in 1918 has had extensive adverse impacts on the natural flora, fauna and ecological processes on the island. Rats have been implicated in the decline and extinction of a number of bird, reptile and invertebrate species. They also have significant impacts on the vegetative parts of a number of plant species on the island. While the impacts of mice have not been intensively studied at Lord Howe Island evidence from other locations would suggest that they are likely to be significant predators of invertebrates, the eggs of smaller birds, and of plant seeds.

Attempts at control of rats have been attempted since shortly after their arrival in 1918. Since 1986 the Lord Howe Island Board has undertaken control at 33 sites on the island primarily to protect the palm industry which is heavily impacted by rats. While control may temporarily reduce number, it can not prevent the ongoing biodiversity impacts by both rats and mice (which are not controlled due to their resistance to the Warfarin used in the programme).

With developments in eradication techniques during the past 20 years, and in particular the use of aerial baiting methods, the eradication of both rodent species on Lord Howe Island in a single operation is considered feasible (Saunders and Brown 2001). To achieve this, while minimising impacts on native species, will require detailed technical and logistical planning. A single eradication operation would have a the major advantages of minimising disturbance to native wildlife, cost efficacy, and limiting the possibility of a dramatic mouse population increase which may occur in the absence of rats on the island.

A prerequisite of all eradications is that all target individuals must be put at risk by the methods used, and impacts on non-target species should be minimised. To this end, this study aims to: determine the palatability of proposed bait types to both rats and mice and assess the risk posed to non-target species. It will also determine the longevity of baits in the environment, and trial and refine aerial bait delivery for use on Lord Howe Island.

Methods

Study Site

Lord Howe Island (31°33'S, 159°05'E) is a crescent shaped, volcanic remnant on the Lord Howe Rise, approximately 600 km east of Port Macquarie, New South Wales. It is 1455 ha in area with very rugged relief, rising to 875 m in the south on the summit of Mount Gower. The central lowland areas have been cleared for agriculture or settlement and are dissected by a network of 11 km of narrow roads. Patches of uncleared evergreen closed forest (Pickard 1983) adjoin grazing leases and urban settlement. Lord Howe Island was included in the World Heritage List in 1982.

Three baiting areas were chosen on the island, two of approximately 30 ha on Transit hill for the rodent trapping study and a third area (~30 ha) to the east of Intermediate hill used for non-target species capture (Fig. 1). Four trapping grids (numbered 1 to 4) of 49 Elliot traps and 49 cage traps spaced at approximately 10 m intervals (60 x 60 m) were established in the area to the east of Transit Hill (the 5.5 mm bait area) and three grids (numbered 5 to 7) on the western slopes of Transit Hill, the 10 mm bait area. Each of the trapping grids was at least 100m from the nearest adjacent grid and from the edge of the baiting area.

Fig. 2 shows the planned extent of the proposed 5.5 mm baiting area to the east of Transit hill which contained trapping grids 1-4. Prior to aerial baiting, but after commencement of live trapping, it became clear that the paddocks on the western side of the area were being used for grazing cattle, and a decision was made to avoid a bait drop over the paddocks as it was unclear as to how the green dye on the bait would impact milk production, quality, or colour. The baiting area was redrawn to exclude the paddocks (Fig. 3), and in the process resulted in a reduction in area, and the exclusion of part of trapping grid 1 from the baited area.

Fig. 1. An aerial photograph of Lord Howe Island showing the location of aerial baiting areas.

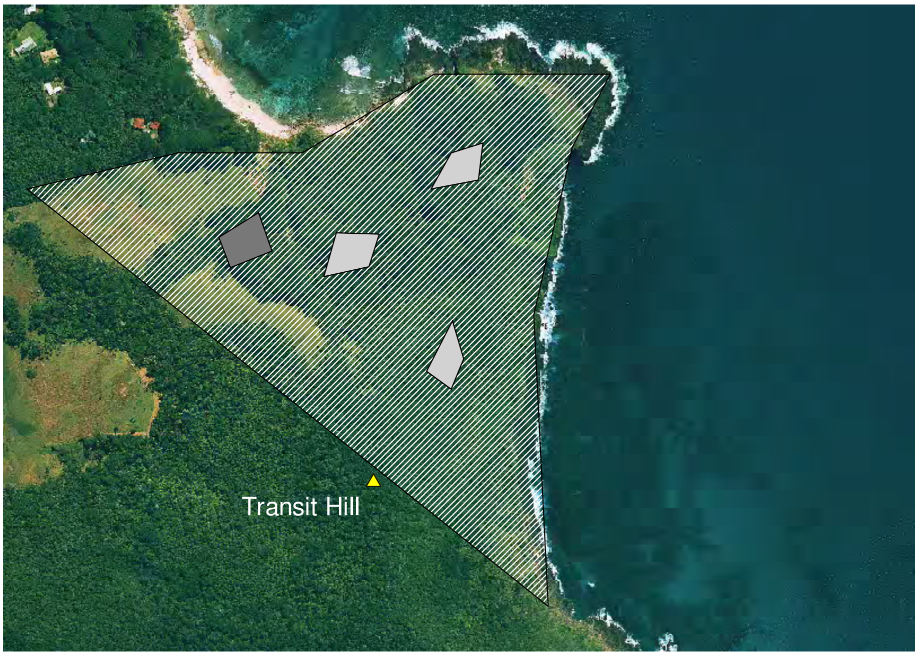

Fig. 2. Proposed 5.5 mm (30 ha) baiting area to the east of Transit hill containing rodent trapping grids 1 – 4. Grid 1 is shown darker than the remaining three grids.

Fig. 3. Revised 5.5 mm baiting zone (23 ha) excluding paddocks on the western edge of the area. Note how trapping grid 1 has been partially excluded from the baiting zone.

The location of the 10 mm bait area to the west of Transit hill is shown in Fig. 4, and the golf course bait area and its proximity to the other two areas is seen in Fig. 5.

Fig. 4. 5.5 mm baiting zone containing four trapping grids to the east of Transit hill, and the 10 mm area (34 ha) containing the three trapping grids to the west of Transit hill.

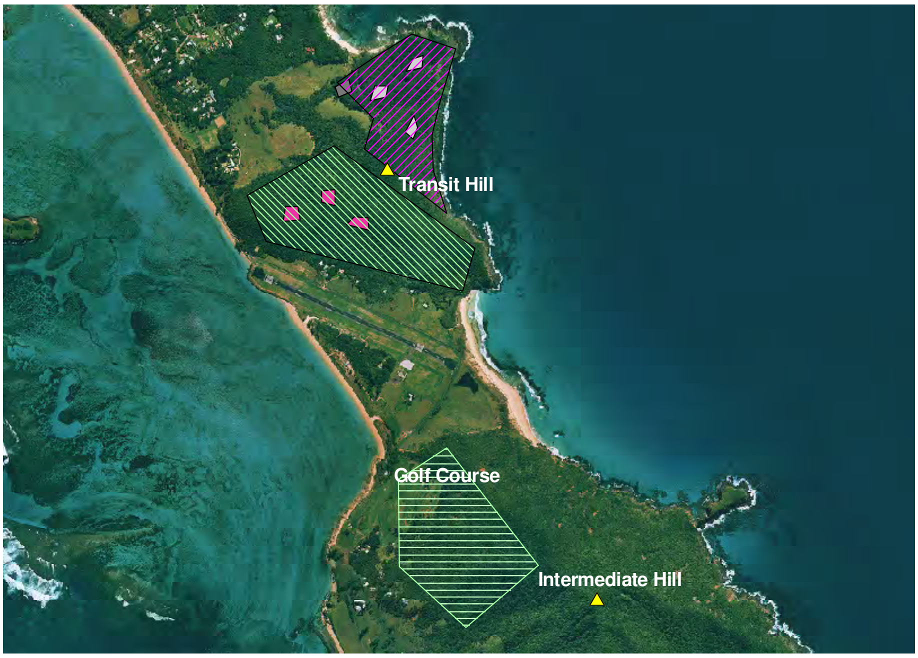

Fig. 5. Location of Golf course baiting area (30 ha) and its proximity to the other two bait areas.

Live capture of rodents

Rodents were live trapped over a period of 8 nights (3-11 August) prior to aerial baiting. Elliot and cage traps (containing leaf litter to prevent trap mortalities) were set in grids, baited with peanut butter and rolled oats. All rats and mice captured were transferred from traps to catch bags to facilitate handling (Fig. 6), and then ear punched (Fig. 7) to allow identification to the grid on which they were captured, and subsequently released. Traps were opened at 16h00 and then checked at 06h00 before closing traps during the day. Any previously marked animals were recorded.

Fig. 6. Transfer of rat from cage trap to facilitate handling

Fig. 7. Ear punching a rat to enable catch bag to identification to grid on which captured

Aerial Baiting operation

All three areas (Fig. 1) were aerially baited on August 14th using a squirrel helicopter and a custom made bait spreader bucket (Fig. 8) slung under the helicopter (Fig. 9) Flight lines over each area were determined using a differential GPS system fitted in the aircraft, to ensure accurate bait coverage, at a targeted rate of ~10 kg per hectare. Baits dropped were non-toxic PESTOFF 20R produced by Animal Control Products, Wanganui, New Zealand. The baits are cereal based, dyed green, and contain the non-toxic biotracer, Pyranine 120 which when exposed to ultra violet light fluoresces green. Both 5.5 mm (~0.5 g) and 10 mm (~2 g) baits were dropped to allow a comparison to be made as to which would be the most appropriate for a two species eradication. Baits were in all ways, other than presence of a toxin, identical to those that would be used in an eradication operation. The 10 mm baits were spread on the western side of Transit hill and the 5.5 mm baits on the eastern side. 5.5 mm baits were spread over an area to the west of Intermediate hill overlapping the island's golf course which had been identified as an appropriate area to trap non-target species (Fig. 10). A baiting rate of 10 kg/ha results in approximately 1 10 mm bait every two square metres on the ground, while 5.5 mm baits will fall at a density 4 times that giving a ground coverage of 2 per square metre.

While exact baiting areas were calculated prior to flight operations, problems with uploading these areas to the onboard GPS system necessitated the manual establishment of areas during flight. Flight lines were set at the effective swath width provided by the bucket manufacturer, using a flow rate aperture (Figs 11 and 12) to give a rate of approximately 5kg per hectare. A second flight was then conducted along lines midway between those of the first flight. This flight plan allowed a 100% overlap in baiting producing the desired baiting rate of 10kg/ha. All flight lines were run in parallel to minimise bait gaps which might occur on right angle flight paths as a result of errors in calculating the effective swath width of the bait spreader.

Fig. 8. Custom built bait spreader bucket being prepared for use on LHI.

Fig. 9. Squirrel helicopter with bait bucket during baiting operations.

While the size of the bucket would have enabled a single loading to conduct both bait runs on each area, the aircraft landed after the first baiting run to allow confirmation of baiting rates. This was facilitated by determining the amount of bait used during the flight. The inside of the bucket was calibrated prior to use by filling with the contents of 25 kg bait bags, raking each 25 kg flat and marking the inside of the bucket to show the amount of bait. At the start of the baiting operation, approximately two thirds of the estimated bait required for the whole area was loaded into the bucket, and the remaining bait quantity determined when the aircraft returned by raking the bait in the bucket flat and recording the amount. Changes to the aperture size at the base of the bucket were made, if required, to achieve required flow rates.

Fig. 10. 5.5 mm bait on the golf course after the aerial baiting operation.

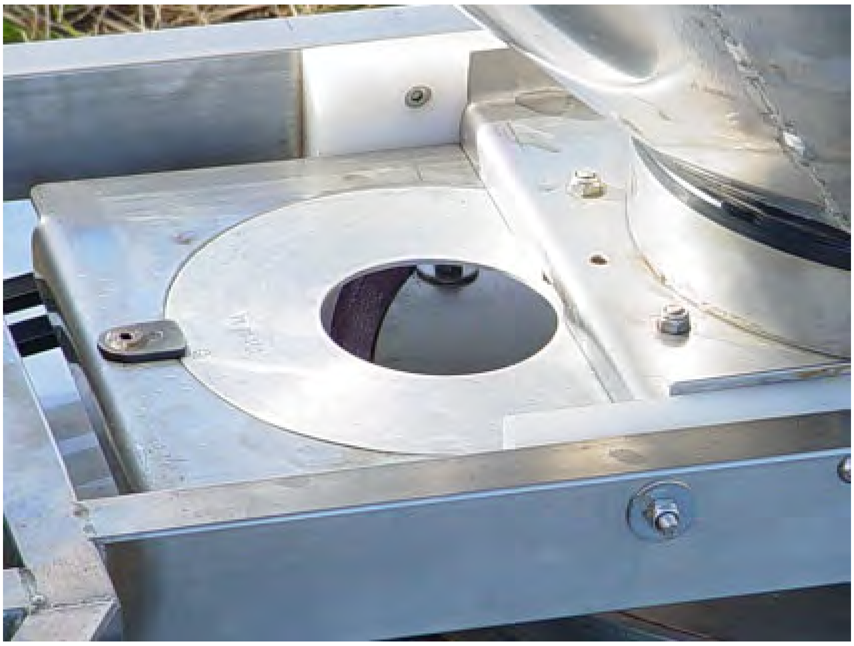

Fig. 11. Adjustable bait flow rate aperture.

Fig. 12. Base of bucket shown with spreader mechanism (spinner) which is powered by lawn mower motor mounted on the side of the bucket. The slide holding the aperture ring shown in Fig. 10 is operated hydraulically by the pilot to allow bait to flow at the required time. This photograph shows the slide in the closed position and no bait would flow from the bucket to the spreader.

Post baiting trapping of rodents

The previously established grids on Transit hill were trapped for 7 days, commencing on the second day after the bait drop (evening of 16 August). Both rat and mouse snap traps were used at each site, placed under cover to prevent non-target bycatch. Subsequent to the first night's trapping, during which there were few captures, Elliot and cage traps were redeployed to provide additional potential forcaptures. All animals captured in live traps were euthanased using blunt trauma techniques in accordance with DECC animal ethics guidelines. Captured animals were weighed to the nearest 2 g and checked for ear marking to determine if they had been captured during the live trapping phase prior to aerial baiting.

All rodents captured were assessed for bait uptake by visual inspection under UV light for pyranine dye (green fluorescence) in their mouth, rectum and in faeces. Any animals which showed no external signs of dye were dissected and examined internally. The proportion of previously marked (an indication of residency), and unmarked (assumed to have originated outside the baited area) rodents was determined. Separate analyses were conducted for the 5.5 mm and 10 mm bait areas.

Assessment of non-rodent impacts

Birds were captured on the golf course area adjacent to Intermediate hill commencing 2 days (16 August) after the bait drop using mist nets and butterfly cage traps, and trapping continued for 9 days. Additional captures using butterfly cage traps were made in the 5.5 mm baiting zone to the east of Transit hill. Once captured, birds were placed in a drawstring bag to minimise handling stress. Mouth linings, and cloaca of all birds were checked under UV light for fluorescence indicating consumption of bait. They were colour banded for identification if recaptured, and then transferred into lined aerated boxes in a quiet, dark place to minimise disturbance until a faecal sample had been produced. Each bird was held for the minimum period necessary for them to produce faeces, which did not exceed 1 hour. All faecal samples were checked for fluorescence under UV light, and then frozen for further analysis if required.

In addition to trapping, opportunistic observations were made of foraging animals, faecal material collected when species producing it were observed, and on several occasions baits were directly presented to birds to determine palatability.

A harp trap was set for five nights on the golf course, and for three in the bait zone to the east of Transit hill, to catch Large Forest Bats (*Vespadelus darlingtoni*).

Bait longevity

Rodent cage traps were covered with 6 mm aperture wire mesh to prevent access by rodents or non-target species to trial baits. Cages containing 5.5 mm and 10 mm baits were placed at three locations: an open site (Fig. 13) with zero canopy cover, a medium cover site with a broken canopy and a full canopy cover site to monitor bait longevity. 100 baits were placed in each cage and samples removed at approximately weekly intervals and photographed to assess the status of the baits, 10mm and 5.5 mm baits are shown in cages in Fig 14. Bait condition was assessed according to a 6 point scale developed by the New Zealand Department of Conservation (Fig. 15).

Fig. 13. Bait cages in 'open' area.

Fig. 14. 10 mm baits shown in bait cage (left), and 5.5 mm baits swollen after rain in bait cage (right).

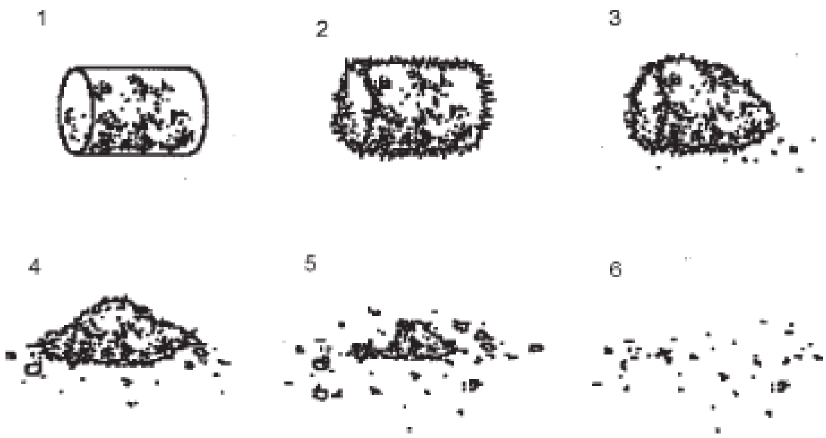

Fig. 15. Scale used to measure bait decomposition (see Green & Dilks 2004).1 = fresh, 2 =soft (may have some mould), 3 = mushy pellet (> 50% may have some mould), 4 = pile of mush (> 50% with mould), 5 = disintegrating pile of mush, 6 = gone or identifiable by grain flakes.

Results

Live capture of rodents

A total of 95 mice and 147 rats were captured and marked during the 8 night period of trapping prior to the aerial baiting operation. Numbers of rats and mice in each trapping grid are shown in Table 1. An estimate of minimum numbers of rodents per hectare was calculated by dividing the total number of marked animals by the area of the grid on which they were captured (Table 1).

Table 1. Numbers of trapping days, trap nights, trapping grid areas, rats and mice caught and marked on LHI, and estimates of minimum numbers of mice and rats per hectare.

Grid	Days grid trapped	Trap nights (nights * # of traps)	Area of grid (ha)	Mice marked	Minimum Mice/ha	Rats marked	Minimum Rats/ha
1	6	492	0.37	37	100.0	13	35.1
2	4	336	0.38	28	73.7	15	39.5
3	5	420	0.31	29	93.5	23	74.2
4	3	252	0.30	0	0.0	22	73.3
5	7	686	0.40	0	0.0	25	62.5
6	7	686	0.37	1	2.7	23	62.2
7	7	588	0.40	0	0.0	26	65.0
Totals		3460		95		147	

Unmarked rats and mice were still being captured on most grids at the cessation of the live trapping period (Figs 16 & 17), indicating numbers marked represented minimum numbers of animals on each grid. Only one mouse was captured during the live trapping period on the western group of grids, which is not shown on Fig. 16.

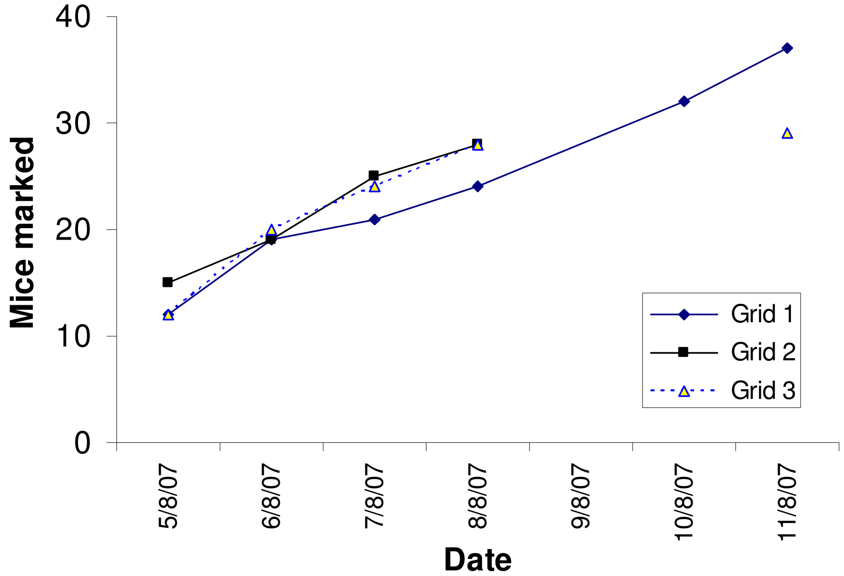

Fig. 16. Cumulative numbers of mice marked on trapping grids prior to aerial baiting.

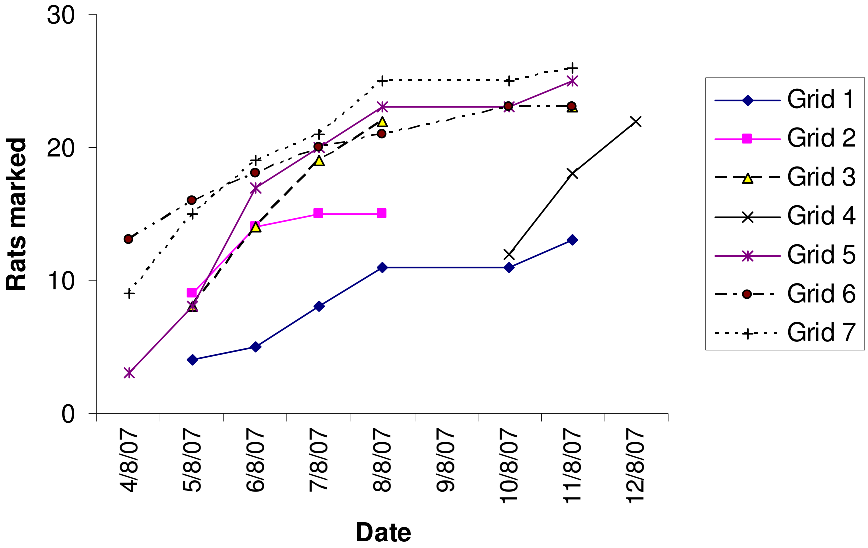

Fig. 17. Cumulative numbers of rats marked on trapping grids prior to aerial baiting

Aerial Baiting

Aerial baiting was conducted during 7 flights on 14 August. A total of 920 kg of non-toxic bait was spread during the flights. Two measured bait drops were undertaken over the first two areas baited. During the 10 mm bait drop to the west of Transit hill 170 kg bait was used on the first run with a 70 mm aperture on the bucket, and a swath width of 70 metres. This resulted in a delivery rate of 4.9 kg/ha over the 34.8 hectares baited. The second run used the remainder of the bait with flight lines offset by 50% of the swath width from the first run.

During the baiting over the golf course the first flight used a 60 mm aperture to spread the 5.5 mm baits resulting in only 75 kg of bait being used over the 29.6 ha. The second run used a 70 mm aperture and 150 kg were used providing a baiting rate of 5.1 kg/ha which was consistent with the figure for the 10 mm runs. A third run dropped a further 75 kg of bait over the area. All baiting with 5.5 mm bait used a swath width of 60 metres.

The details of the baiting, with baiting rates and numbers of baits spread per hectare are shown in Table 2.

Table 2. Details of aerial baiting conducted on LHI on 14 August.

Zone	Bait size (mm)	Area (ha)	Bait (kg)	Baiting rate (kg/ha)	Baits/ha
West	10	34.8	320	9.2	4600
East	5.5	23.1	300	13.0	26000
Intermediate hill	5.5	29.6	300	10.1	20200

The modification to the planned baiting area to the east of Transit hill (Fig. 2) resulted in baits only being distributed over part of trapping grid 1. In flight changes to the baiting area resulted in an area of 23.1 ha (area shown in Fig. 2) being sprayed, rather than the planned 25 ha. All baiting for the east area was conducted in a single flight, with bucket apertures set for a 5 kg/ha baiting rate. At the start of the fight sufficient bait to achieve the 10 kg/ha coverage was loaded (250 kg), along with an extra 50 kg to cover variation on flow rate, and to allow extra baiting along the boundaries of the area which may be missed during the flight lines. The reduction in the actual size of the East bait area, combined with a slight increase in bait loaded resulted in higher baiting rate ~13 kg c.f. ~10 kg/ha for the other two areas.

Within 7 days of the aerial operation (21 August), baits which had been easily visible on the ground in both baiting areas had all but disappeared, presumably as a result of removal by rodents, and invertebrate activity.

Bait uptake by rodents

A total of 132 mice, and 39 rats were caught over 7 nights on the trapping grids. 10 of 24 (41.7%) adult rats, 1 of 15 (6.7%) of juvenile rats, and 56 of 132 (42.4%) mice were ear marked indicating capture prior to aerial baiting. All marked animals were captured in the grid in which they were marked indicating a high degree of fidelity to the area. Fifty six (58.3%) of the 96 mice marked on the grids were captured, compared to only 11 (7.5%) of the 147 rats.

Mass of 122 mice and 37 rats were recorded. Adults rats weighed 207.4 ± 10.2 g (range 92 – 266 g, n = 24), juveniles 43.8 ± 3.0 g (range 28 – 62 g, n = 13), and mice 19.2 ± 0.4 g (range 8 – 28 g, n = 122). mean 43.8 ± 3.0 g), and mice (n=122) ranged from 8-28g with a mean of 19.2g.

Uptake of 5.5 mm bait for 131 marked and unmarked mice inferred from the presence of pyranine fluorescence (Fig. 18) is estimated at 78.6%, with corresponding figures of 88.9% for 18 adult rats and 91.7% for 12 juvenile rats (Table 3). Both rats and a single mouse showed 100% uptake of 10 mm bait

Table 3. Estimates of rates of uptake of 5.5 mm and 10 mm non-toxic baits indicated by pyranine fluorescence.

Species	Consume 5.5 mm bait		% Positive	Consume 10 mm bait		% Positive
	No	Yes		No	Yes	
Mouse	28	103	78.6	0	1	100.0
Rat - Adult	2	16	88.9	0	6	100.0
Rat - Juvenile	1	11	91.7	0	3	100.0

The corresponding values for marked animals, those assumed to be resident in the area, are shown in Table 4.

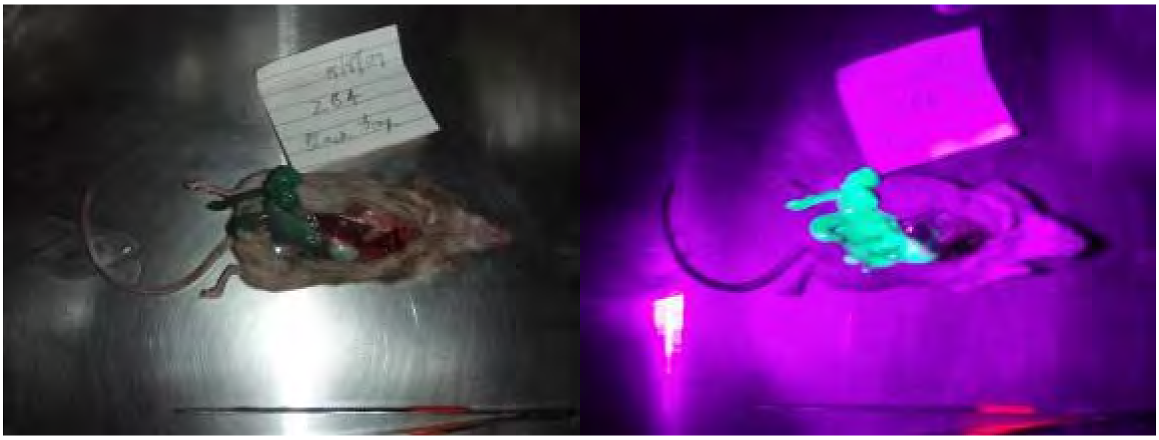

Fig. 18. Mouse captured on 5.5 mm trapping grid 2 showing green colouring in gastro intestinal tract under natural light (left), and pyranine fluorescence confirming ingestion of bait under UV light (right).

Table 4. Estimates of rates of uptake by previously marked rodents of 5.5 mm and 10 mm non-toxic baits indicated by pyranine fluorescence.

Species	Consume 5.5 mm bait		% Positive	Consume 10 mm bait		% Positive
	No	Yes		No	Yes	
Mouse	9	47	83.9	0	0	-
Rat - Adult	1	7	87.5	0	2	100.0
Rat - Juvenile	1	0	0	0	0	-

The marked adult rat which showed no signs of bait consumption was captured in grid 3 on 16 August, the second night after the aerial baiting. The juvenile rat was captured on 21 August on grid 1 in an area that was missed during the baiting (see Fig. 3)

Nine marked mice showed no sign of bait uptake during the trial. Seven of these animals were captured on the partly baited grid 1, the two remaining animals were trapped in grid 3, 7 and 9 days after the aerial baiting. Data for mice in grids other than the partially baited grid 1, show 100% positive results until day 6 after baiting (20 August), and a significant drop by 9 days post baiting. (Fig. 19).

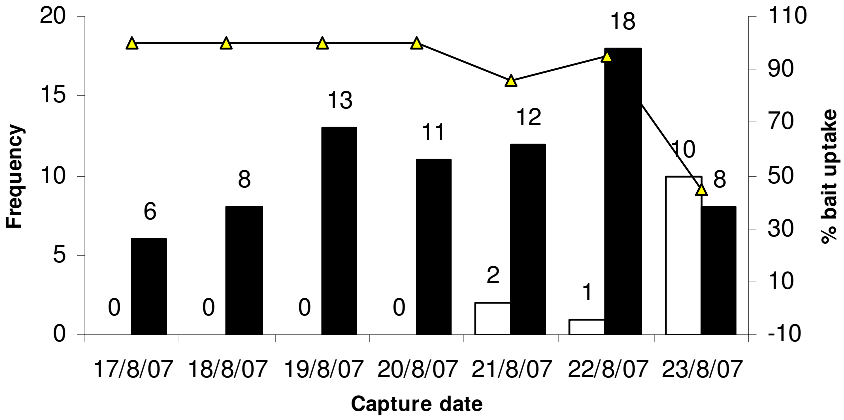

Fig. 19. Numbers of mice in grids other than grid 1 recording positive (solid bars) and negative (hollow bars) pyranine fluorescence by day through the trapping period, and the percentage of inferred bait uptake (line)

Numbers of adult rats captured in the 5.5 mm bait area showed an increase towards the end of the trapping period with more captured in the final 2 days of trapping than in the previous five (Fig. 20). Juvenile rats showed a similar, non-significant pattern (Fig. 20), while mice, after the first day, showed no difference in capture rates through the period. (Fig. 21). In the 10 mm area, the total numbers of captures were very low (13 rats and mice), but numbers of adult rats showed an increase on the final day of captures (Fig. 22).

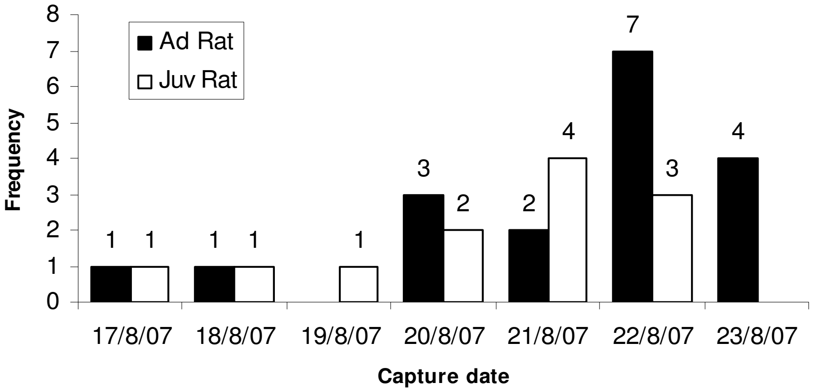

Fig. 20. Daily captures of juvenile and adult rats in the 5.5 mm bait area

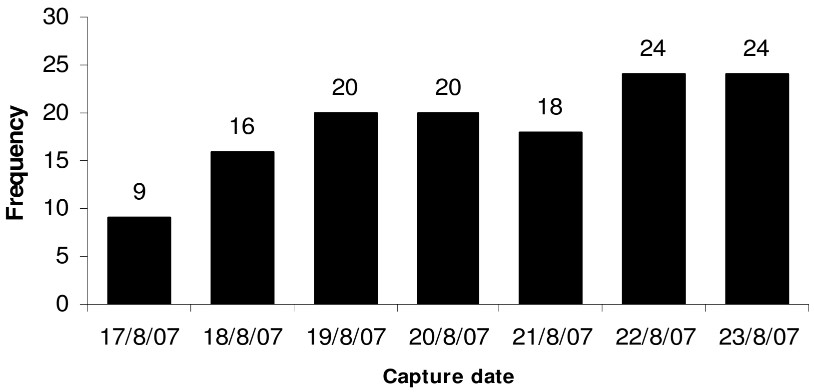

Fig. 21. Daily captures of mice in the 5.5 mm bait area

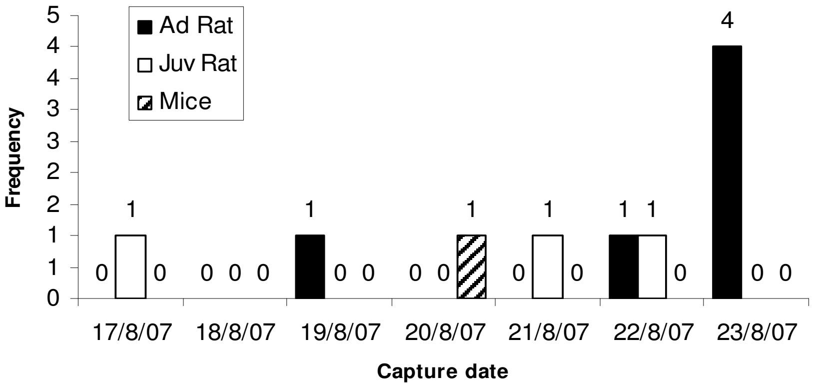

Fig. 22. Daily captures of juvenile and adult rats, and mice in the 10 mm bait area

Non-target bait uptake

11 species of birds were examined during the study for indication of bait uptake (Table 5). Woodhens, Buff banded rails, blackbirds and Mallards all provided fluorescing faecal samples (Fig. 23) indicating consumption of the dyed bait. In addition to the confirmation provided by the positive faecal samples, woodhens and mallards were both seen feeding directly on baits, while a single case of an emerald dove picking up bait and then discarding it was recorded. The remains of an owl kill were found on the golf course and the gizzard fluoresced brightly indicating that the owl's prey had ingested bait. The identity of the prey species was thought to be a woodhen.

Table 5. Results of pyranine fluorescence to assess uptake of bait for bird species caught in mist nets and traps, for faecal samples of known source, and autopsied* animals.

Species	Pyranine Fluorescence	
	No	Yes
Currawong	7	0
Emerald dove	7	0
Silvereye	4	0
Buff Banded Rail	3	1
Whistler	4	0
Woodhen	2	1
Kingfisher	3	0
Blackbird*	0	2
Mallard	0	1
Owl Kill - Gizzard (Woodhen?)	0	1
Magpie Lark	1	0
Purple swamp hen*	1	0
Totals	32	6

Fig. 23. Duck faeces under natural light (left), and fluorescing under ultra violet light confirming ingestion of bait (right).

Seven currawongs captured in clap traps showed no signs of pyranine fluorescence, either in faecal samples, or during physical inspection of their mouth or cloaca. Physical inspection of the 21 large forest bats captured in the harp trap provided no positive results (Fig. 24).

Fig. 24. All 21 large forest bats captured showed no signs of pyranine fluorescence in the mouth or anus during physical inspections.

Baits, both 10 mm and 5.5 mm, presented directly to buff banded rails, emerald doves, currawongs and whistlers elicited no response. Similar non-toxic bait dyed red, or un-dyed (beige in colour) was immediately taken when presented to buff banded rails.

Observations of baits in the field showed invertebrate damage occurred within a day of the bait drop. Several species of invertebrates were scanned externally with UV light to determine if they had ingested bait. Slugs, and snails (not *Placostylus*) fluoresced brightly indicating bait uptake (Fig. 25), and ants, cockroach and slugs were observed feeding directly on bait (Table 6). A single delicate skink, *Lampropholis delicata,* was scanned with UV light but did not show any evidence of bait consumption.

Fig. 25. Slug sp. feeding on bait viewed in natural light (left) and viewed under UV light (right), fluorescence indicates bait consumption.

Table 6. Results of pyranine fluorescence to assess uptake of bait for non-avian species collected, and * those observed feeding directly on baits.

Species	Pyranine Fluorescence	
	No	Yes
Slug spp.	1	2*
Snails (not *Placostylus*)	4	1
Delicate Skink	1	
Millipede sp	1	
Termite sp.	1	
Ant sp.		*
Large wing Cockroach (Sp. A)	1	
Cockroach sp B		*

Bait longevity

Observations of bait integrity showed that 5.5 mm baits in the medium cover site had completely broken down after 55 days, and 164.2 mm of rainfall (Table 7). The other 5.5 mm sites showed advanced decomposition by this time, but still retained recognisable pieces of bait (code 5). All samples of 10 mm baits showed less decomposition than the corresponding 5.5 mm baits after 55 days in the field.

Table 7. Rates of decomposition of bait following NZ Department of Conservation scale measured at intervals up to 55 days after being placed in decomposition cages on 10 August. Rainfall figures provided by the Bureau of Meteorology.

Date	Day	Rainfall (mm)	5.5 mm bait			10 mm bait		
			Open	Medium cover	Full cover	Open	Medium cover	Full cover
10/08/07	1	0	1	1	1	1	1	1
31/08/07	21	14.2	2	1	2	3	1	2
10/09/07	31	70.8	3	2	2	3	3	2
14/09/07	35	76.2	3	3	3	3	3	3
29/09/07	50	164.2	5	5	3	3	4	4
5/10/07	55	164.2	5	6	5	4	4	4

Discussion

The primary goals of the non-toxic bait trial were four fold, to determine uptake rates of 5.5 mm and 10 mm bait by rodents, uptake of bait by non-targets, to determine longevity of bait in the environment, and to trial the use of aerial baiting techniques on Lord Howe Island. While some of the results in the study are equivocal they provide important data on which further planning towards an eradication can be based.

The motivation for comparing two size baits in the trial was a direct result observations from global eradications which indicate that mouse operations are less successful than those for rats and the failures for mice have been linked with inadequate baiting densities which reduce encounter rates (Howald et al.

2007). Changes to bait densities can be addressed by increasing the amount of bait distributed (kg/ha), or by reducing the size so that each individual bait is smaller, and there are more for a similar baiting rate (kg/ha). By using 5.5 mm baits weighing ~0.5 g it is possible to achieve 400% of the coverage, in terms of numbers of baits, that you achieve with 10 mm (~2 g) baits, for the same baiting rate i.e. 10 kg/ha.

Live capture of rodents and bait uptake

The justification for conducting trapping prior to aerial baiting in the current study was to provide a pool of marked individuals that we knew were present in the grid areas, and thus would be exposed to the baits when dropped. Given that all marked animals were recaptured in the grid in which they were marked, there is likely to be very limited movement by both species on LHI, and based on that observation allows conclusions to be drawn from the entire capture sample, as they are likely to have been 'resident' in the grid areas at the time of the baiting and thus exposed to bait. Previous work on LHI rats found that 70% of animals were recaptured within 40 m of the initial capture site, and mean dustance moved was approximately 45 m, with a maximum distance moved of 450 m (Billing 1999). The high rate of residency found in the current study is consistent with previous data.

The lack of mouse captures on the 10 mm bait grids, 1 was caught, prevented a robust comparison of palatability of 5.5 mm and 10 mm baits. During the live trapping, prior to aerial baiting, there was evidence that mice were present but not being caught, this included numerous observations of cage traps being triggered and associated bait removal, and removal of bait from untriggered cage traps by burrowing under the trap to access the bait sitting on the floor of the cage. In the case of the closed traps, mice are able to squeeze between through bars of the cage to escape, and burrows under cages were too small to have enabled a rat to access the bait. Assuming that mice were present on the grids it is puzzling that there was only a single capture in an Elliot trap on 686 trap nights on grid 6, and on a combined total of 1960 trap nights in the 10 mm bait area. Despite the lack of mice captured in the area it had been hoped that the use of snap traps to catch animals after aerial baiting would result in the capture of mice that were believed to be in the area, and have escaped from cage traps and avoided Elliot traps. This did not occur and only one mouse was captured during this period.

The ability to assess the uptake of bait by these species is also dependent on trapping animals to examine them for pyranine fluorescence with a UV light. Post baiting trapping was characterised by very low captures of rats with only 7.5% of those marked being recaptured, compared to 58.3% of marked mice. However, similar proportions of marked to unmarked adult rats and mice (41.7% c.f. 42.4%) were captured indicating that the low overall rate of marked rats in the sample was not a result of their previous capture experience, but rather a consequence of the low trapping rates.

Captures of rats were almost zero for first 5 days of trapping, i.e. 7 days from aerial baiting. One explanation is that rats were foraging as normal during this period but were feeding entirely on the abundant cereal baits that were dropped, and were not attracted to the peanut butter and rolled oat baited traps. As the availability of the preferred food, in this case the bait, declined animals would have been more likely to seek alternative food and increase their probability of approaching a trap baited with peanut butter which would have increased probability of capture and translated to more captures.

An indication of bait available to each animal can be determined by estimating the numbers of animals inhabiting each grid. If we consider a mouse (mean wt 19.2 g) to be equivalent to ~0.1 rats (mean mass 207.4 g), and assume the population inhabiting the grid equates to the numbers of marked individuals (rats + mice – see Table 1), and then divide this into the product of the number of baits dropped per hectare (Table 2) and the size of the trapping grid (Table 1) then rats in the 5.5 mm zone had between 310 and 580 pellets (155 – 290 g) available to each of them, while mice had 31 and 58 pellets (15.5 – 29.0 g) and in the 10 mm zone rats had between 70 and 75 of the larger pellets (140 - 150 g), and mice 7 to 8 (14 – 15g).

An alternative suggestion is that rats cached pellets in the first few days after the bait drop, and then were not active on the grid until several days later when again searching for food, with the associated higher risk of capture. It would seem from the low proportion of marked rats caught compared to mice, that rats may show a stronger preference for the cereal baits to the exclusion of other food sources, which is beneficial in an eradication to ensure bait is consumed. If the rats did cache baits it increases the probability that during a toxic bait drop they would be more likely to succumb to toxicosis underground, and thus not pose a secondary poisoning threat to species that prey upon them.

The situation with mice differed in that captures did not show any changes during the trapping period, suggesting that while mice fed on the bait, they were also willing to take other available food as evidenced by their attraction to peanut butter in the traps.

Despite the apparent willingness of mice to take alternative food when bait is in abundance, uptake of 5.5mm bait was still 100% up to 6 days after the bait drop (Fig. 18), with the rate declining to 44% by day 9. In the context of an eradication operation, even if bait is in abundance and mice eat both bait and alternative food, based on a lethal dose of brodifacoum, (the toxin of choice for current eradications) of 0.4 mg/kg (Haydock and Eason 1997), a 20 g mouse would have to consume only 80% of a single 5.5 mm bait or 20% of a 10 mm bait to get a lethal dose of the toxin. Based on the uptake rates in the first days after the bait drop, it would appear that as long as bait is available at sufficient density to mice they will ingest it, and succumb to the effects of the toxin. At a baiting rate of 10 kg/ha, 20000 5.5 mm baits would fall per hectare, and 5000 10 mm baits. Given a combined rat and mouse density of 85 (75 rats and 100 mice rat equivalents based on a mouse being ~0.1 rat) each rat would have access to approximately 200 small baits and 50 larger baits, while the figures for mice would be 20 and 5. The available baits represent 25 times the lethal dose for mice, suggesting that there would be sufficient bait available.

The supposition in the study that rats are feeding intensively on the baits provides confidence that they would consume the required quantity of a toxic bait to facilitate eradication. A lethal dose of brodifacoum in ship rats is 0.46 mg/kg (O'Connor & Booth 2001), and therefore a 200 g rat would need to consume 2.5, 10 mm baits or 9, 5.5 mm baits to ingest this amount of toxin. Calculations above of bait availability to rats at a baiting rate of 10 kg/ha indicate that there would be around 20 times the required level of toxin available to kill animals. It is unclear why the marked adult rat captured in grid 3 on the second night after baiting had not consumed bait, but it may be reasonable to expect that if it had not been trapped it would have had the opportunity to consume the amount of bait required to receive a lethal dose. The marked juvenile rat that had not ingested bait was trapped in grid 1 which was only part baited during the aerial operation, and so during its movements it may not have encountered bait. This would not occur during an eradication given the comprehensive coverage across the entire island

In addition to the single mouse capture in the 10 mm bait area compromising the bait size comparison, the low numbers of rats captured at the two sites also prevented a statically robust assessment. Despite this shortcoming in the data, it is important to note that all rats and the single mouse captured in the 10mm bait area had consumed the bait, while uptake in the 5.5 mm bait area is discussed above.

Bait longevity

The period during which bait remains intact in the field is a critical factor in operational planning for any proposed eradication to be undertaken on LHI. The primary requirement is that the bait remains intact for long enough for the target species to encounter and consume it, once that criterion is met, any undue delay in decomposition of the remaining bait increases the risks to non-target species. In the case of LHI persistence of toxic bait will determine the period of high risk to human residents and pets, it will also determine when non-targets being held in captivity can be returned to the wild, and livestock returned to paddocks.

The observations suggest that both sizes of bait will persist for at least 55 days which is long enough for uptake by the target rodent species, but the more rapid breakdown of the 5.5 mm bait would facilitate a shorter holding period for island endemics such as Woodhen and Currawong, and livestock. At the time of writing this report, baits had been observed in the field for 55 days, after 164.2 mm rainfall. The only baits that had completely degraded (decomposition code 6) within this period were the 5.5 mm baits in medium cover, but all 5.5 mm baits were at a more advance rate of decomposition than the larger 10 mm baits (Table 7).

Decomposition rates may be slower than would be expected during an eradication operation as the cages in which they were held kept the baits off the ground which may reduce invertebrate and microbial breakdown. The elevation of baits off the ground also facilitates the drying of bait through air movement after rainfall events, which assists in maintaining bait integrity. This may explain why baits in the open test area seemed to exhibit slower rates of decomposition than those in the higher humidity medium and full canopy cover areas.

All planning of captive management of island endemics and holding periods for livestock will utilise the slowest decomposition rates for a given bait size in the current study. Given the observation of the delayed decomposition of caged baits utilising the slowest decomposition rates will provide a conservative and safe estimate of the point at which risk to livestock and endemics is eliminated.

While final figures for decomposition times (in excess of 55 days) will only be known after this report has been submitted, it would appear that from an environmental risk standpoint, the more rapid breakdown of the smaller 5.5 mm baits would enable shorter captive periods for island endemics, livestock and risks posed to island residents through the presence of the toxin in the environment.

Non-target impacts

The potential for impact on non-target species is a very important planning issue for rodent eradications. While brodifacoum has been widely shown to be effective in eradicating mice and rats (Howald et al. 2007), it can pose risks to non-target species, both through primary and secondary poisoning (Eason and Spurr 1995, Towns and Broome 2003). These non-target issues are particularly important when the at-risk species are threatened endemic species such as the case with the Lord Howe Island Woodhen *Gallirallus sylvestris,* and LHI Currawong *Strepera graculina crissalis*. While the impacts of invasive rodents on offshore islands are widely accepted (Towns et al. 2006), and have been the catalyst for many eradications globally (Howald et al. 2007), non-target issues must be taken into consideration and methods of mitigating risk be incorporated into eradication planning processes.

The iconic status of woodhens on LHI, and their probable vulnerability to both primary and secondary brodifacoum poisoning, given the succeptibility of the congeneric New Zealand weka, *Gallirallus australis*, (Eason and Spurr 1995), focuses attention during any planned rodent eradication on non-target issues. On Tawhitinui island in New Zealand the entire weka population was exterminated during a brodifacoum baiting for ship rats (Taylor 1984).

The observation of woodhens consuming non-toxic bait during the study, and producing faeces that fluoresced confirmed expectations for this species. While the techniques used in the non-toxic trial do not enable us to determine the quantity of bait consumed, given the threatened status of this species it is prudent to prepare mitigation measures. In New Zealand weka were captured prior to a rodent eradication on Kapiti Island and successfully housed in captivity until release after bait disintegration (Empson and Miskelly 1999). A similar solution is suggested for woodhens on LHI. In addition to woodhens, currawongs are also thought to be at high risk of exposure to brodifacoum. The current study examined seven currawongs and none showed signs of bait ingestion. Despite the lack of evidence of either primary or secondary exposure to bait, the potential risks posed to this threatened species during an eradication can not be ignored given the high probability of birds feeding on either dead or moribund brodifacoum poisoned rats and mice. Captive management of currawongs during any eradication operation is recommended.

Other bird species which showed signs of bait ingestion species during the study were blackbirds, mallards and buff banded rails. Both blackbird and mallard mortality resulting from brodifacoum poisoning have been recorded in New Zealand eradications (Dowding et al. 1999). None of these three species is threatened, nor are they endemic to LHI. It is not recommended that any measures be taken to mitigate impacts of toxins. Island endemics the LHI Golden Whistler, *Pachycephala pectoralis contempta*, and the LHI Silvereye, *Zosterops lateralis tephropleur* were both negative for bait uptake.

Several emerald ground doves were examined during the trial and despite the expectation that they would be vulnerable to ingestion of the bait, there was no evidence collected to support that view. An individual was also observed picking up bait, but soon dropped it and showed no further interest. Kingfishers, magpie lark and purple swamp hen also showed no evidence of bait uptake, although kingfishers may be vulnerable through secondary poisoning, and purple swamp hens are known to suffer significant (~50%) mortality during New Zealand rodent eradications (Dowding et al. 1999).

While no Masked Owls (*Tyto novaehollandiae*) were captured during the trial an opportunistic discovery of the remains of an owl kill indicated it had fed on a bird which had ingested bait. In cases where such prey species had fed on toxic baits predators are vulnerable to secondary poisoning. Work in New Zealand has shown that Moreporks (native owls), *Ninox novaeseelandiae,* have been killed during brodifacoum operations (Stephenson et al. 1999). The removal of rodents as a source of prey for Masked owls will result in them switching prey, possibly to endemic species, and it would be appropriate to undertake a cull or attempted eradication of the owl during any rodent eradication. In addition to avian non-target species, 21 large forest bats were examined and found negative for bait uptake. This species is potentially at risk from secondary poisoning from invertebrates it may consume.

Several invertebrates either fluoresced under UV light, or were observed feeding on the bait. While invertebrates are known to consume anticoagulant baits (Ogilvie *et al.* 1997, Spurr and Drew, 1999) they do not have the same blood clotting systems as vertebrates and are therefore thought to be at low risk of toxicosis from ingesting brodifacoum. Indeed a review of brodifacoum impacts on non-target species in New Zealand reported no mortality to invertebrate species as a result of brodifacoum baiting (Hoare and Hare 2006). More importantly brodifacoum residues of up to 7.47 µg/g have been recorded in NZ terrestrial invertebrates (Craddock, 2003). Residue levels take in excess of four weeks to return to background levels, and trace levels are detectable up to ten weeks following brodifacoum baiting operations, which potentially poses a risk to insectivorous bird species (Booth *et al.*, 2003; Craddock, 2003).

Notwithstanding the potential risk of secondary poisoning, the only reported case of insectivorous birds succumbing to brodifacoum poisoning was in a zoo, where several species died in an aviary after feeding on pavement ants and cockroaches that had eaten brodifacoum baits (Godfrey 1985).

While brodifacoum clearly impacts non-target species (Hoare and Hare 2006), short term losses of individuals are more than offset by population level benefits resulting from rodent eradication (Towns and Broome 2003).

Aerial baiting

Aerial broadcast by helicopter is becoming the most common method of rodenticide delivery (Towns & Broome 2003), and the current study provided valuable experience in planning and conducting an aerial baiting operation. The spreader bucket worked flawlessly, and we were able to establish the correct flight configuration: air speed and aperture ring size to produce the required flow rate of bait during operations. Methodologies for loading procedures, and determination of bait usage on flight runs were developed for use in future baiting operations.

Problems with the interface between office computers and the aircraft's onboard digital GPS system to allow the uploading of baiting areas and flight lines have been resolved since the trial and will be incorporated into all future operations.

The aerial baiting operation attracted considerable attention from island residents, and provided an opportunity to further discuss eradication plans with them.

Conclusions

While the primary function of the bait used in an eradication attempt is to remove rodents, its impacts on non-target species must be taken into consideration when planning an operation. Results on uptake of bait while equivocal, suggest that both are palatable to both species of rodents. Further testing of the two sized baits should be undertaken, with some modifications to experimental design to try to achieve 100% bait uptake. Assuming both bait sizes produce the required result relating to uptake, then what other factors should be considered when choosing the bait for an eradication?

Risk to non-target species can largely be mitigated in an operation on LHI by putting populations of high risk species (woodhens, currawongs and possibly *Placostylus* snails) into captivity to prevent them accessing baits, or consuming dead and dying poisoned rodents. However, captive management poses its own risks and periods of captivity should be kept to a minimum. The period of captivity will be determined by the length of time that uneaten baits remaining in the environment take to break down to a point at which they are no longer in a form that they may be ingested. Preliminary data on bait decomposition suggests that the smaller 5.5 mm baits decompose at a more rapid rate than the larger 10 mm baits, thus posing a risk for a shorter time period.

The success of the aerial baiting operation during this project confirms that this technique can be used to bait a significant proportion of the island outside of the settlement area during an eradication. Problems associated with uploading of bait areas during the project have subsequently been solved, and future aerial baiting will utilise accurate bait maps prepared prior to flying uploaded onto the aircraft's GPS system.

Work conducted during the project has provided valuable input to the planning of a future rodent eradication on LHI.

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Measuring uptake of non-toxic baits by ship rats (*Rattus rattus*) and house mice (*Mus musculus*): essential information for planning a rodent eradication programme on Lord Howe Island

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Summary

A non-toxic bait trial was conducted on Lord Howe Island (LHI) to inform preparations for a proposed eradication of ship rats *Rattus rattus* and house mice *Mus musculus* that are widespread on the island and have significant, adverse environmental impacts. The study examined the palatability of two sizes of bait to rodents, a critical input to project feasibility and planning.

Non-toxic baits were distributed across two study areas on LHI, each approximately 3 ha in size. Each area was dosed at a rate of approximately 10 kg/ha, one using 10 mm diameter pellets, the other using 5.5 mm pellets. Baits of both sizes contained a biomarker that fluoresced under ultraviolet (UV) light. Bait ingestion was confirmed by the presence of fluorescence in the gut of trapped rats and mice. Prior to baiting, each area was trapped for seven days, and captured rodents were ear marked and released. After baiting, rodents in the study areas were sampled using live traps and snap-traps. Rodents trapped after the baiting and which had previously been marked were assumed to be resident and thus would have had access to bait. All resident rats and mice captured after baiting had consumed bait.

Two of the 47 mice captured after baiting had not consumed bait. Both these animals were unmarked and both were caught at the end of the trapping period when bait had largely gone from the forest floor. It is likely that these individuals were transients and had not encountered baits. Three of the 43 rats captured after baiting had not consumed bait. All three were juveniles, had only recently emerged from the nest, and almost certainly had yet to encounter baits. Bait distribution during the proposed eradication would have placed all five of these individuals at risk from the poison, as bait would be distributed over the entire island on two separate occasions, each about 10 days apart.

Baits of both sizes (10 mm and 5.5 mm) were highly palatable to both rats and mice, and so their suitability for use in the proposed rodent eradication programme on LHI is now confirmed. However, given the advantages of large baits in aerial operations and the need for a higher encounter rate for mice in the settlement area on LHI, it is recommended that 10 mm baits be used for aerial operations and 5.5 mm baits for hand broadcast operations.

Introduction

In common with many oceanic islands, Lord Howe Island (LHI) has unique faunal and floral assemblages, with a high degree of endemism. The introductions of house mice *Mus musculus* in *c.*1860 and ship rats *Rattus rattus* in 1918 have had extensive adverse impacts on the natural flora and fauna of the island, and have disrupted numerous ecological processes (DECC 2007). Rats have been implicated in the decline and extinction of a number of bird, reptile and invertebrate species (DECC 2007). They also have significant impacts on the survival and reproductive processes of a number of plant species on the island. While the impacts of mice have not been intensively studied at LHI, evidence from other locations suggests that they are likely to be significant predators of invertebrates, the eggs of smaller birds and plant seeds (Towns *et al.* 2006).

The economy of LHI has long been dependent on the export of the endemic kentia palm *Howea forsteriana*. In recognition of the destructive impact that rats have on the seeds of this palm, attempts to control the rats commenced shortly after their arrival. These attempts, albeit using different methods, continue to the present day. Since 1986, the LHI Board (LHIB) has undertaken rat control at 33 sites on the island, primarily to protect the palm industry but more recently to also minimise their impact on a few select species of endemic flora and fauna. The total area of these 33 treated sites is approximately 140 ha, about 10% of the island. Mice are not controlled due to their resistance to the particular toxin (warfarin) used (LHIB 2009). The community also undertakes rat and mice control within the settlement area. While control may temporarily reduce rat numbers in selected areas, it does not eliminate the broader biodiversity impacts caused by either rats or mice.

Developments in eradication techniques during the past 20 years (Howald *et al*. 2007), in particular the use of aerial baiting methods, now make it feasible to eradicate both species of exotic rodent on LHI in a single operation (Saunders and Brown 2001). A single eradication operation is not only cost-effective it has the advantage of minimising disturbance to native wildlife and preventing any increase in the mouse population that may occur in the absence of rats. Achieving eradication of both species of exotic rodents, while minimising potential impacts on native species, requires detailed technical and logistical planning.

An essential prerequisite for any eradication is that all target individuals be put at risk by the methods employed. It is critical, therefore, to test the palatability of proposed baits to ensure that they are taken up by each target species. Observations from other eradications indicate that operations aimed at eradicating mice are less successful than those targeting rats. In some instances the failure to eradicate mice has been linked to inadequate bait encounter rates (Howald *et al.* 2007, MacKay *et al*. 2007). Bait encounter rates can be increased by either increasing the amount of bait distributed (kg/ha) or by reducing the size of the bait pellet. The smaller the pellet the more individual baits are broadcast for any given dose rate (kg/ha). In addition to assessing the palatability of the proposed bait formulation, it is important to assess whether the size of the bait is appropriate for the species targeted.

Previous studies, conducted on LHI investigated the longevity of bait in the environment and assessed the risks to non-target species from aerial baiting with baits laced with brodifacoum. Baits were found to persist for about 100 days and a number of bird species were found to be at risk, including woodhens, blackbirds, buff-banded rails and mallard ducks. This earlier work also examined the palatability of Pestoff 20R bait to rats and mice on LHI. Bait palatability was tested by aerially baiting large areas (23 and 34 ha) and then trapping animals to assess whether they had consumed bait. Baits were non-toxic and contained a biomarker that fluoresced under ultraviolet (UV) light. Bait ingestion was confirmed by the presence of fluorescence in the gut of trapped rats and mice. Although these earlier studies demonstrated that Pestoff 20R baits are palatable to both rats and mice on LHI, the effect of pellet size was not adequately resolved. The current study aims to confirm the palatability of the proposed bait type to both rats and mice on LHI, and examine any differences related to size of baits. This information will provide critical input into the planning of a rodent eradication on LHI.

Methods

Study site

Lord Howe Island (31°33'S, 159°05'E) is a crescent shaped, volcanic remnant on the Lord Howe Rise, approximately 600 km east of Port Macquarie, New South Wales. It is 1,455 ha in area with very rugged relief, rising to 875 m in the south on the summit of Mount Gower. The central lowland areas have been cleared for agriculture or settlement and are dissected by a network of 11 km of narrow roads. Patches of uncleared evergreen closed forest (Pickard 1983) adjoin grazing leases and urban settlement. The LHI Group was inscribed on the World Heritage List in 1982.

The study site was on the eastern side of Transit Hill in the vicinity of the Clear Place (Figure 1). Two baiting areas were established to test uptake of 5.5 mm baits (Area 1; 3.4 hectares) and 10 mm baits (Area 2; 3.2 hectares). A single trapping grid was established within each area. Each trapping grid (~60 x 60 m) consisted of 49 grid points spaced at approximately 10 m intervals. Trapping grids were at least 50 m from the edge of the baited area.

Live capture of rodents

Rodents were live trapped for seven nights prior to baiting. Two Elliott and two cage traps (containing leaf litter to provide bedding and concealment from predators) were placed at each grid point. Each trap was baited with a mixture of peanut butter and rolled oats. Traps were opened in the afternoon (commencing about 1600 h), checked soon after dawn (commencing about 0600 h) and then closed. Captured animals were transferred from traps to cloth bags to facilitate handling. All rats and mice were weighed to the nearest 2 g and then ear punched in either the left or right ear to identify the grid on which they were initially captured. They were then released. Any retrapped animals were recorded and released.

Baiting operation

Both areas were baited by hand on a single day. Approximately 10 kg/hectare of bait was distributed over each area. Baits were non-toxic Pestoff® 20R produced by Animal Control Products, Wanganui, New Zealand. The baits were cereal based, dyed green and contained the non-toxic biotracer pyranine 120, which, when exposed to ultraviolet light, fluoresces bright green. Both small (5.5 mm, ~0.5 g per pellet) and large (10 mm, ~2 g) baits were used to allow a comparison to be made as to which would be the most appropriate for the proposed two-species eradication. Baits were in all ways, other than presence of pyranine and the absence of a toxin, identical to those that would be used in an eradication operation. Small baits were spread in Area 1 and large baits in Area 2. A baiting rate of 10 kg/ha results in approximately one large bait every two square metres, while small baits give a density of approximately two per square metre (i.e. 4 times that of the large bait).

Post-baiting sampling of rodents

Both areas were trapped for seven days, with traps set on the evening of the day following bait application. Two snap traps and two Elliot traps at each grid point were baited with peanut butter and rolled oats, set and placed under cover to minimise the likelihood of capturing non-target species such as birds. All animals captured in live traps were euthanased using blunt trauma techniques in accordance with the Department of Environment, Climate Change and Water (DECCW) animal ethics guidelines. Captured animals were weighed to the nearest 2 g and checked for ear marking to determine if they had been captured during the live trapping undertaken prior to baiting.

All rodents captured were assessed for bait uptake by visual inspection under UV light for pyranine dye (green fluorescence) in their mouth, rectum and faeces. Any animals which showed no external signs of dye were dissected and examined internally. The proportion of previously marked (an indication of residency), and unmarked (assumed to be non-resident) rodents was determined. Separate analyses were conducted for each of the two grids.

Results

Live capture of rodents

A total of 53 mice and 34 rats were captured and marked during the seven nights of trapping prior to the baiting operation. Numbers of rats and mice in each trapping grid are shown in Table 1. Estimates of the density of rodents on each grid were calculated by dividing the total number of marked animals by the area of the grid on which they were captured (Table 1).

Unmarked mice were still being captured on both grids, and rats on grid 2 at the cessation of the live trapping period (Figs 2 & 3), indicating numbers marked represented less than the total number of animals on each grid.

Bait removal

While no formalised monitoring of bait removal was undertaken, baits had all but disappeared from both areas within 7 days (6 trap nights) of the baiting operation.

Bait uptake by rodents

After the bait drop, a total of 47 mice and 43 rats were caught over seven nights on the trapping grids. Five of 21 (24%) adult rats, none of 22 juvenile rats, 25 of 45 (56%) adult mice and neither of the two juvenile mice were ear marked, indicating they had not been captured prior to baiting. All marked animals were captured in the grid in which they were originally captured. Of the 53 mice marked on the grids before baiting, 25 (47%) were recaptured, compared to only 5 (15%) of the 34 rats.

Both adult rats (χ^2 = 16.0, df = 6, $P<0.05$) and mice (χ^2 = 36.1, df = 6, $P<0.01$) showed a significant departure from a constant capture rate through the trapping period (Fig 4). Mouse captures increased dramatically on day 6 and rat captures increased from day 4 onwards. In sharp contrast, there was a relatively constant capture rats of juvenile rats.

Adult rats weighed 197 ± 9 g (range 110–265 g, *n* = 21), juveniles 51 ± 5 g (range 21–79 g, *n* = 22), adult mice 20 ± 1 g (range 15–26 g, *n* = 45), and juvenile mice 14 ± 2 g (range 12–15 g, n = 2).

Uptake of small bait by both marked and unmarked individuals was 100% for rats and the single juvenile mouse. One of 28 adult mice did not consume baits, but this animal was not marked (Table 2). Uptake of large bait was 100% for both adult mice and rats, but lower in juveniles.

When results for adult and juvenile rats are combined there was no difference in the proportions of the population consuming either small or large baits (Fishers Exact test P=1). A similar finding is evident from the mouse data (Fishers Exact test P=1).

All marked animals that were captured after baiting had consumed baits (Table 3). Three unmarked rats and two unmarked mice captured in snap traps showed no sign of ingestion of baits. All three rats were juveniles ranging in mass from 21–23 g, and all three were caught in the same trap, two at the same time (Fig. 5). One mouse was juvenile caught on the 7th night of trapping, the other was an adult caught on the 6th trapping night.

Three blackbirds (*Turdus merula*) were live captured on Grid 1 on trap nights 3, 4 and 5. Inspection of the birds under UV light indicated that all had passed faecal material containing pyranine. Characteristic markings on each of these birds indicated that they were three different individuals.

Discussion

The goal of the non-toxic bait trial was to determine if 100% of rats and mice would consume the non-toxic baits, and to determine if there were any differences between uptake of differing sized baits to inform decisions of bait choice in an eradication on LHI.

The reason for conducting trapping prior to baiting was to provide a pool of marked individuals that were known to be present before bait was distributed. If these individuals were recaptured on the same grid after the baiting it could be reasonably assumed that these individuals had been exposed to the bait. The high rate of residency found in the current study is consistent with previous findings from LHI. Billing (1999) found that 70% of rats were recaptured within 40 m of the initial capture site, and mean distance moved was approximately 45 m, with a maximum of 450 m. Elsewhere, mice have been shown to have average movements as low as 6 m (Goldwater 2008), although they have been recorded moving up to 90 m (Wanless *et al*. 2008). Based on these collective observations, it is likely that most animals captured in the grid were 'resident' at the time of the baiting and thus exposed to the bait, however the potential exists for movements of individuals into the area.

Both mice that had not consumed bait were non-residents (unmarked) and captured at the end of the trapping period (nights 6 and 7) when there was little bait remaining on the forest floor. Thus, it is likely that these individuals came from outside the baited area, and had not encountered baits. This scenario would not occur during an eradication operation when bait would be present across the entire island. A previous study (Wilkinson unpublished data) showed similar findings: that the proportion of mice consuming bait declined after the 6th day post baiting, in association with a decline in availability of bait on the forest floor.

All three rats that had not consumed bait were juveniles and were caught at the same trap at the same location. Given their size (21–23 g) and the fact that two individuals were captured in the same snap trap (see Figure 5) it is probable that all these animals had recently emerged from a nest (a hole was situated within centimetres of the trap) and had not yet had the opportunity to encounter baits. Again, this scenario would not occur during an eradication operation because any juvenile rats that emerged from the nest would be exposed to bait delivered in second bait drop.

The immediate kill of all individuals may not be necessary to achieve eradication. Courchamp *et al.* (1999) noted that populations occurring at extremely low densities can sometimes become extinct through the 'Allee Effect'. This occurs when not all target animals are killed, but survivors are few and separated by distances sufficient to prevent them meeting and breeding. Notwithstanding, a central tenant in planning the eradication of exotic rodents on LHI (LHIB 2009) has been to ensure that each and every rat and mouse is exposed to sufficient toxic bait to ensure it succumbs to the poison.

The ability to capture rats and mice in traps after baiting occurred indicates that both species will consume food other than baits, if alternative food is available. However, increases in captures for rats from day 4 and mice from day 6 suggests that prior to this time they were preferentially taking baits, and ignoring the peanut butter in the baited traps. It seems that as baits disappeared on the forest floor, they were more likely to seek alternatives, resulting in the observed captures. Importantly, all rats and mice captured early in the trapping period (prior to the increase in capture rates) tested 100% positive for bait uptake.

In the context of an eradication operation, each mouse would need to consume only 80% of a single small bait or 20% of a large bait to get a lethal dose of toxin (based on a lethal dose of brodifacoum of 0.4 mg/kg; Eason and

Wickstrom 2001). Each rat would need to consume 2.5 large baits or 9 small baits to ingest a lethal dose (0.46 mg/kg, O'Connor and Booth 2001). These quantities represent approximately 2% of the body weight of the two species, which is a fraction of the daily consumption estimates of 10% of body weight for rats (mass ~200 g) and 10–20% for mice (mass ~20 g, Billings 2000).

This study confirms that, provided bait is available at sufficient density, both mice and rats will ingest it. At a dose rate of 12 kg/ha (the proposed baiting rate on the first drop during an eradication on LHI, LHIB 2009) there will be 24,000 small baits or 6,000 large baits available per hectare. In the current study densities of rats ranged from 31–64 per hectare, and mice from 67–81 per hectare. Densities in a previous trial ranged from 35–74 for rats and 74–100 for mice (Wilkinson unpublished data). At the highest densities recorded (74 rats 100 and mice per hectare), each rodent would have access to numerous baits containing many times the lethal dose.

The rapid disappearance of baits, together with the low capture rates of rats and mice immediately after baiting, suggests that rodents may have cached pellets in the first few days after the bait drop. These animals were not active on the grid until several days later when less bait was available and these animals were again searching for alternative food. Caching of baits increases the probability that, during a toxic bait drop, rodents would succumb to toxicosis underground, and thus not pose a secondary poisoning threat to species that may potentially prey upon them.

The lower proportion of marked rats (compared to mice) caught immediately after baiting is possibly because rats exhibit a greater tendency for trap shyness after initial capture than do mice. Alternatively, rats may have a stronger preference for cereal baits to the exclusion of other food sources. This behaviour may potentially explain why eradications targeting rats have been more successful than those targeting mice (Howald *et al.* 2007).

There were no differences in bait uptake among rats and mice based on bait size. This finding has important implications for planning the eradication of rodents on LHI. Typically, 10 mm (or larger) diameter bait pellets are used for eradications targeting rats (Broome 2009), but the most appropriate size bait to target mice is less certain. Mice typically have smaller home ranges than rats and are less likely to be exposed to bait when it is broadcast relatively sparsely (Goldwater 2008). This is thought to have been the reason for some mice eradications failing (Howald *et al*. 2007). For operations involving bait stations, a solution is to put the stations as close as 10 m apart. For aerial operations, a possible solution is to use smaller bait that provides a greater number of pellets per unit area. On average, each 5.5 mm bait pellet weighs approximately half a gram, and each 10 mm pellet weighs approximately two grams. Therefore, when smaller bait pellets are applied at the same number of kilograms per hectare, there is four times the number of pellets on the ground compared to when 10 mm baits are used. This provides a greater number of pellets per unit area and increases the chances of mice encountering bait, thus improving the chances of all individuals having access to bait. The recent successful eradication of mice on Montague Island, NSW, also demonstrated that both bait sizes are capable of eradicating mice (LHIB 2009).

The reasoned explanations for the lack of bait uptake by 3 juvenile rats and 2 mice in this study offered above, allow an assumption of full bait uptake by both rats and mice for both bait sizes. These data are critical to the successful planning of an eradication on LHI, and every contingency will be considered in planning to ensure that each and every rat and mouse is exposed to sufficient toxic bait to ensure the success of the operation. Notwithstanding the prerequisite for 100% uptake by target animals of any toxin used in an eradication, a 100% kill is not necessarily required to achieve a positive outcome. Courchamp *et al.* (1999) noted that populations occurring at extremely low densities can become extinct through the Allee Effect: ie. the probability of encountering potential mates is too low. In any eradication attempt it is possible that if all rodents are not killed, then eradication may still be achieved as long as survivors are few and separated by distances sufficient to prevent them meeting and breeding.

It is anticipated that the most difficult component of the proposed eradication of exotic rodents on LHI will be removing mice from the settlement area, where alternative foods may be more readily available. Accordingly, a high encounter rate (i.e. smaller bait) may be preferable. On the other hand, there are practical advantages of using 10 mm baits over 5.5 mm baits for aerial operations. These include (i) 10 mm baits have been used successfully in aerial sowing buckets in large quantities, (ii) the pilot can see baits as they are being spread which can be an advantage when distributing baits next to exclusion zones or sensitive boundaries, and (ii) it is feasible to retrieve baits accidentally over-sown into exclusion zones during aerial baiting operations. Considering the advantages and disadvantages of each bait size, it is proposed that 10 mm baits be used for all aerial operations on LHI, and 5.5 mm baits for all hand-baiting operations. While the use of two bait sizes adds complexity to the operation, it is justified by the benefits associated with each.

Ingestion of bait by blackbirds in the current study is consistent with other eradication operations (Dowding *et al.* 1999), and indicates that numbers of this introduced species are likely to drop during an operation to eradicate rodents on LHI. The impact on exotic blackbirds is of no concern from a conservation perspective, but their loss highlights the potential risks to non-target species that can occur through both primary and secondary poisoning (Eason and Spurr 1995, Towns and Broome 2003). Previous research has identified that the endemic species most at-risk on LHI are the Lord Howe woodhen *Gallirallus sylvestris* and Lord Howe currawong *Strepera graculina crissalis*. The proposed eradication operation incorporates significant mitigation measures to ensure that these and other non-target species are not adversely affected (LHIB 2009).

Conclusions

Both small (5.5 mm) and large (10 mm) baits were shown to be palatable to rats and mice. Consequently, either baits would be appropriate for use in an eradication operation on LHI. Each bait size has its advantages and disadvantages, and each is best suited to different aspects of the operation.

Large baits are recommended for aerial operations, and small baits for hand broadcasting where it is critical to increase bait encounter rates for mice.

Acknowledgements

This study forms part of the planning phase of the LHI rodent eradication programme. The Australian Government provided funding for the work through a Caring for our Country programme grant to the LHI Board (LHIB). Additional funding and support was provided by the LHIB and the NSW Department of Environment, Climate Change and Water (DECCW). The study was conducted under National Parks and Wildlife Service (NSW) Scientific Licence S12340, and Department of Environment and Climate Change (NSW) Animal Ethics Committee research licence 070618/03

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Table 1. Numbers of trapping days, trap nights, area of trapping grid, numbers of rats and mice caught and marked, and estimates of the density of each species.

Grid	Days grid trapped	Trap nights	Area of grid (ha)	Mice marked	Mice/ha	Rats marked	Rats/ha
1	7	1372	0.36	29	80.6	11	30.6
2	7	1372	0.36	24	66.7	23	63.9
Totals		2744		53		34	

Table 2. Estimates of rates of uptake of small and large non-toxic baits, as indicated by pyranine fluorescence.

Species	Consume small bait (Grid 1)		% Positive	Consume large bait (Grid 2)		% Positive
	No	Yes		No	Yes	
Mouse - adult	1	27	96.4	0	17	100.0
Mouse - Juvenile	0	1	100.0	1	0	0.0
Rat – Adult	0	4	100.0	0	17	100.0
Rat - Juvenile	0	5	100.0	3	14	82.4

Table 3. Estimates of rates of uptake by marked rodents of small and large non-toxic baits, as indicated by pyranine fluorescence.

Species	Consume small bait		% Positive	Consume large bait		% Positive
	No	Yes		No	Yes	
Mouse	0	16	100.0	0	9	100.0
Rat	0	0	0.0	0	5	100.0

Captions for figures

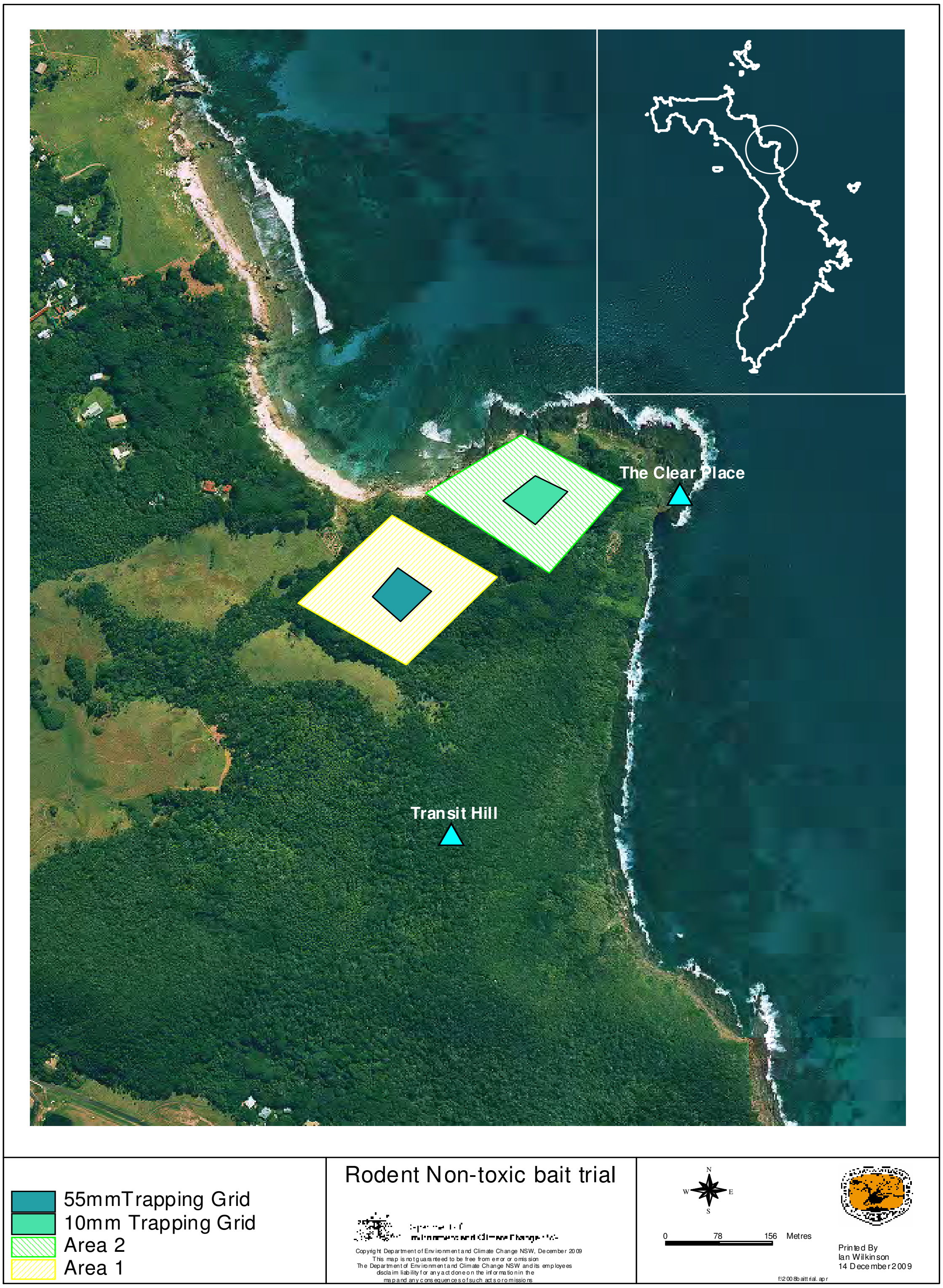
Figure 1: Map of Lord Howe Island showing the locations of baiting areas and trapping grids for the non-toxic bait trial at the Clear Place.

Figure 2. Cumulative numbers of mice marked on trapping grids prior to baiting.

Figure 3. Cumulative numbers of rats marked on trapping grids prior to baiting.

Figure 4.. Daily cumulative captures of adult and juvenile rats and mice.

Figure 5. Juvenile rats captured in the same snap trap.



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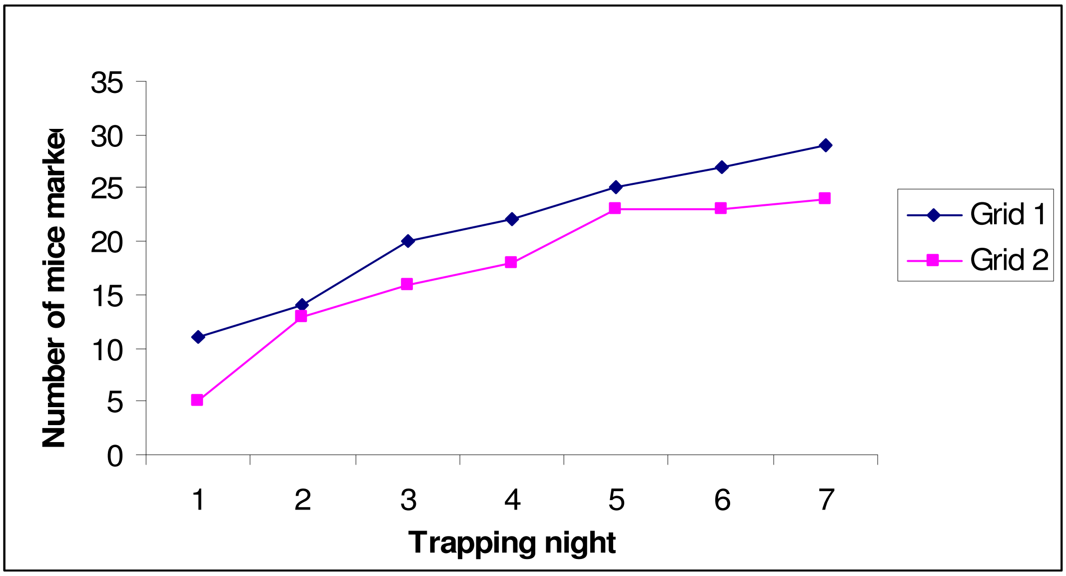

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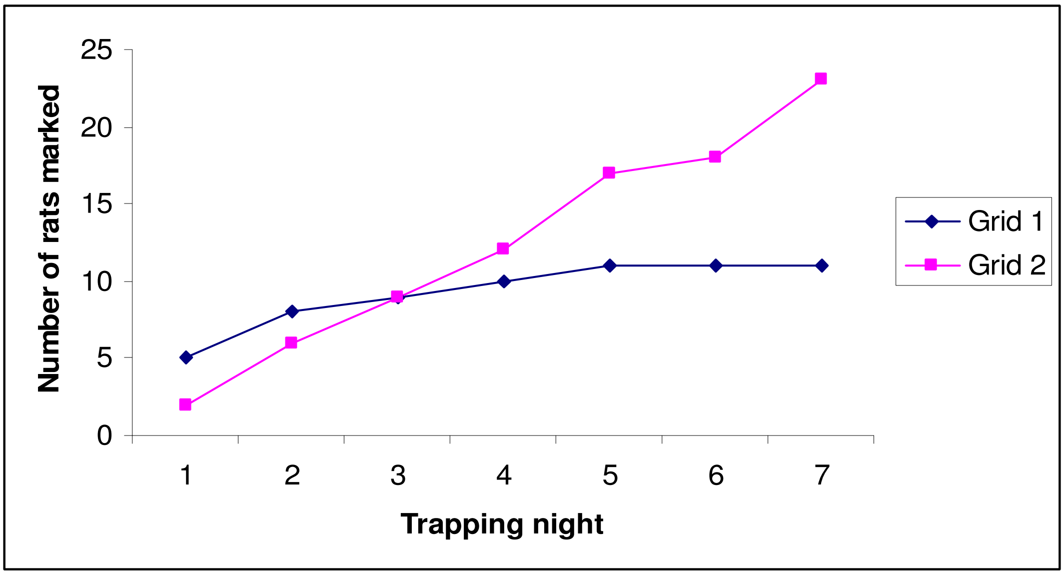

Figure 3. Cumulative numbers of rats marked on trapping grids prior to baiting.

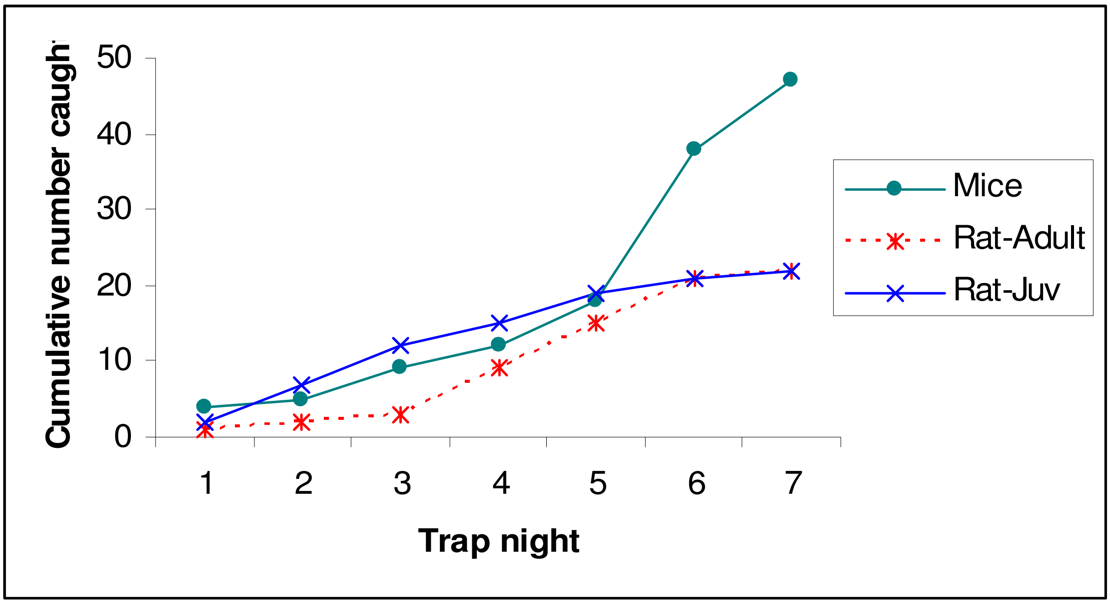

Figure 4. Cumulative captures of adult and juvenile rats and mice.

Figure 5. Juvenile rats captured in the same snap trap.

Assessing the risk of Pestoff® 20R brodifacoum baits to the Lord Howe Island flax snail (*Placostylus bivaricosus)*

Dr Ian Wilkinson and Ian Hutton 2013

Introduction

The Lord Howe Island flax snail (*Placostylus bivaricosus*) is endemic to Lord Howe Island (LHI), and listed as endangered on both the NSW *Threatened Species Conservation* (TSC) Act 1995 and the Australian Government's *Environment Protection and Biodiversity Conservation* (EPBC) Act 1999. Ship rats (*Rattus rattus*) are recognized under both state and federal legislation as a key threat to *Placostylus on* LHI (DECC 2007, LHIB 2009).

The planned eradication of exotic rodents—ship rats and house mice (*Mus musculus*)—on LHI is considered a critical action to mitigate negative impacts on both *Placostylus* and the island's biodiversity as a whole (DECC 2007). While eradication will eliminate the threat of rodent predation to the *Placostylus* population, there are potential risks associated with the use of toxins to achieve the eradication (Booth *et al.* 2003).

Brodifacoum, the toxin proposed for use in the eradication, is a second generation anticoagulant. Brodifacoum, like other anticoagulant toxicants, acts by interfering with the normal synthesis of vitamin K-dependent clotting factors in the liver of vertebrates (Hadler & Shadbolt 1975). This results in an increase in blood clotting time until the point where no clotting occurs, resulting in haemorrhaging and death. While brodifacoum is thought to lack insecticidal properties because invertebrates do not possess the same blood-clotting systems as vertebrates (Shirer 1992), several studies have been conducted to examine its impacts on invertebrates (see Booth *et al.* 2001).

Captive studies with large-headed tree-weta (*Hemidenina crassidens*) and Ascension Island land-crab (*Gecarcinus lagostoma*) indicate that neither of these species are particularly susceptible to brodifacoum, with no brodifacoum residues being detected in weta four days after sub-lethal exposure and in land crabs one month after sub-lethal exposure. Arthropods exposed to brodifacoum during captive trials were unaffected (Booth *et al.* 2001), and earthworms only showed toxic effects at extreme doses (Booth *et al.* 2003), several orders of magnitude higher than would occur during an eradication. Field evaluations following aerial application of brodifacoum at a number of sites in New Zealand indicate that few insect species are at risk of primary poisoning, and no deleterious effects on arthropod populations have been detected (Spurr and Drew 1999, Booth *et al.* 2001).

There is however, some indication that molluscs may be susceptible to brodifacoum poisoning. Gerlach & Florens (2000) reported 100% mortality of two Seychelles Islands snail species (*Achatina fulica* and *Pachnodus silhouettanus,* a common species used as a model for the threatened *P. fregatensis*) that had consumed brodifacoum bait in a laboratory trial. They also suggested that brodifacoum poisoning may have contributed to observations of significantly higher numbers of recently dead *Pachystyla bicolor*, lower numbers of live adult *P. bicolor*, and shells of the critically endangered *Erepta stylodon* at Mauritian field sites subject to rodent baiting.

Given the conservation status of *Placostylus* on LHI, it is important to assess the risk posed to this species by the widespread distribution of brodifacoum baits to eradicate rodents. This study investigated whether *Placostylus* snails fed on baits, and if toxic baits were consumed, whether ingestion resulted in mortality.

Methods

Snails were collected from the property Arajilla on LHI and held in captivity for seven days to acclimate to conditions before commencement of experimental protocols.

Animals were held in 9-litre plastic containers (300 x 200 x 150 mm) with small holes in the bottom to drain excess water. Each container had a 30 mm deep layer of gravel placed at the bottom, covered by a 50 mm layer of calcareous sand. A top layer of leaf litter comprised of Banyan (*Ficus columnaris*), Cottonwood (*Celtis conferta*) and Sallywood (*Lagunaria Patersonia*), both fresh and dead, was added as a source of natural food. Small shallow dishes to hold water were placed in the sand layer as per farming protocols developed for a congeneric in New Caledonia (Brescia *et al.* 2008).

The whole tank was sprayed with water, and any free water drained from the bottom of the tank. The gravel layer enabled sand to remain moist, but not waterlogged, permitting animals to burrow into it. Leaf litter was kept moist by spraying every second day, and high humidity maintained by covering the tank with damp hessian. High humidity was maintained in the tanks by placing both ends of the Hessian in water-filled containers, thereby keeping the hessian damp.

Animals were exposed to two experimental protocols. The first, using non-toxic baits, involved a choice-based feeding trial to ascertain if snails fed on the baits. The second, using toxic baits, aimed to determine if *Placostylus* were killed by the toxin.

Non-toxic bait uptake trial

Two groups of 5 snails were exposed to 10 g of intact Pestoff® 20R non-toxic baits placed in the tank along with the natural food described above. The remaining two groups of 5 animals were exposed to 10 g of crushed baits to simulate a later stage of bait disintegration. The baits used contained the biomarker pyranine, which fluoresces under ultraviolet light. Baits were placed in tanks along with natural food providing a choice for the snails in the tank.

Snails were left for seven days and daily checks of each tank were made to locate their faeces. These samples were then scanned with UV light to confirm whether or not pyranine was present, thus indicating whether animals had or had not ingested baits. Results were recorded as presence or absence of fluorescing faecal samples over the period the trial.

Toxic bait trials

Four tanks were used in the experiment, and all natural food was removed prior to the commencement of the trial.

In the first tank, 10 g of intact Pestoff® 20R baits containing brodifacoum at a concentration of 20 mg/kg was added. In the second treatment, 10 g of crushed toxic bait was placed in the tank. Two additional tanks were set up using non-toxic baits containing pyranine, one with intact baits and one with crushed baits. Five snails were placed in each of the four tanks. All tanks were then monitored for 30 days to observe if any mortalities occurred. Faecal material in the tanks containing non-toxic baits, were examined to assess whether or not snails had ingested baits.

Return of captured animals to the wild

All *Placostylus* exposed to non-toxic baits were returned to the site from which they were captured at the completion of the experiment.

Results

Four groups of snails (n=5) that were fed non-toxic baits both intact and crushed produced no fluorescing faecal samples (Table 1), and there was no mortality associated with the treatment over 7 days.

Table 1. Results of non-toxic bait uptake trial

Tank	Number of individuals	Toxic/Non-toxic baits	Intact/crushed baits	Fluorescent faecal sample	Ingested baits	Mortality recorded
1	5	Non-toxic	Intact	No	No	No
2	5	Non-toxic	Intact	No	No	No
3	5	Non-toxic	Crushed	No	No	No
4	5	Non-toxic	Crushed	No	No	No

Placostylus exposed to toxic baits over a period of 30 days suffered no mortality associated with the treatment. Those animals exposed to non-toxic baits (either intact or crushed) produced fluorescing faecal samples confirming ingestion of baits, but there was no mortality associated with the ingestion of non-toxic or toxic baits (see Table 2).

Table 2. Toxic bait uptake trial

Tank	Number of individuals	Toxic/non toxic	Intact/crushed baits	Fluorescent faecal sample	Ingested baits	Mortality recorded
1	4	Toxic	Intact	No	?	No
2	5	Non-toxic	Intact	Yes	Yes	No
3	5	Toxic	Crushed	No	?	No
4	5	Non-toxic	Crushed	Yes	Yes	No

Discussion

The eradication of rats and mice from LHI is an important management measure to prevent ongoing environmental damage, and further erosion of the Island's World Heritage values. However, it is critical that such an operation does not endanger populations of any of the Island's endemic species (DECC 2007, LHIB 2009).

This research was directed at the collection of data that could inform a risk assessment dealing with the impact of the proposed eradication on the *Placostylus* population. Any risk assessment considers both the likelihood of occurrence and the consequence of occurrence, with their product providing a measure of overall risk (LHIB 2009). Consequences of risk are measured on a 5-point scale from insignificant to catastrophic. Similarly, likelihood is measured on a 5-point scale ranging from very unlikely to almost certain.

The lack of pyranine fluorescing faeces in the non-toxic food choice test suggests that when presented with a choice, as would occur in an eradication where poison baits would be distributed on the forest floor among the leaf litter *Placostylus* prefer their natural diet. This finding is significant as it indicates that the potential for a significant proportion of the population to ingest toxic pellets would be extremely low. Thus, whatever the result of brodifacoum ingestion, the overall impact on the population is likely to be low, as it would only involve a small proportion of the threatened population. Non-toxic bait trials conducted in 2007 on LHI to examine uptake of baits by the two rodent species showed that some snails (not *Placostylus*) and slugs would feed on bait pellets (Wilkinson unpubl. data).

The second finding from this study—that no mortality occurred after bait consumption—indicates that the *consequences* of the eradication operation would be insignificant to minor. Consequently the overall risk posed by the operation to *Placostylus* is minimal. This is an important finding that is in sharp contrast to that found by Gerlach and Florens (2000). While Gerlach and Florens (2000) noted the mortality of both *Pachnodus silhouettanus* and *Achatina fulica* snails in laboratory trials, they failed to explore whether these species would feed on baits if given the choice between baits and their natural diet. In risk assessment terms, while consequences may be at the high end, there is no information regarding the likelihood of them consuming baits. Therefore, there is no ability to adequately assess the overall risk posed by such a bating operation.

An eight-year research project on the congeneric *Placostylus ambagiosus* in northern New Zealand showed that pulse baiting four times a year to control rodents (Sherley *et al.* 1998) resulted in increased adult recruitment which was attributed to the reduction in predation pressure by rodents. The potential impacts of the toxin on snails was not considered in this study, but the clear increases in population indicate that any impacts the toxin may have had were more than offset by the benefits that accrued due to the removal of predation pressure. This finding, in conjunction with the lack of bait ingestion and mortality seen in the current study, provide a basis for assessing risks posed to four recently listed snail species on LHI.

The critically endangered land snails: Masters' charopid land snail (*Mystivagor mastersi),* Mount Lidgbird charopid land snail (*Pseudocharopa lidgbirdi*), Whitelegge's land snail (*Pseudocharopa whiteleggei*) and an unnamed land snail (*Gudeoconcha sophiae magnifica*) are all highly threatened by rat predation (LHIB 2009) and it is likely that if rats are not removed these species may become extinct; indeed some may already be extinct. The extreme rarity of these species precludes any testing of their susceptibility to brodifacoum. However, given the findings of this study, the threats for these species associated with not removing rodents likely exceed the potential risk associated with a rodent eradication operation.

This study has found that there is negligible risk posed to *Placostylus bivaricosus* by the eradication operation proposed for rodents. Notwithstanding, given the endemicity of *Placostylus bivaricosus* and its threatened status under both NSW and Australian Government environmental legislation, it would be prudent to hold a captive population until bait breakdown in the environment is complete. This recommendation is consistent with that for other endemic species including the LHI silvereye (*Zosterops lateralis tephropleura)* and LHI golden whistler (*Pachycephala pectoralis contempta*). Although the eradication operation poses no obvious threat to these species, it would be prudent to hold a small captive population on the island during the operation (LHIB 2009).

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Testing for brodifacoum resistance in invasive rodents on Lord Howe Island:

Summary of Work Undertaken by the Office of Environment and Heritage in 2013

Prepared for

The Lord Howe Island Board

By

Robert Wheeler and Nicholas Carlile

New South Wales Office of Environment and Heritage

Introduction

The arrival of Ship Rats (*Rattus rattus*) and House Mice (*Mus musculus*) to Lord Howe Island (LHI) has resulted in significant changes to the Island's ecosystem, including the loss of several bird species (Hindwood 1940, Recher & Clark 1974), and impacts on reptiles, invertebrates and plants (Cogger 1971, Recher & Clark 1974, Hutton 2001, Priddel *et al*. 2003).

The Lord Howe Island Board (LHIB) has undertaken a concerted rat-control programme since 1986 to primarily protect the island's Kentia Palm industry (Harden and Leary 1992). In 2001 the LHIB contracted the Endangered Species Recovery Council to investigate the feasibility of eradicating rodents from LHI. The report on the investigation suggested that despite the difficulty, eradication was feasible (Saunders & Brown 2001).

Successful eradication is contingent on 1) 100% of target animals being exposed to a poison and 2) all of them being susceptible to that poison. Baits containing the anti-coagulant brodifacoum have been successful in eradicating introduced rodents from many of the world's islands (Howald *et al*. 2007). The bait used for rodent eradication in New Zealand, Western Australia and on Macquarie Island has been the Pestoff 20R cereal bait containing brodifacoum at a nominal concentration of 20 parts per million. Trials in 2007 and 2008 determined that the rodent populations on Lord Howe Island will readily consume non-toxic Pestoff 20R cereal baits (Wilkinson *et al*. 2008). However, as rodenticides containing brodifacoum have been used for more than a decade by residents and the Lord Howe Island Board, there is potential for rodents on Lord Howe Island to have developed a tolerance to this poison. Any such tolerance could undermine an eradication. Consequently it is important to establish if rodents are susceptible to the proposed poison (brodifacoum) to be used in the operation. To this end a captive-feeding trial using Pestoff 20R baits was conducted on LHI in 2013 to assess the likelihood of resistance in the mouse and rat populations located in the settlement or at the waste-treatment works. Rodents around human habitation were seen as having the most potential to be tolerant to brodifacoum. Full details of this trial are given in Appendix 1 which is an unpublished manuscript (and therefore not for general circulation) written by David Priddel, Robert Wheeler, Nicholas Carlile and Ian Wilkinson.

Testing the Susceptibility of LHI Rodents to Brodifacoum

The feeding trial involved offering rodents various concentrations of brodifacoum expressed as multiples of the known lethal dose required to kill 50% (i.e., the LD_{50}) of a typical population of a specific rodent. The trial was divided into two parts for the test animals, with each part having five treatments. For mice in the first part of the trial, four groups were, respectively, offered pellets containing the equivalent of 1 LD_{50}, 2 LD_{50}, 3 LD_{50}, and 5 LD_{50}, of brodifacoum. Black Rats were also offered one of four poison diets in the first part of the trial, but in this case the LD_{50} equivalent was that for the Brown Rat, which is less than that for the Black Rat, the goal here being to determine if a relatively low dose of brodifacoum would still be effective in killing this species. For both the mice and rats, a fifth group served as a control to monitor the potential for subject rodents to die from other causes (e.g., such as being held in prolonged captivity). There were 10 rats and 10 mice in each initial treatment. Survivors from this first part of the trial were then fed an additional amount of brodifacoum equivalent to 10 LD_{50}.

The results indicated that the susceptibility of rats to brodifacoum was in line with that for the species as a whole. That is, judging by the results of this trial, all the rats on LHI are susceptible to low levels of brodifacoum. Based on an observed LD_{50} of 0.54 mg kg^{-1}, an average body weight of 196 g and a brodifacoum concentration in bait of 18.2 ppm (as determined by chemical assay of the Pestoff bait used in this feeding trial), the average rat on Lord Howe Island (in terms of both size and susceptibility) would need to consume 5.8 g of bait to ingest a lethal dose. The dosage needed to kill all rats on Lord Howe Island (LD_{100}), as determined in the feeding trial, is 0.81 mg kg^{-1}. Based on an observed LD_{100} of 0.81 mg kg^{-1} and a maximum body weight of 275 g (this feeding trial), the largest and least susceptible rat on Lord Howe Island would need to consume 12.2 g of bait to ingest a lethal dose. An adult rat will typically eat 25–30 g of food per day, taken in about ten small meals, with the maximum consumption per meal of around 3 g. Thus all rats on Lord Howe Island could consume a lethal dose in one day, but may require four or five meals to do so.

However, mice exhibited a tolerance to brodifacoum significantly in excess to the LD_{50} of 0.4 mg kg^{-1} prescribed for mice. Ingestion of brodifacoum at dose rates 1 and 2 LD_{50} by mice on the trial resulted in no mortality. A dose rate of 3 LD_{50} resulted in 10% mortality, and 5 LD_{50} resulted in 60% mortality. After 14 days, survivors from all dosage groups were weighed and fed additional bait containing a further 10 LD_{50}. Mortality for these treatments ranged from 67% to 100%, but mice consuming dosages equivalent to 12 LD_{50} (two individuals) and 13 LD_{50} (three individuals) survived despite consuming at least 4.8 mg kg^{-1} of brodifacoum. These survivors were still alive after 23 days (five days longer than any animal that died) and all appeared healthy, with no signs of bleeding or lethargy. These survivors did not originate from any particular location, but were captured in locations throughout the settlement including the nursery and waste management facility. These individuals were euthanized at the conclusion of the study, a condition of the Animal Ethics approval. The survival of these individuals demonstrated that some mice have developed a high level of tolerance to brodifacoum, but it is not firm evidence of complete resistance as it is possible that these individuals would have succumbed to higher doses of brodifacoum. In a similar study involving mice on Gough Island, two individuals (approximately 1% of those tested) survived after apparently ingesting doses of brodifacoum estimated to be 5 and 10 times the oral LD_{50} for the population, but subsequent exposure at higher doses resulted in mortality (Cuthbert *et al.* 2011). On Lord Howe Island, 28 mice that survived low doses of brodifacoum, died after subsequent feeding with the same toxic bait. Importantly, no mouse exhibited any inhibition to consume additional bait following its initial exposure to brodifacoum.

From the observations above, the observed LD_{50} for mice on Lord Howe Island was approximately five times the standard LD_{50} for mice, with some individuals showing a high level of tolerance, up to at least 13 LD_{50} (5.2 mg kg^{-1}). Although the LD_{50} for mice (0.4 mg kg^{-1}) was that reported for laboratory mice, similar values have been obtained for wild populations (0.52 mg kg^{-1}, O'Connor and Booth (2001); 0.44 mg kg^{-1}, Cuthbert *et al.* (2011)). The unusually high LD_{50} for mice on Lord Howe Island indicates that this population exhibits increased tolerance to brodifacoum. Based on an observed LD_{50} of 2.0 mg kg^{-1}, an average body weight of 16.5 g and a brodifacoum concentration of 18.2 ppm (this study), the average mouse on Lord Howe Island (in terms of both size and susceptibility) would need to consume 1.8 g of bait to ingest a lethal dose. Mice typically consume approximately 3 g of food per day, in many small meals of up to 0.2 g (Morriss *et al.* 2008; Wade 2011). Thus, the typical mouse on Lord Howe Island could consume a lethal dose in one day, requiring up to nine meals to do so. However, the dosage needed to kill all mice on Lord Howe Island (LD_{100}) is at least 15 LD_{50}. Based on an observed LD_{100} of 6.0 mg kg^{-1} and a maximum body weight of 22 g (this study), the largest and least susceptible mouse on Lord Howe Island would need to consume at least 7.3 g of bait to ingest a lethal dose. This would take at least 37 meals or 3 days to complete, longer if alternative food was also eaten.

In August 2008, non-toxic Pestoff® 20R baits distributed at a density of 10 kg ha^{-1} within the palm forest on Lord Howe Island remained available above ground for at least seven days (Wilkinson *et al.* 2008). In these circumstances, bait would be available long enough for mice to find and consume a lethal quantity of bait following a single application. However, in sites with a high density of non-target consumers of bait (e.g. ducks and rails) bait may disappear much faster. In these situations, higher dose rates or multiple bait applications may be needed to increase the likelihood of mice receiving a lethal dose.

Efficacy of Brodifacoum in Eradicating Mice from LHI

Mice on LHI, at least those associated with the human environment, are less susceptible to brodifacoum than mice in other parts of the world. Although tolerance to the poison in a proportion of those mice used in the feeding trial was high, this, in itself, does not mean that some mice will survive baiting LHI with brodifacoum. However, it is crucial that further feeding trials are conducted before the eradication programme is undertaken. Not only should mice distant from human habitation be tested to determine how widespread this tolerance may be, but further tests should be conducted on mice from the settlement to gauge what is the minimum exposure to brodifacoum required to kill all mice. The feeding trial conducted in 2013 produced 100% mortality in those mice fed the equivalent of 15 LD_{50} but the sample size was small, too small to assume that the most tolerant mouse on LHI will succumb to such a dose.

Rats on LHI are susceptible to relatively small doses of brodifacoum, so it is likely that this species will be eradicated if all rats encounter baits. However, this is not necessarily so for mice. If rats are eliminated but not mice then there is likely to be:

- Increased seabird, and possibly land bird, numbers; e.g. Grey Ternlet and Little Shearwater. Note landbirds would no longer have the same predation pressure but will still have competition for food from mice. As mouse numbers are likely to significantly increase without rat predation, possibly decreasing the amount of food available for birds, the actual benefit is unknown.
- Likely recolonisation of the island by the Kermadec Petrel.
- Allow consideration of introducing closely related surrogate species to replace those driven to extinction by rats and or humans.
- Possibly some increase in recruitment by some tree species. Trials are currently being carried out to try to quantify this although removing rats will alter the dynamic with mice allowing them to potentially have a greater impact.
- Probable increase in the number of arboreal invertebrate species as mice seldom venture higher than one metre up into vegetation, therefore the successful re-introduction of the LHI Phasmid is feasible.
- Little if any change in most terrestrial invertebrate numbers as ground-dwelling invertebrates will still be vulnerable to rodent predation.
- Little change in recruitment by most plant species.
- Need for ongoing mouse control around the settlement and possibly key ecological sites.
- Likely increase in mouse numbers due to the absence of rat predation on mice. The relative impact of this is likely to increase as poison tolerance in mice increases.
- Some members in the community will see the whole project as a failure as the promoted social gains will be significantly reduced.
- Reduced community support for the required ongoing biosecurity systems.
- Unlikely to get political or social support for a mouse eradication in the foreseeable future (assuming any such eradication using a non anti-

coagulant poison would be possible, or any such eradication proposal would not elicit the same level of opposition as the current one).

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Recommendations

- A similar feeding trial to the one undertaken in 2013 is conducted on mice obtained from locations that are unlikely to have been subjected to brodifacoum baiting;
- A feeding trial is conducted on mice obtained from the same areas as those mice used in 2013 so as to determine the unequivocal LD_{100} dose;
- If brodifacoum resistance is only found in the settlement mice than consideration is given to increasing the concentration of brodifacoum in baits used in the settlement to the level of 50 parts per million (as per the baits currently used); and
- If brodifacoum resistance is only found in the settlement mice than a feeding trial involving brodifacoum and another poison (e.g., flocoumafen) is conducted on mice to determine the efficacy of using a combination of poisons.

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Appendix 1

The following is the manuscript detailing the feeding trials undertaken on Lord Howe Island in 2013. The manuscript was submitted to, but rejected by, Australian Wildlife Research.

The two referees that assessed the manuscript stated that there was insufficient evidence submitted by the authors to validate their assertion that the reduced susceptibility of the mice to brodifacoum on the island was due to long-term exposure to this poison. However, one referee did say “Most of the resistance problems in rodents has developed following the prolonged use of ineffective anticoagulants, in particular the first generation anticoagulants, and more recently, the less toxic second generation anticoagulants, bromadiolone and difenacoum.”

“In both species (*Brown Rats and House Mice*) a single dominant autosomal gene has been identified (the VKORC1 gene), mutations of which can confer a degree of resistance to anticoagulants, with a considerable degree of cross resistance between active ingredients. …………………..”

“A low incidence of these genes appear to be present in many populations of rodent, and ineffective use of anticoagulant rodenticide raises the incidence of the gene in the population, selectively killing susceptible animals, and thus creating a resistance problem. Furthermore, the selection of a particular VKORC1 gene that confers a high degree of resistance to a second generation anticoagulant can be achieved using a first generation anticoagulant. It is not necessary for there to be a link between the toxicity of the anticoagulant used and the magnitude of the resistance selected.”

"The occurrence of high levels of resistance across Europe is primarily the result of the widespread use of ineffective active ingredients (initially from the use of first generation anticoagulants, and more recently bromadiolone and difenacoum). Currently, the most effective anticoagulants, brodifacoum, flocoumafen and difethialone, cannot be used in and around farm buildings and along hedgerows in the UK, **and there is a strong belief that the use of both brodifacoum and flocoumafen** could eradicate these highly resistant populations of Brown Rats."

One referee criticised the lack of a control treatment in the second part of the feeding trial. Although this is technically correct, the lack of a control does not invalidate the findings. A control group would be important if all the poisoned mice died but there were several survivors. Death occurring in any such control group would merely suggest that some deaths in the poisoned group may be due to other causes besides brodifacoum.

The following manuscript may be amended by the authors to cover the concerns expressed by the referees. As such it is not for general distribution but only for the information of the LHIB. It can be cited as *Priddel, Wheeler, Carlile and Wilkinson unpublished data*.

Resistance to second-generation anticoagulants adds to the challenge of eradicating exotic rodents on inhabited islands

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Abstract

Eradication of exotic rodents has become a powerful tool to prevent species extinctions and to restore degraded insular ecosystems. Current eradication techniques utilise rodenticide baits containing second-generation anticoagulant poisons. Success is dependent on all targeted individuals consuming toxic bait and dying as a result thereof. The long-term use of anticoagulant rodenticides to control commensal rodents on inhabited islands is likely to lead to local populations of these pests developing inherent resistance to anticoagulants. On Lord Howe Island, reduced susceptibility of mice to brodifacoum (a five-fold increase in the nominal LD_{50}) makes the planned task of eradication more challenging and increases the potential risk of failure. To ingest a lethal dose, some mice on Lord Howe Island will require numerous feeds, over many days. Current rodent-control practices on the island are likely to lead to further reduction in susceptibility to anticoagulants, eventually rendering these poisons ineffective and leaving no means of eradicating or controlling rodents on the island, with potentially catastrophic ecological and social impacts. Widespread resistance to anticoagulants could render current eradication techniques ineffective on islands with a history of rodenticide use. Possible modifications to current techniques include lengthening the period that bait is available to the target animal or using bait with a higher concentration of anticoagulant. Both changes increase the potential risk to non-target species and, on inhabited islands, have possible social ramifications.

Introduction

The presence of invasive rodents on islands is one of the prime causes of species extinction and ecosystem degradation (Groombridge 1992; Towns *et al.* 2006). Rats (*Rattus* spp) and house mice (*Mus musculus*) prey heavily on birds, bats, reptiles, snails, insects and other invertebrates (Atkinson 1985; Cuthbert and Hilton 2004; Towns *et al.* 2006). They consume vast quantities of seeds and seedlings, severely reducing seedling recruitment and modifying vegetation communities (Rance 2001; Shaw *et al.* 2005; Brown *et al.* 2006). The loss of invertebrate fauna involved in plant decomposition or nutrient recycling can have devastating effects on soil fertility (Fukami *et al.* 2006). Similarly, suppression of seabird numbers by invasive rodents can result in a significant loss of marine-derived nutrients in the form of droppings, regurgitations, failed eggs and corpses, which in turn can profoundly affect the health and condition of island ecosystems (Holdaway *et al.* 2007).

Recognising the devastating impacts of invasive rodents on island ecosystems, conservation practitioners have developed techniques to eradicate these pests from islands. Rodents have been removed from at least 284 islands worldwide (Howald *et al.* 2007), and eradication has become a powerful tool to prevent species extinctions and to restore degraded insular ecosystems (Towns and Broome 2003). First developed in New Zealand in the 1980s (Moors 1985; Taylor and Thomas 1989), current rodent eradication techniques rely on the use of rodenticide baits containing anticoagulant poisons; substances that act by effectively blocking the production of vitamin-K in the liver, thereby reducing the ability of the blood to clot (Samama *et al.* 2003). Bait dispersal methods utilising novel computerised tracking and mapping technology (Lavoie *et al.* 2007) have improved to such an extent that eradications are now being attempted on increasingly larger and more complex islands, including those with human populations.

The success of any rodent eradication operation is dependent on all targeted individuals consuming toxic bait and dying as a result thereof. Anticoagulant rodenticides are freely available and commonly used throughout the world to control commensal rodents, and the sustained use of these products has seen the development of resistance in rodent populations worldwide (Bailey and Eason 2000; Pelz *et al.* 2005). Greaves (1994) described anticoagulant resistance as a major loss of efficacy in practical conditions where the anticoagulant has been applied correctly, the loss of efficacy being due to the presence of a strain of rodent with a heritable and commensurately reduced sensitivity to the anticoagulant. Rodents that are tolerant of a particular anticoagulant can still be killed by it, but population control or eradication generally requires ever-increasing doses to be efficacious. Over time, it becomes increasingly impractical to deliver a lethal dose and consequently the anticoagulant loses its utility for rodent control.

The use of anticoagulant rodenticides to control commensal rodents on inhabited islands could potentially lead to local populations of these pests developing resistance to anticoagulants. The current suite of second-generation anticoagulants is the only proven tool available for effectively eradicating rodents from islands. Reduced susceptibility to these compounds will make eradication challenging or impossible. Furthermore, if resistance to anticoagulants develops in island populations of invasive rodents there may be no effective way to control them, with potentially catastrophic environmental and social impacts.

The eradication of rodents from Lord Howe Island using brodifacoum baits is planned (LHIB 2009). The aim is to kill every rat and mouse on the island in a single operation that involves the distribution of baits containing brodifacoum (a potent second-generation anticoagulant) to all parts of the island in two applications several weeks apart. Specific measures will be undertaken to mitigate the risk to humans, pets, livestock and non-target species. Although challenging, such an operation is logistically feasible (Saunders and Brown 2001), provided that the populations of rats and mice remain susceptible to brodifacoum.

This study examined the susceptibility of both rats and mice on Lord Howe Island to brodifacoum by assessing the amount rodents needed to ingest to cause death. It also determined the time interval between ingestion and death, information that would help to identify the optimal time interval between sequential applications of bait.

Methods

Study Site

Lord Howe Island (31°31'S, 159°03'E), New South Wales, Australia, is located 760 kilometres north east of Sydney. The island is 1455 ha in area, 12 km long, 1–2 km wide and formed in the shape of a crescent with a coral reef enclosing a lagoon on the western side. Mount Gower (875 m), Mount Lidgbird (777 m) and Intermediate Hill (250 m) form the southern two-thirds of the island, which is extremely rugged. The northern end of the island is fringed by sheer sea cliffs approximately 200 m in height.

The environmental significance of Lord Howe Island was formally recognised in 1982 when the entire island group was inscribed on the World Heritage Register for containing (i) superlative natural phenomena; (ii) areas of exceptional natural beauty and aesthetic importance; and (iii) important and significant natural habitats for the conservation of biological diversity, including threatened species of outstanding universal value (Deparment of the Environment 2013). Lord Howe Island is a hotspot for endemism; 44% of native plants and more than 50% of native invertebrates are endemic (Recher and Clark 1974; Green 1994).

Lord Howe Island falls under the jurisdiction of the New South Wales Government. The Lord Howe Island Board is responsible for the care, control and management of the island in accordance with the Lord Howe Island Act 1953. Approximately 75% of the main island plus all outlying islets and rocks within the Lord Howe Group are protected under the Permanent Park Preserve, which has similar status to that of a national park. First permanently settled in 1833, the resident population is now approximately 350 in 150 or so households. Lord Howe Island is the only island within the Lord Howe Group on which settlement has occurred. The settlement is restricted to the central lowlands and covers about 15% of the island. Islanders were given perpetual leases on blocks of up to 2 ha for residential purposes, and short-term leases on larger tracts for agricultural and pastoral activities (Hutton 1998). Today, there are approximately 1000 buildings or structures on the island.

Tourism is the island's major source of income. The island contains an airstrip with frequent commercial air services to Sydney and Brisbane. About 16 000 tourists visit the island each year, but numbers are regulated, with a maximum of 400 visitors allowed on the island at any one time. Until recently, the Lord Howe Island Board operated a nursery that produced and exported 2–3 million palm seedlings annually. The local palm industry was a prime source of revenue for the island, but the nursery closed in 2012, and its future is uncertain.

Two species of rodent—black rat (*Rattus rattus*) and house mouse (*Mus musculus*)—have been accidentally introduced to Lord Howe Island; mice probably around 1860, and rats in 1918. These pests have reduced, and continue to erode, the island's intrinsic biodiversity values (DECCW 2010), potentially threatening its World Heritage status. Predation by black rats on Lord Howe Island is listed as a *Key Threatening Process* under the environmental legislation of both national (Australia) and state (New South Wales) governments. Rodents also infest buildings and residences where they are a social nuisance and a threat to human health, destroying foodstuffs and contaminating homes with excrement. Rats also damage the kentia palm (*Howea forsteriana*), which resulted in economic losses to the local palm industry before it recently shut down.

Capture of rodents

Commensal rodents were captured from within the settlement; rats (n = 50) by the use of cage traps and mice (n = 50) using metal box traps (Elliott Scientific Equipment, Upwey, Victoria). Traps were placed throughout the settlement but concentrated in public areas with a long history of brodifacoum use, such as the nursery and the waste management facility. Traps were opened shortly before sunset and baited with a mixture of peanut butter and rolled oats. Traps were emptied and closed soon after sunrise. Trapping was conducted during 23–29 July 2013, eight weeks after routine broad-scale baiting. Captured rodents were transported back to the Lord Howe Research Centre in the trap, shielded from daylight, noise and wind inside a lidded plastic tub. Each individual was then weighed and housed separately in a polypropylene cage with a stainless steel lid (rat box RB-001and high top lid RL-001, mouse box MB-001-PP and lid ML-002; R.E. Walters Pty Ltd, West Sunshine, Victoria). Internal dimensions of cages were approximately 42 x 28 x 25 cm for rats and 29 x 16 x 18 cm for mice. All individuals had access to water from a polypropylene bottle fitted with a stainless steel sipper tube (600 ml for rats and 250 ml for mice; R.E. Walters Pty Ltd, West Sunshine Victoria) and feed pellets formulated for rodents (Rat and Mouse Nut, Vella Stock Feeds, Plumpton). A cardboard tube cut to form a half-cylinder was provided for shelter, along with shredded paper for bedding, and small blocks of wood to chew. The room holding the cages was maintained at ambient temperature and with natural light cycles, but windows were covered to block direct sunlight.

Resistance testing

The toxicity of a substance is usually expressed as the median lethal dose required to kill half the members of a population (LD_{50}) and is measured as the mass of substance per unit body mass of the animal. For brodifacoum the generally accepted acute oral LD_{50} for laboratory or brown rats (*Rattus norvegicus*) is 0.27 mg kg^{-1}, and for mice is 0.4 mg kg^{-1} (Redfern *et al.* 1976; Godfrey 1985). Hereafter, we refer to these values as the nominal LD_{50} (nLD_{50}). Although the published LD_{50} for black rats (*R. rattus*) is higher than that for brown rats, the lower LD_{50} value was used with the objective of determining the very minimal effective lethal dose required to kill rats on Lord Howe Island. Acute oral LD_{50} values for a particular species can vary depending on the laboratory procedures used and the population tested, thus toxicity values are indicative rather than absolute.

Food consumption by each captured individual was monitored until the animal was confirmed to be eating (0–2 days). Ten individuals of each species were then randomly assigned to one of four treatments that were fed cereal bait (Pestoff® 20R, Animal Control Products, Wanganui, New Zealand), the amount of bait varying among treatments such that different amounts of brodifacoum (1, 2, 3 and 5 times the relative nLD_{50}) were on offer. After the toxic bait was consumed (typically within 24 hours of it being offered) feeding with non-toxic food recommenced. The efficacy of each dosage was assessed by the percentage mortality. Another 10 individuals of each species were used as controls and were fed non-toxic pellets *ad libitum*.

All individuals were observed at 6-hourly intervals for signs of brodifacoum toxicosis including: pale extremities, bleeding from orifices, hunched posture, paresis, paralysis, prostration and death. Symptoms and time to death were recorded. As a requirement of Animal Ethics approval, any individual rendered prostrate by the effects of the poison was observed hourly, and if it remained prostrate for 3 hours it was euthanized. After death, all individuals were examined for internal bleeding.

The control group and some individuals receiving low dosages of brodifacoum were expected to survive. After 14 days, these individuals were weighed and fed additional bait containing the equivalent of 10 nLD_{50} for the respective test species. Observations of these individuals continued for a further 23 days.

Brodifacoum content of bait

Pestoff® 20R contains brodifacoum at a nominal concentration of 20 mg kg^{-1} (20 parts per million (ppm)). Twelve individual pellets (5.5 mm diameter, 0.5–0.8 g) were assayed for brodifacoum content by the Landcare Research toxicology laboratory, Lincoln, New Zealand using method TLM017 (the assay of brodifacoum baits and concentrates by high-performance liquid chromatography) based on the methods of Hunter (1983) and ICI (1983).

Results

Mortality

For rats, mean mass at the time of capture was 196.1 ± 44.8 g (range: 110–275 g). Ingestion of brodifacoum at a dose rate of 1 nLD_{50} resulted in no mortality (Table 1). Twice this dose rate (2 nLD_{50}) resulted in 60% mortality. Three or more nLD_{50} produced 100% mortality. After 14 days, survivors from the control and low-dosage groups were weighed and fed additional bait containing a further 10 nLD_{50}. Resultant mortality was 100% (Table 1). From these observations we conclude that the observed LD_{50} for Black Rats on Lord Howe Island was roughly twice the nLD_{50}, the latter being equivalent to the LD_{50} of the Brown Rat.

For mice, mean mass was 16.5 ± 2.5 g (range 11.0–22.0 g). Ingestion of brodifacoum at dose rates 1 and 2 nLD_{50} resulted in no mortality (Table 2). A dose rate of 3 nLD_{50} resulted in 10% mortality, and 5 nLD_{50} resulted in 60% mortality. After 14 days, survivors from all dosage groups were weighed and fed additional bait containing a further 10 nLD_{50}. Mortality for these treatments ranged from 67% to 100%, but mice consuming dosages equivalent to 12 LD_{50} (2 individuals) and 13 LD_{50} (3 individuals) survived (Table 2). These survivors were still alive after 23 days (5 days longer than any animal that died) and all appeared healthy, with no signs of bleeding or lethargy. These survivors did not originate from any particular location, but were captured in locations throughout the settlement including the nursery and waste management facility.

From the observations above we conclude that the observed LD_{50} for mice on Lord Howe Island was approximately five times the nLD_{50}, with some individuals showing a high level of tolerance, up to at least 13 nLD_{50} (5.2 mg kg^{-1}).

Time to death

For both rats and mice, the interval between ingestion and death was independent of the amount of brodifacoum consumed (rats: $F_{5, 44} = 0.2580$, $P = 0.933$; mice: $F_{5, 37} = 0.7714$, $P = 0.576$), so data from all dosages were combined. Rats died 3–13 days after ingestion of the bait (mean 6.9 ± 1.9 days, n = 50, Figure 1); mice died 1–18 days after ingestion (mean 7.3 ± 3.9, n = 44, Figure 2). Time to death was similar for both species ($t = 0.5729$, $P = 0.569$).
Mean time to death may be a slight underestimate because five rats and four mice were euthanized once rendered prostrate by the effects of the anticoagulant.

Brodifacoum content of bait

The assayed concentration of brodifacoum in baits (Figure 3) was 16–22 ppm (μg g^{-1}). The 95% confidence interval was ± 7%, equivalent to ± 1 ppm. Mean brodifacoum concentration was 18.2 ± 1.6 ppm, close to the nominal concentration of 20 ppm.

Discussion

Rats

This study has demonstrated that the dose of brodifacoum needed to kill 50% of the rats on Lord Howe Island (LD_{50}) is roughly twice the nominal LD_{50} (nLD_{50}) for rats. The nLD_{50} for rats was measured using laboratory brown rats. The LD_{50} for a laboratory population of black rats is 0.65 mg kg^{-1} for females and 0.73 mg kg^{-1} for males (Dubock and Kaukeinen 1978) and 0.46–0.77 mg kg^{-1} for wild populations (Mathur and Prakash 1981; O'Connor and Booth 2001), all similar to that obtained in this study (0.54 mg kg^{-1}). Thus, rats on Lord Howe Island show no signs of having developed increased tolerance to brodifacoum. Based on an observed LD_{50} of 0.54 mg kg^{-1}, an average body weight of 196 g and a brodifacoum concentration in bait of 18.2 ppm (this study), the average rat on Lord Howe Island (in terms of both size and susceptibility) would need to consume 5.8 g of bait to ingest a lethal dose.
The dosage needed to kill all rats on Lord Howe Island (LD_{100}) is roughly three times the nLD_{50} for rats. Based on an observed LD_{100} of 0.81 mg kg^{-1} and a maximum body weight of 275 g (this study), the largest and least susceptible rat on Lord Howe Island would need to consume 12.2 g of bait to ingest a lethal dose. An adult rat will typically eat 25–30 g of food per day, taken in about ten small meals, with the maximum consumption per meal of around 3 g (Wade 2011). Thus all rats on Lord Howe Island could consume a lethal dose in one day, but may require four or five meals to do so.

Mice

The dose of brodifacoum needed to kill 50% of the mice on Lord Howe Island (LD_{50}) is roughly five times the nLD_{50}. Although the nLD_{50} for mice (0.4 mg kg^{-1}) was measured using laboratory mice, similar values have been obtained for wild populations (0.52 mg kg^{-1}, O'Connor and Booth (2001); 0.44 mg kg^{-1}, Cuthbert *et al.* (2011)). The unusually high LD_{50} for mice on Lord Howe Island indicates that this population has developed increased tolerance to brodifacoum. Based on an observed LD_{50} of 2.0 mg kg^{-1}, an average body weight of 16.5 g and a brodifacoum concentration of 18.2 ppm (this study), the average mouse on Lord Howe Island (in terms of both size and susceptibility) would need to consume 1.8 g of bait to ingest a lethal dose. Mice typically consume approximately 3 g of food per day, in many small meals of up to 0.2 g (Morriss *et al.* 2008; Wade 2011). Thus, the typical mouse on Lord Howe Island could consume a lethal dose in one day, requiring up to nine meals to do so.
The dosage needed to kill all mice on Lord Howe Island (LD_{100}) is at least 15 nLD_{50}. Based on an observed LD_{100} of 6.0 mg kg^{-1} and a maximum body weight of 22 g (this study), the largest and least susceptible mouse on Lord Howe Island would need to consume at least 7.3 g of bait to ingest a lethal dose. This would take at least 37 meals or 3 days to complete, longer if alternative food was also eaten.
In August 2008, non-toxic Pestoff® 20R baits distributed at a density of 10 kg ha^{-1} within the palm forest on Lord Howe Island remained available above ground for at least 7 days (Wilkinson *et al.* 2008). In these circumstances, bait would be available long enough for mice to access and consume a lethal quantity of bait following a single application. However, in sites with a high density of non-target consumers of bait (e.g. ducks and rails) bait may disappear much faster. In these situations, higher dose rates or multiple bait applications may be needed to increase the likelihood of mice receiving a lethal dose.

Five mice survived the study despite consuming at least 4.8 mg kg^{-1} of brodifacoum (Table 2). These individuals were euthanized at the conclusion of the study, a condition of the Animal Ethics approval. The survival of these individuals demonstrated that some mice have developed a high level of tolerance to brodifacoum, but it is not firm evidence of complete resistance as it is possible that these individuals would have succumbed to higher doses of brodifacoum. In a similar study involving mice on Gough Island, two individuals (approximately 1% of those tested) survived after apparently ingesting doses of brodifacoum estimated to be 5 and 10 times the oral LD_{50} for the population, but subsequent exposure at higher doses resulted in mortality (Cuthbert *et al.* 2011). On Lord Howe Island, 28 mice that survived low doses of brodifacoum, died after subsequent feeding with the same toxic bait. Importantly, no mouse exhibited any inhibition to consume additional bait following its initial exposure to brodifacoum.

Time to death

The ingestion of a sufficient amount of brodifacoum can lead to death through internal haemorrhaging, which typically takes 3–10 days in rats (Hadler and Shadbolt 1975) and a few days longer in mice (Fisher 2005). For rats on Lord Howe Island, time to death following exposure averaged 6.9 ± 1.9 days, marginally less than that reported for this species in another study: 8.5–11.0 days (Lund 1981). For mice, time to death averaged 7.3 days, within the range reported for this species in other studies: 5.2 days (Cleghorn and Griffiths 2002), 5.5 days (Cuthbert *et al.* 2011) and 7.1–11.0 days (Lund 1981). Necropsy findings of free or clotted blood in the thoracic and/or abdominal cavity, kidney and subcutaneous tissues are consistent with the anticoagulant mode of action of brodifacoum. The rigours of living in the wild would probably reduce the time to death, as poisoned individuals would be exposed to movements and minor injuries that would probably exacerbate the likelihood of fatal haemorrhage caused by poisoning (Morriss *et al.* 2008).

Worldwide development of resistance

Anticoagulant rodenticide resistance is a worldwide phenomenon (Pelz *et al.* 2005) that occurs after sustained use of anticoagulant poisons for rodent control (Bailey and Eason 2000). Resistance to warfarin was first discovered in brown rats in Britain in 1958 (Boyle 1960), and in house mice shortly thereafter (Dodsworth 1961). Resistance to this and other first generation anticoagulants is now widespread across the globe and involves all three common commensal species: brown rat, black rat and house mouse (see review in Lund (1984)).

Second-generation anticoagulants initially proved effective at controlling rodents that were resistance to earlier anticoagulants. But within two decades, resistance to these more-potent second-generation anticoagulants was reported (Redfern and Gill 1978). Resistance to both bromadiolone and difenacoum has since been widely reported for brown rats, (e.g. Greaves 1994), black rats (e.g. Desideri *et al.* 1979) and house mice (e.g. Rowe *et al.* 1981; Siddiqi and Blaine 1982). Resistance to brodifacoum is less prevalent, possibly because significant constraints restrict the use of this substance in many countries. Notwithstanding, some degree of cross-resistance occurs (Lund 1984)) and increased tolerance to brodifacoum has been observed in brown rats (Greaves *et al.* 1982; Gill *et al.* 1992) and house mice (Siddiqi and Blaine 1982).

Development of resistance on Lord Howe Island

Mice on Lord Howe Island developed resistance to warfarin sometime before 2000, less than two decades after systematic baiting began. Little more than a decade later, the same population has developed a tolerance to brodifacoum, the most potent anticoagulant rodenticide available. This tolerance has developed through long-term exposure to bait containing brodifacoum (at the concentration of 50 parts per million) distributed throughout the settlement.

The potential for resistance to second-generation anticoagulant poisons to develop on Lord Howe Island has long been recognised. In 2001, an evaluation of the feasibility of eradicating rodents from Lord Howe Island (Saunders and Brown 2001) recommended that the ongoing use of brodifacoum baits be stopped to avoid the potential for resistance in the rodent population to develop. In 2009, the draft eradication plan (LHIB 2009) reiterated the same concerns.

Use of anticoagulants on Lord Howe Island

Widespread rodent control has occurred on Lord Howe Island for the past 90 years, aimed largely at reducing damage to the kentia palm seed, although more recently it has also been used for conservation purposes in specific areas. The use of warfarin, a first-generation anticoagulant, to control rats in palm

seeding areas began in the early 1960s (Harden and Leary 1992). Diphacinone was also trialled, but was withdrawn because of concerns of the risk to non-target birds (Harden and Leary 1992). In 1980, a more systematic control programme using warfarin began, but because the baits were simply placed out on the ground in sheltered sites, concerns about the risk to birds led to this programme being abandoned (Harden and Leary 1992). In 1986, baiting with warfarin was re-instigated, but this time in association with the use of bait stations. While changes have been made to the type of bait and baiting frequency, the locations targeted for control have remained essentially the same, albeit with a few minor additions.
Nowadays, approximately 1000 permanent bait stations are dispersed among 33 separate patches of palm forest around the island, covering a total area of approximately 140 ha (approximately 10% of the island). Between 1986 and 2009, approximately 119 tonnes of bait containing 83 kg of warfarin was distributed on the island (LHIB 2009). Initially, bait was available continuously. However, the mice developed resistance to warfarin and were feeding on the bait, which was being distributed in ever-increasing quantities of up to 7 tonnes per annum (Billing 2000; Billing and Harden 2000). To counter the mice, baiting frequency was reduced such that bait was available only intermittently. Bait is now replenished six times per annum (approximately every 8–9 weeks), and the amount of bait now dispersed is approximately 1.2 tonnes per annum (LHIB 2009). In 2012, the Lord Howe Island Board changed to using coumatetralyl, another first-generation anticoagulant but which has lower toxicity to birds.

In addition to protecting the palm seed crop, the Lord Howe Island Board also undertakes rodent control at strategic locations within the settlement, primarily at the waste management facility and, until recently, the now-defunct commercial palm nursery. First-generation anticoagulant baits (currently coumatetralyl, previously warfarin) are used to control rats, and second-generation anticoagulant baits (brodifacoum 50 ppm) used to control mice. Until the nursery closed in 2012, approximately 100 kg of brodifacoum-based bait was used annually (LHIB 2009).

Baiting with anticoagulants has long been undertaken by the Lord Howe Island community to reduce the social impacts of rats and mice within the area of human habitation. Residents use coumatetralyl (previously warfarin) bait supplied by the Lord Howe Island Board as well as brodifacoum and other second-generation anticoagulant baits purchased from shops on the island and on the mainland. The amount of bait supplied to residents by the Lord Howe Island Board was estimated at approximately 380 kg per annum (Saunders and Brown 2001). In the absence of any records, the quantity of brodifacoum-based rodenticide used by residents on the island is difficult to determine, but probably exceeds 100 kg per annum (LHIB 2009).

Based on the usage estimates above, the Lord Howe Island Board and local community together distributed a total of approximately 2.6 tonnes of brodifacoum baits within the settlement between 2000 and 2012. Although usage by the Board has declined significantly since the closure of the nursery, use of brodifacoum baits by the Lord Howe Island community continues largely unabated.

Conservation implications

Eradication of exotic rodents on Lord Howe Island will deliver significant biodiversity benefits to the local ecosystem (LHIB 2009), and end the ongoing use of rodenticides on the island. The presence of mice that are tolerant to brodifacoum increases both the difficulty of eradicating this species from the island and the potential risk of failure. The objective, however, remains unchanged—to provide each individual rodent on the island with access to a lethal dose of bait. This study has provided the first experimental estimate of the size of that lethal dose.

Mice on Lord Howe Island are known to be resistant to warfarin (Billing 2000), but this study provides the first evidence that they have also developed a tolerance to brodifacoum. This situation is already parlous but will get worse if the current use of anticoagulants continues. Extensive and prolonged use of resisted compounds increases the severity of the resistance as the baiting programme selects for the most resistant individuals. Experience from Britain (Buckle 2013) suggests that, within a decade or so, anticoagulants will soon prove ineffective on Lord Howe Island, leaving no other means to effectively control mice on the island. This will have both biodiversity and social costs. For example, resistant mice containing high concentrations of anticoagulants spread to control rats would increase the risk of secondary poisoning of native predators and scavengers, and companion dogs. Also, businesses such as shops and restaurants may be unable to fulfil their statutory obligations with respect to human health.

Reduced susceptibility of mice to brodifacoum may also reduce the effectiveness of the use of anticoagulants to control rats. Baiting would provide resistant mice with a supplementary food resource that may enable them to sustain higher population numbers than they otherwise would. By consuming large quantities of bait, resistant mice would reduce the amount of rodenticide available to rats, leading to a situation where more and more rodenticide has to distributed to maintain the same level of control on rat numbers; a scenario that mirrors the history of warfarin use on Lord Howe Island. Also, if current practices persist, rats are also likely to further increase their tolerance to anticoagulants, as has occurred elsewhere (Pelz *et al.* 2005), with catastrophic results for biodiversity and tourism as well as the general well-being of the islanders.

Conclusions

This study has (1) confirmed that on Lord Howe Island rats are more susceptible to brodifacoum than mice; (2) demonstrated that mice on Lord Howe Island have a much greater variability in susceptibility to brodifacoum than do rats, and (3) identified low susceptibility to brodifacoum by a small proportion of the mouse population. In essence, mice on Lord Howe Island will need to consume relatively large amounts of brodifacoum over several days for it to be fatal, and thus mice will be much more difficult to eradicate than rats. Consequently, a priority objective for the proposed eradication on Lord Howe Island must be to maintain a continuous supply of bait for long enough to ensure that the entire mouse population has ample opportunity to ingest a lethal dose.

Globally, the failure rate for mouse eradications is greater than that for rats (MacKay *et al.* 2007). Mice have smaller home ranges than rats (MacKay 2011) so are less likely to have access to bait dispersed thinly or unevenly. Mice also have a higher natural tolerance and greater individual variability in susceptibility to anticoagulants. Mice also appear to have a high propensity to develop inherent resistance. These traits make them difficult to eradicate, particularly on islands with a long history of anticoagulant use.

Techniques to eradicate rodents from islands have essentially been designed for rats. Anticoagulant baits for aerial dispersal, for example, have been formulated primarily for highly susceptible rats on islands with little or no history of rodenticide use. Eradications targeting mice (or resistant rats) should consider the use of higher concentrations of brodifacoum to increase the likelihood of all individuals obtaining a lethal dose when small quantities of bait are consumed. This option would need to be considered in relation to the increased risks to non-target species, particularly those that are not taken into temporary captivity during the eradication operation. If bait stations are used in particular areas, rather than hand- or aerial distribution, high toxicity baits could probably be used within these stations without significantly increasing the risk to non-target species.

Widespread use of anticoagulants on inhabited islands may mean that eradication techniques developed on uninhabited islands need to be modified on an island-by-island basis if they are to be effective on inhabited islands, or on islands with a long history of anticoagulant use. Second-generation anticoagulants are often described as single-feed rodenticides, i.e., a lethal dose is consumed in a single meal. This is seldom the case, but if baits are palatable and available in sufficient quantity, non-resistant individuals can generally consume a lethal dose in a single day, albeit over numerous feeds. Resistant individuals, however, will require many more feeds, spread over several days. Therefore, if eradication operations on rodent populations with any level of tolerance are to be successful, bait must be available over a sufficiently long period to enable a lethal dose to be consumed.

The possibility of some resistant rodents receiving a sub-lethal dose of poison emphasises the need to undertake a second or third application of bait. Undertaking multiple applications will provide the opportunity for the targeted species to consume repeat doses. However, to maximise bait availability for any initial survivors the second application of bait should not occur until after the majority of rodents that have consumed a lethal dose have died (up to 18 days for mice on Lord Howe Island). This study found that captive mice would readily consume bait after an initial sub-lethal exposure. The apparent absence of bait avoidance upon second exposure suggests no short-term inhibition to consume a second and toxic dose of brodifacoum. Whether or not wild mice, with access to alternative natural foods, behave similarly is unknown.

Although invasive rodents have been eradicated from approximately 300 islands worldwide (Howald *et al.* 2007), the use of anticoagulants, largely on inhabited islands, makes eradication much more challenging. Also, time is of the essence. Rodents, particularly mice, can quickly develop resistance to even the most potent anticoagulants (Rowe *et al.* 1981; Siddiqi and Blaine 1982). Once rodents have developed a high level of resistance to these substances, the opportunity for both eradication and effective control is lost.

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Table 1. Mortality rate and interval to death for black rats following ingestion of various concentrations of brodifacoum

	x LD_{50}							Combined
	1	**2**	**3**	**5**	**10**	**1 + 10**	**2 + 10**	
Dosage (mg kg^{-1})	0.27	0.54	0.81	1.35	2.70	2.97	3.24	
Mortality ***n***	0% (10)	60% (10)	100% (10)	100% (10)	100% (10)	100% (10)	100% (4)	
Days to death Mean ± SD Range ***n***		7.5 ± 2.3 4–11 (6)	6.6 ± 0.7 6–8 (10)	6.7 ± 1.8 4–10 (10)	7.2 ± 2.4 5–13 (10)	6.7 ± 2.3 4–12 (10)	7.0 ± 1.4 5–8 (4)	6.9 ± 1.9 4–13 (50)

Table 2. Mortality rate and interval to death for house mice following ingestion of various concentrations of brodifacoum

	x LD_{50}									Combined
	1	**2**	**3**	**5**	**10**	**1 + 10**	**2 + 10**	**3 + 10**	**5 + 10**	
Dosage (mg kg^{-1})	0.40	0.80	1.20	2.00	4.00	4.40	4.80	5.20	6.00	
Mortality ***n***	0% (10)	0% (10)	10% (10)	60% (10)	100% (9)	100% (10)	80% (10)	67% (9)	100% (4)	
Days to death Mean ± SD Range ***n***			6.0 (1)	6.3 ± 2.6 3–10 (6)	8.1 ± 3.6 4–13 (9)	8.8 ± 5.5 1–18 (10)	5.5 ± 3.3 3–13 (8)	6.7 ± 2.7 3–11 (6)	7.8 ± 5.3 1–14 (4)	7.3 ± 3.9 1–18 (44)

Testing the efficacy of Pestoff® 20R to kill House Mice *Mus musculus* on Lord Howe Island.

Prepared for

The Lord Howe Island Board

By

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MAY 2016

Executive Summary

An invasive rodent eradication programme targeting Ship Rats (*Rattus rattus*) and House Mice (*Mus musculus*) is proposed for Lord Howe Island in the winter of 2017. The proposed bait to be used in the trial is Pestoff® Rodent Bait 20R containing brodifacoum at 20 ppm. The bait will be distributed by hand broadcasting or in bait stations within the settlement area, and by helicopter outside the settlement area. The aims of this study were to demonstrate that Pestoff 20R will be effective against mice when the bait is provided in a manner that is consistent with its application in the field.

Between 4 and 8 April 2016, 90 mice were captured at various locations across the settled parts of the island. After an up to seven day acclimatisation period the mice were placed in three treatment groups: Control (C) where 29* mice were fed *ad libitum* with commercial pet feed; Aerial Simulation (AS) where 30 mice were given Pestoff 20R for three days followed by seven days of pet food, followed by another three days of Pestoff 20R; Bait Station Simulation (BS) where 30 mice were provided with Pestoff 20R *ad libitum*.

The first death in the AS group occurred after 2 days and the last mouse died (euthanized as per animal ethics requirements^) after 22 days. In the BS group, the first death occurred after 4 days and the last mouse died after 22 days (euthanized as per animal ethics requirements^). After 16 days more than 90% of mice had died or had been euthanized in both the AS group and the BS group. All 29 mice in the Control Group were alive at the end of the trial.

This study shows that, while there is a wide range in the time until death following ingestion of Pestoff 20R, the bait will kill Lord Howe Island mice when the bait is provided in a manner that is consistent with field conditions. Initially, the mice in the AS trial died faster than those in the BS trial. Only six mice of the original 30 in the AS group survived to receive the second dose of poison. This indicates that a single ingestion of the bait (from a limited exposure) will be sufficient to kill the majority of mice relatively quickly. During the actual eradication, the period between poison exposure and death is likely to be faster than in this simulation. The mice in this trial were not challenged physically due to the confinement of their holding cages. In a natural setting with normal physical activity and exertion, there should be more likelihood of bleeding leading to death.

Note: **One mouse died during the acclimation period, presumably from poison consumed prior to being captured.*

^In a moribund state as measured by immobility and a lack of response to stimuli

Introduction

An invasive rodent eradication programme targeting Ship Rats (*Rattus rattus*) and House Mice (*Mus musculus*) is proposed for Lord Howe Island in the winter of 2017. The proposed bait to be used in the trial is Pestoff® Rodent Bait 20R (Pestoff 20R) in the form of pellets containing the anticoagulant brodifacoum at 20 ppm. In 2013, a trial was performed to test the efficacy of brodifacoum on Lord Howe Island rodents (Wheeler & Carlile 2013). In those trials, rats and mice were fed a measured and restricted amount of brodifacoum in line with their respective accepted LD50. The results showed that, while rats died as expected, the LD50 of mice caught from within the settlement area of the island was five times the accepted value of 0.4 mg/kg. Moreover, some mice could survive a dose of 15 times the accepted LD50. As brodifacoum has long been used by island inhabitants in an effort to control rodent numbers (particularly in and around the settlement area), the results of the 2013 trial suggested that the mice had developed some resistance to brodifacoum.

In the proposed rodent eradication, Pestoff 20R will be applied across the entire island. Within the settlement area, pellets will be either broadcast by hand or made available to rodents in bait stations. Outside of the settlement area, pellets will be broadcast by helicopter in two drops. The first drop will spread pellets at a density of 12 kg/ha (one bait every two square metres). The second drop will occur 14 to 21 days later (depending on conditions) and will spread bait at a density of 8kg/ha. A single 2 g pellet of the bait will provide mice with the LD50 of brodifacoum as determined in the 2013 study.

This toxicity trial was designed to simulate potential exposure to bait that mice will experience under field situations. The main aim of the trial was to examine the efficacy of Pestoff 20R to kill Lord Howe Island mice, when the bait is provided in a manner that is consistent with its application in the proposed eradication.

Methods

With the aim of catching 90 mice, 250 Elliot traps were set between 4 and 6 April 2016, at various locations across the island: Southern Settlement (200 trap nights); Waste Management Facility (WMF)/Airport (100 trap nights); and Nursery (200 trap nights). The locations were chosen to include mice from within and on the edge of the settlement area to reflect potential differences in previous exposure to brodifacoum in mice from different parts of the inhabited sections of the island.

The majority of the 90 mice were caught in the Nursery area (63%), followed by the WMF/Airport (37%). No mice were caught at the Southern Settlement. The mice were weighed, and then placed in individual purpose-built mouse cages. Every seven days the cages were cleaned and the bedding was replaced. The mice were allowed to acclimatise for up to seven days in a mouse housing facility which provided 12 hours of natural/artificial light/12 hours of darkness each day throughout the trial. On 12 April 2016 the mice were placed in three treatment groups:

Control (C; N =29*. Mice fed *ad libitum* with pet food pellets and mixed seeds)

Aerial Simulation (AS; N = 30. Mice given Pestoff 20R for three days followed by seven days of pet food, followed by another three days of exposure to Pestoff 20R)

Bait Station Simulation (BS; N = 30. Mice provided with Pestoff 20R *ad libitum*)

The distribution of mice by treatment group and capture location is shown in Fig 1. At the beginning of the trial, there was no significant difference in the mean body mass of mice in different treatment groups ($F_{2,86}$= 3.10, P = 0.12; Fig. 3).

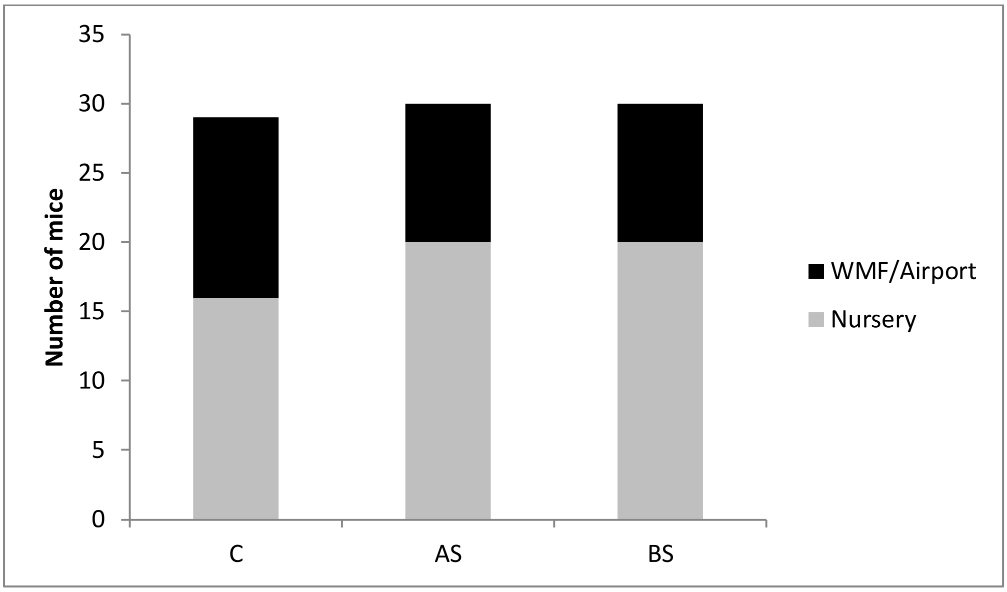

Figure 1. The proportion of mice used in the trial by treatment group and capture location.

The condition of mice was checked every six hours. The characteristics examined included, activity level, gait, posture, respiration, condition of fur, and condition of eyes. If a mouse was found to be prostrate, it was checked every hour for the next three hours. As per Office of Environment and Heritage Animal Ethics Committee requirements (AEC 160202 02), the mouse was euthanized if its condition had not changed after those three hours. Mice were also euthanized if they became moribund to the extent that they were found to be immobile and unresponsive to stimuli in two consecutive 6-hourly checks.

Results

The first death in the AS group occurred after two days of exposure to toxic bait and the last death occurred after 22 days after commencement of exposure (the mouse was in a severe moribund state and was therefore euthanized). After 15 days, more than 90% of the mice in the AS group had died or been euthanized. The average time until death in the AS group was 8.7 ± 4.4 days. In the BS group, the first death occurred four days after exposure and the last mouse died after 22 days after commencement of exposure (the mouse was in a severe moribund state and was therefore euthanized). More than 90% of mice were dead 16 days after commencement of exposure. The average time until death in the BS group was 9.9 ± 4.8 days. There was no significant difference in the mean number of days until death between the AS and BS groups ($t_{(1), 58}$ = 2.00, P = 0.33). All 29 mice in the Control group were alive at the end of the trial, at which time these mice were euthanized as per ethics licence requirements. The attrition of mice in each treatment group is shown in Figure 2.

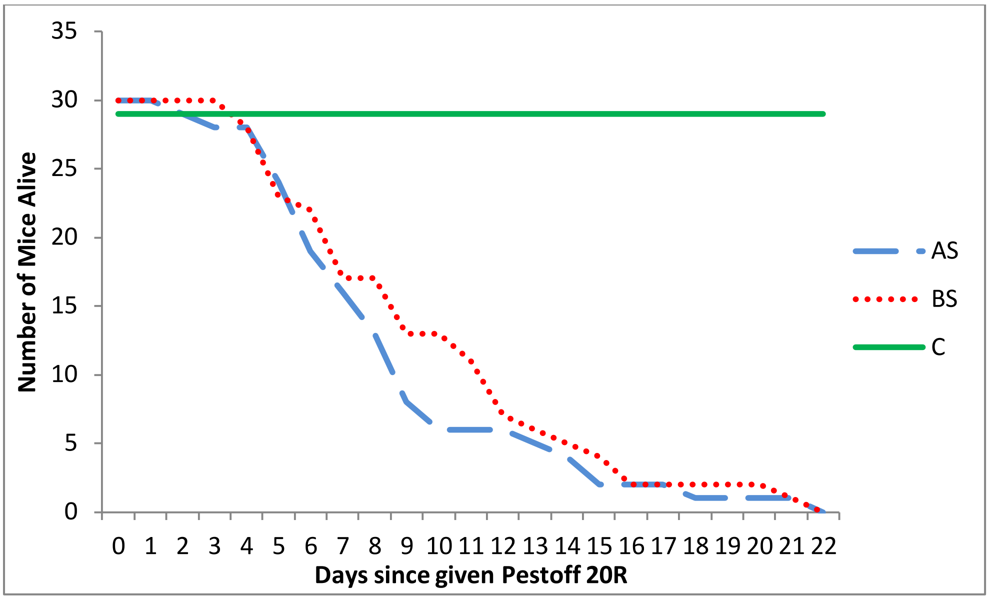

Figure 2. Survival of mice *Mus musculus* in the baiting trial.

Mice in all three groups had a lower body mass at the end point (i.e. death in the baited groups or at 29 days in the control group); however the average decrease in the baited mice was more than twice that of the control mice (Fig 3).

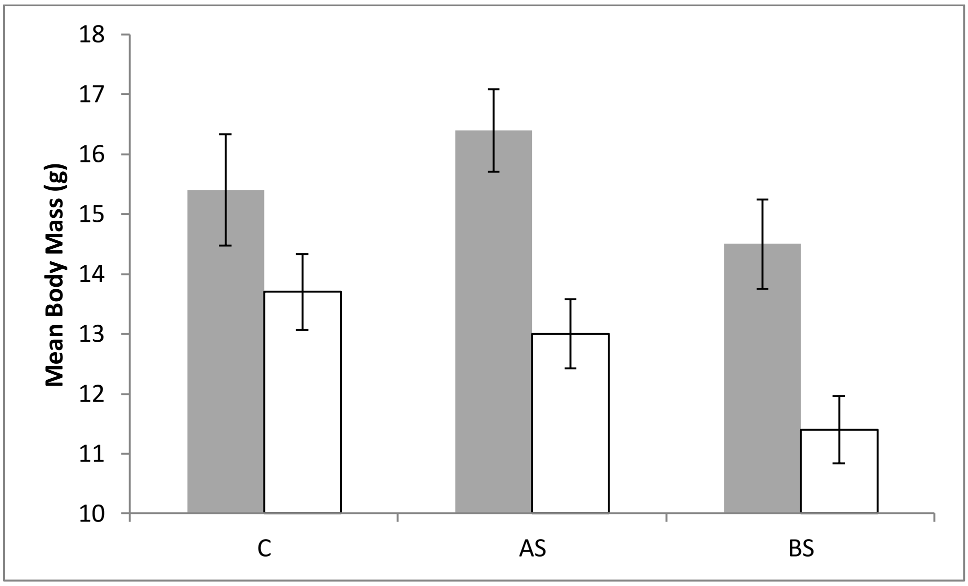

Figure 3. Body mass of mice *Mus musculus* at the beginning and end of the trial. Filled columns represent initial body mass, open columns represent body mass at the end point.

**One mouse died during the acclimatisation period. The mouse had blood around its nose and mouth and thus had presumably consumed poison prior to being captured.*

Discussion

The finding that no mice died in the Control group while all mice died in the groups given Pestoff 20R, indicates that the poison was effective against Lord Howe Island mice when provided in a manner that is consistent with field conditions. Initially, the mice in the AS group (mice that had access to bait for three days) died faster than those in the BS group (mice with *ad libitum* access to bait). Only six of the original 30 mice in the AS group survived to receive the second dose of poison on day 10. This indicates that a single ingestion of the bait will be sufficient to kill the majority of mice relatively quickly.

The results also confirmed that there is a broad range in tolerance to brodifacoum, with the time until death following ingestion of Pestoff 20R varying from just two days to 22 days. The fact that 90% of mice were dead after 16 days in both of the baited groups and that only three mice made it past 18 days, suggests that an extensive range of tolerance levels in the mouse population have been captured in the trial. The results of this trial, therefore, provide some level of confidence that all wild mice will receive a lethal dose of brodifacoum in the proposed eradication. Indeed, death from ingestion of brodifacoum is expected to be faster during the eradication. The mice in this trial were not challenged physically due to the confinement of their holding cages. In a natural setting percussive damage from normal activities, and therefore the likelihood of more excessive bleeding leading to death, would be expected. In addition, once mice in the trial became strongly affected by the poison they became unresponsive to gentle stimuli and did not readily seek refuge within their cardboard tubes or beneath shredded paper but rather sat out in the open. Wild mice displaying these behaviours would be vulnerable to predation and, because the eradication is planned for winter, they would be exposed to cold temperatures, both of which are likely to reduce the survivability of wild mice following consumption of bait.

One mouse died during the acclimatisation period. Bait is used by residents in and around the settlement area, and there was evidence that this mouse had been poisoned prior to capture. It is possible that the mice that were the quickest to die during the baiting trial had also eaten bait prior to being captured. However, no mice in the control group died once the baiting component of the trial had begun, suggesting that few if any of the mice used in this trial had previously ingested a lethal dose of bait and that the deaths in the baited groups were a result of ingestion of Pestoff 20R during the trial.

While there is little doubt that the death of mice was due to ingestion of Pestoff 20R (i.e. no mice in the control group died), necropsies of dead mice were performed to provide confirmation that the cause of death was brodifacoum poisoning. A number of mice examined showed external signs of haemorrhaging as evidenced by bleeding around the nose and mouth and darkening in the rear leg joints. Mice that showed no external signs of haemorrhaging were dissected. These mice exhibited various signs of being affected by brodifacoum including bleeding in the pericardium, subcutaneous bleeding along the flanks, discoloured kidneys, and blotchy lungs.

Mice in the baited groups lost more body mass throughout the trial than did mice in the Control group. It is likely that this loss of body mass is due to illness and a loss of appetite once the poison had begun taking an effect rather than an aversion to the bait and therefore a lack of overall food intake. Pestoff 20R does not contain the bitter compound (Bitrex®) found in commercially available rodenticides containing brodifacoum. Previous trials on LHI have shown that Pestoff 20R is palatable to LHI rodents (Wheeler & Carlile 2013) and in this trial a number of mice were seen to almost immediately begin to chew the pellets following the provision of them. Conversely, mice that were fed commercial pet food during the acclimatisation period and those in the control group, were rarely seen consuming food.

In conclusion, this trial demonstrated that, despite there being a broad range of tolerance levels to brodifacoum in the Lord Howe Island mouse population, Pestoff 20R, when provided in a manner consistent with the methods proposed for the rodent eradication, will be effective against Lord Howe Island mice.

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Wheeler, R. & Carlile, N. Testing for brodifacoum resistance in invasive rodents on Lord Howe Island: Summary of Work Undertaken by the Office of Environment and Heritage in 2013. Unpublished report prepared for the Lord Howe Island Board.

Lord Howe
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Lord Howe Island Rodent Eradication Project

NSW Species Impact Statement

February 2017

Appendix E - Non-target Impact Management Plan

Lord Howe Island Rodent Eradication Project

Non-target Species Impact Mitigation Plan

Table of Contents

Executive Summary

The Non-target Species Impact Mitigation Plan (the Plan) is a document containing the methodology and techniques proposed for the mitigation of negative impacts of the Lord Howe Island Board Rodent Eradication Project (REP) on non-target wildlife species. REP is a large-scale project with the aim of eradicating Black rats (Rattus rattus) and House mice (Mus musculus) to protect natural ecosystems and World Heritage Values on Lord Howe Island and surrounding islets. The REP also intends to concurrently eradicate the Masked Owl a species that was introduced to Lord Howe Island (LHI) IN 1920.

The one-off eradication proposes to distribute a cereal-based bait pellet (Pestoff 20R) containing 0.02g/kg (20 parts per million) of the approved active constituent, Brodifacoum across the Lord Howe Island Group (LHIG) including islets (excluding Balls Pyramid). Methods of distribution will be dispersal from helicopters using an under-slung bait spreader bucket in the uninhabited parts of the island (most of the LHIG) and by a combination of hand broadcasting and the placement of bait stations in the settlement areas. In dwellings (e.g. in ceiling spaces or floor spaces) bait trays and bait stations will be used. Bait stations will also be used around pens for the remaining dairy herd containment area. Given the size and rugged terrain of the LHIG, and the home ranges of rats and mice, the exclusive use of baits stations is not feasible for an eradication.

The operation is targeted for winter of 2017 however, to allow operational flexibility and to account for unforeseen delays, a permit is sought for at least a three year period.

The following additional measures are planned for implementation during the 2017 baiting season:

- The establishment of the Scientific Advisory Committee (SAC) to inform the development and implementation of the non-target species impact mitigation plan;
- A planned and adequately resourced non target carcass collection and disposal process undertaken by a dedicated team through the settlement area where feasible;
- An intense 3 week baiting period with 2 individual baiting programs staged to allow missed or young denned rodents to have access to bait
- Additional monitoring and reporting requirements, including monitoring of mortality and cause of death of non-target species, and long-term monitoring of the population recovery of native species that are currently impacted by rodents.
- This Plan sits alongside the Lord Howe Island Pest Eradication Plan which also contains elements outlining non-target species mitigation measures. These documents will be referred to within this Plan.

This Plan sits alongside the Lord Howe Island Pest Eradication Plan which also contains elements outlining non-target species mitigation measures. These documents will be referred to within this Plan.

Summary of Proposed Management Actions

No.	Proposed management action	Section
Non-target species		
1	Implementation of the non-target mitigation plan will be based upon advice from the SAC. Weekly reporting to the SAC, the Project Manager, and the Steering Committee will enable real time tracking of non-target mortality, the efficacy of carcass search and removal operations and implementation of adaptive management. This information will be used to adapt carcass search and removal activities as required to further minimise impacts on non-target species, in particular threatened bird species.	4.2
2	Captive Management: The protection of LHPC and LHW requires that a proportion of the population of these species be taken into captivity during the eradication. Approximately 80 - 85% of woodhen and 50-60% of currawong population will be captured prior to the baiting and will remain in captivity for the duration of the operation; that is, until the baits and rodent carcasses have disintegrated and pose no further risk. The captive population will include both adults and juveniles, and will be collected from across LHI to capture genetic diversity within the population. Birds originating from the remotest parts of LHI (e.g., the summit of Mt Gower) will be transported to, and back from, the holding facility by helicopter to minimise transport time and its associated stress on the birds. The captive facility will be located on LHI and will be managed by a highly experienced aviculturist from Taronga Zoo.	3.1
3	Bait spreading to be confined to periods of the day when the majority of non-target species, particularly Providence Petrels, are inactive.	3.2
4	A dedicated collection team will remove and dispose of poisoned carcasses to reduce the incidence of secondary and tertiary poisoning through the settlement areas and selected beach and walking track areas. This dedicated team will be supplemented with additional personnel as required to ensure effective and adequate carcass collection and removal activities are undertaken and will average about 10 people per day after the initial bait drop. Adequate records of these activities will be maintained to verify that this occurs. Where non-target species impacts as a result of secondary poisoning are observed, additional resources will be allocated on advice of the SAC as required to minimise impacts on non-target species.	3.8
5	Helicopter staff and pilots to be briefed on the location of nesting areas for Providence Petrel, and how to minimise impacts when working within these zones. Observer teams to be strategically positioned both at sea and on land to monitor bird movement around the southern mountains	3.3
6	Monitoring of mortality and cause of death of non-target species, with weekly reporting of this information to the SAC, Project Manager, and Lord Howe island Rodent Eradication Team. Biological samples to be	3.6

No.	Proposed management action	Section
	taken when cause of death is required to be known.	
7	Label procedures to be followed to minimise accidental poisoning of non-target species.	3.5
8	Dogs trained to detect rodents will be engaged for the post operation and monitoring program.. Dogs will be trained to avoid non-target species on Lord Howe Island.	3.7
9	Spotlighting and shooting teams of Masked Owls during and after the program will be made aware of the location of vulnerable species and undergo training to minimise impacts.	3.4
10	A non target mitigation team will be established to monitor and coordinate team members to collect and collate collection of non target species from the settlement areas, designated walking tracks and beaches	3.8
11	Search protocols to facilitate and observe detection of carcasses from the settlement areas, walking tracks and selected beach areas will be developed within 2 weeks of the commencement of baiting	3.11
13	Disposal protocol will be developed to effectively and safely dispose of both rodent and non target carcasses on Lord Howe Island. Personnel will be trained in implementation of disposal protocols.	3.12
13	Additional emergency measures will be considered during the baiting operation with the aim of minimising non-target species mortality. This will include consideration of contingency measures included in this plan where non-target species impacts are high or unacceptable, as determined based on advice from the SAC or other experts.	3.16
12	Undertake identified selected beach and walking trails to locate rodent and non-target carcasses.	3.14
13	Selected field staff will be trained in the appropriate techniques of identifying moribund non target and rodent species. A documentation system will be developed to record all incidences.	3.15
14	Implement a monitoring of non target species post baiting program on LHI woodhens and currawongs	3.17
15	Reporting format and timelines protocols and requirements	4.1

1 Introduction

1.1 Background

The overall Lord Howe Island Rodent Eradication Project comprises the following documents:

- Part A – Overview
- Part B – Operational Plan (including Masked Owl eradication)
- Part C – Environmental Impact Statement
- Part D – Occupational Health and Safety Plan
- Part E – Project Biosecurity Plan
- Part F – Monitoring Plan
- Part G – Communications Plan
- Part H – Project Plan
- Part I – Procurement Plan
- Part J – Staff Recruitment and Training Plan.

This document (Non-target Species Impacts Mitigation Plan, hereafter referred to as the Plan) documents the non-target species impact mitigation measures to be implemented on Lord Howe Island during the REP.

The proposed operation involves an initial bait drop of the second generation anti-coagulant poison brodifacoum in Pestoff 20R form followed by a second application up to 21 days later to ensure all rodents have been exposed to bait.

Brodifacoum presents a significant risk of primary and/or secondary poisoning to a small number of non-target native species, in particular the Lord Howe Island Woodhen and Lord Howe Island Currawong (listed as threatened species under State and Commonwealth legislation) as well as other species. The use of helicopters for operational purposes on the island presents additional potential impacts on non-target species, particularly the Providence Petrel.

1.2 Objectives of the Non-target Species Mitigation Plan

The Lord Howe Island REP has prepared this Plan to outline the techniques to reduce the incidence of non-target mortalities as a result of the eradication operation. The aim of the plan is to provide clear and effective guidance for the REP team and project stakeholders in the implementation of mitigation, monitoring and adaptive management actions to minimise impacts on non-target species.

The objectives of the plan are to:

- Minimise mortality of non-target species as a result of primary/secondary/tertiary poisoning from baiting, in particular listed threatened and migratory bird species;
- Minimise disturbance to populations of non-target species from baiting techniques, aerial, hand broadcast and bait stations.
- Monitor the impacts of the REP on non-target species and the efficacy of mitigation measures to inform adaptive management and report to project stakeholders.

2 Scope

This Plan is a working document designed to provide field staff with guidance for non-target mitigation actions to be undertaken during the REP. Implementation of the Plan will be supported by ongoing advice from the SAC as the impacts of the REP on non-target species and the efficacy of mitigation measures included in this plan become apparent through ongoing monitoring and reporting.

The scope includes:

- A summary of the mitigation measures within the project design.
- A description of non target mitigation measures to be implemented including:
- Protocols to ensure systematic, targeted and effective carcass search through the settlement areas, walking trails and selected beaches, collection and disposal from the commencement of baiting until at least late August 2017;
- Contingency planning and adaptive management provisions with the aim of minimising non-target species mortalities;
- Provisions for long-term monitoring of the of Lord Howe Island Woodhen and Currawong populations for a period of at least 5 years following completion of baiting;
- Regular short-term and longer term reporting of non-target species mortality and the efficacy of carcass search and removal operations and other mitigation measures to key project stakeholders, including the SAC, the Steering Committee and LHIREP team.

The actions detailed in this Plan cover the time period of the REP. Following the proposed winter 2017 baiting operation, there is an approximate two year follow-up monitoring period to determine if the program has been successful in eradicating all rodents. Therefore, the proposed endpoint of the on-ground REP operations is November 2019.

2.1 Target Audience

The target audience of this Mitigation Plan is the REP team and project stakeholders. The Plan will provide a detailed adaptive management framework to mitigate, monitor, document and report on the impacts of the REP on non-target wildlife. The Plan will assist the REP in its development of project priorities and resource allocation by ensuring that implementation is guided by ongoing monitoring of impacts, and efficacy of mitigation measures and advice from relevant experts, such as the SAC.

Roles and responsibilities for key personnel are identified for each mitigation measure. Key personnel and stakeholders identified in the plan are:

- REP Manager
- Eradication Team Leader
- Mitigation Team Manager/Leader
- Lord Howe Island ranger-in-charge
- SAC: the Scientific Advisory Group established to advise implementation of the plan and assist with reducing non target casualties.
- Project Steering Committee: for the Lord Howe Island Pest Eradication Project.

2.2 Summary of Non-target Species Impact Mitigation Measures Considered

Documents were produced from 2009-2015 examining the impacts of the 2017 LHIREP baiting operation on non-target species and evaluating measures that could be implemented to reduce the impact in a subsequent baiting operation. These are:

- Lord Howe Island DRAFT Plan of Action-bait toxicity trials 2 and Biodiversity Benefits Project (November 2015)
- Lord DRAFT Plan of Action-bait toxicity trials 2 and Biodiversity Benefits Project (November 2015)
- Zoo management for LHI Woodhen and LHI Currawong associated with the Lord Howe Island Rodent Eradication project
- Monitoring, Evaluating and Reporting the biodiversity benefits of eradicating exotic rats from Lord Howe Island 2015

Of the many issues raised by these reports, 3 were determined to be worth pursuing for the LHIREP. These are:

1. Captive Management Program for Listed Endangered Species
2. An intense two staged baiting program during winter period June – August 2017
3. A planned and resourced carcass collection process with a dedicated team in designated areas of the Island, including the settlement areas.

3 Overview of Mitigation Measures

A number of these measures are copied from other REP Plans, with modifications made to reflect changed permit and operating conditions from when the earlier LHIREP plans were written.

3.1 Captive Management of Listed Threatened Species

The proposed rodent eradication poses a significant threat to two Listed Threatened Species on Lord Howe Island, the Lord Howe Island Currawong *Strepera graculina crissalis* and Lord Howe Woodhen *Gallirallus sylvestris*. Currawongs are very unlikely to eat the baits deployed in the rodent eradication programme but there is a significant risk that they will succumb to secondary Brodifacoum poisoning by eating poisoned rodents. To mitigate for this, as many individuals of the population (approximately 50-60%) as possible from across the island will be captured immediately prior to the baiting, and will remain in captivity until baits and rodents breakdown (estimated to be approximately 100 days post baiting), after which the risk of secondary poisoning for currawongs is likely to be negligible (as by then poisoned rodents will no longer be a potential food source). Although approximately 90% of those rodents poisoned are likely to die in dens underground (Vercauteren et.al. 2002, Howard et al 1999) or amongst dense vegetative cover, it is possible that a number of those currawongs left at large during the eradication will consume baited rodents, thereby placing some of the current population at risk. It should be noted, however, that rodents do not from a large part of the Currawong's diet (Carlile and Priddel 2006) and it is unlikely that a large number of free-ranging Currawongs will die from secondary poisoning.

The captive facility will be located on LHI and will be managed by a highly experienced aviculturist from Taronga Zoo. To ensure all husbandry protocols are correct, a trial involving 10 birds was conducted in 2013 (Taronga Conservation Society Australia, 2014) with all birds successfully released. Holding currawongs in captivity from approximately June until October may disrupt the birds' breeding season for one year. However, as stated above, it is unlikely that all birds left in the wild will be poisoned by the operation and thus disruption would not affect the entire population, and given that currawongs can live for up to 24 years (ABBBS 2016) such disruption is not expected to result in long-term harm to the population.

The Lord Howe Island Woodhen is at risk of both primary and secondary poisoning during the eradication program. Woodhen have been recorded eating non-toxic Pestoff bait pellets. They are also known to eat rodents that have been poisoned during the ground baiting that currently takes place around the Settlement area.

Approximately 80 - 85% of the population will be captured prior to the baiting and will remain in captivity for the duration of the operation; that is, until the baits and rodent carcasses have disintegrated and pose no further risk (expected to be around 100 days). The captive population will include both adults and juveniles, and will be collected from across LHI to capture genetic diversity within the population. Birds originating from the remotest parts of LHI (e.g., the summit of Mt Gower) will be transported to, and back from, the holding facility by helicopter to minimise transport time and its associated stress on the birds. The captive facility will be located on LHI and will be managed by a highly experienced aviculturist from Taronga Zoo. Woodhen have previously been successfully held in captivity (Gillespie 1993) so information is already at-hand for captive management. A trial involving of 22 birds was conducted in 2013 to ensure all husbandry protocols are correct (Taronga Conservation Society Australia, 2014). At least one other captive colony will be established on the Australian mainland. These actions, namely the establishment of on-site and off-island captive facilities, are in accordance with recommendations made in the "Recovery Plan for the Lord Howe Woodhen *Gallirallus sylvestris*" (NPWS 2002) which calls for the development of a plan for the establishment of an on-island captive-breeding facility in the event of a substantial reduction in woodhen numbers; and the establishment of captive populations at sites other than LHI as insurance against a catastrophe affecting the wild population.

Action	Responsibility
Undertake captive management program for LHI Woodhen and Currawongs on LHI Establish captive management facility on mainland to ensure insurance for woodhen populations	LHIREP Manager/ Taronga Zoo LHIREP Manager

3.2 Baiting Strategy: Temporal and Spatial Considerations

One of the primary management approaches to minimise the risk of poisoning to migratory sea birds, is to conduct the baiting operation during winter when numbers of species present on the island are significantly reduced. A significant proportion of these species' populations are away from the island during the winter, and as a result may be less significantly affected by secondary or primary poisoning.

The listed Migratory species, the Providence Petrel, breeds principally in the southern mountains, particularly the two mountain summits. From March to November annually they arrive at LHI from mid-afternoon onwards to display in the airspace above the breeding sites, find mates and visit burrows (Hutton 1991). Baiting is currently scheduled to commence in June 2017. Helicopter strike with those birds involved in courtship and incubation will be avoided by restricting helicopter flights around the southern mountains to midday on each day of baiting. The majority of returns from foraging to provision chicks occur after early July (Marchant and Higgins 1990) avoiding any overlap with proposed helicopter movements, which will be monitored closely during the program..

Whilst temporal considerations are important, it must also be recognised and acknowledged that due to the persistence of the toxicity of the bait, primary non target mortality could continue until the baits disintegrate, and thus a secondary poisoning risk is present. However, this is expected to be minimal as the Providence Petrels forage in deep water at sea where its diet consists of fish and squid. Ongoing monitoring during and following the baiting operation will be used to determine the efficacy of mitigation measures and the significance of impacts on non-target species. Where non-target species mortality is significant (which is expected to be minimal), procedures and protocols will be adapted and contingency measures will be adopted. These decisions will be informed by the SAC and project stakeholders.

Action	Responsibility
Undertake baiting program during winter while the majority of migratory seabirds are absent from LHI group. Undertake aerial baiting of the southern mountains between mid morning and early afternoon to avoid Providence Petrel flight paths.	LHIREP Manager

3.3 Helicopter Over Flight Heights Around Providence Petrels

Only experienced pilots with island eradication bait laying experience will be used during the REP to aerially bait areas around providence Petrel nest sites. Pilots will be briefed daily before flights to be well informed of the location and direction of departing foraging birds before baiting begins. Although it is very unlikely any birds will be present due to early departure from the island to foraging grounds at sea, pilot safety and bird impacts at anytime must be taken into consideration.

Providence Petrel breeding grounds are located on the southern end of Lord Howe Island on the slopes of Mt Lidgebird and Mt Gower. Due to the inaccessible terrain, a mitigation team member will view all baiting over-flights from Capella Hill which provides a clear view of all mountainous nesting areas on the southern mountains. In order to view Providence Petrels flight paths behind the mountains a second mitigation team will be observing flight paths via a boat from the ocean behind Mt Gower. Should Providence Petrels display unusual behaviour or become overly agitated during baiting over-flights, the observer will contact the pilot by radio to instruct on an alternative action, which may include gaining further altitude to reduce the proximity to birds while maintaining the flight path, or abandoning the flight path and returning at a later time from a different altitude. Both observers will, in any case, provide a commentary on the birds' behaviour to the pilot during each flight, to supplement or confirm what the pilot will be seeing beneath the helicopter.

Action	Responsibility
All aerial baiting over seabirds colonies to be conducted while foraging birds have departed for sea feeding grounds on LHI	Mitigation Team Manager
Two observer teams will be on site and in contact with pilots. If unacceptable disturbance is observed baiting is to be temporarily ceased pending advice from SAC and mitigation Team Leader	Mitigation Team Manager
Report over flight observations of bird movement to pilots ASAP from observation points nominated.	Mitigation Team Manager / Pilots

3.4 Spotlighting and Shooting Masked Owls

Spotlighting is expected to be a component of the field work in both locating and eliminating surviving Masked Owls during the REP. Spotlighting is generally low-impact on non-target species although one area of concern has been identified. Firstly, large numbers of burrow-nesting petrels are active at night and may be drawn to light beams used for locating owls. Disorientation of some birds is possible in this circumstance and care will need to be exercised by field staff to keep light beams as horizontal as practical in searching for owls. Field staff will be fully briefed on possible impacts and shall be instructed to minimise the use of spotlights around Petrel nest sites. If impacts on breeding colonies are observed, SAC advice will be sought to assist with minimising further impacts. It needs to be recognised however that although the majority of Masked Owls are likely to succumb to secondary poisoning by eating poisoned rodents, spotlighting will be an essential tool for locating owls and some impact may occur as a result of searching for remaining owls. Any deleterious impacts to wildlife that results from these activities shall be fully documented.

The primary rifle calibre to be used is the .17 HMR. While shooting is expected to account for the majority of owls surviving secondary poisoning from baiting, the numbers are expected to be relatively low. . It is estimated that currently there are between 10 and 100 pairs present on LHI (DECC 2007). Shooting teams will only comprise of fully qualified and experienced licensed hunters under LHI Firearms Policy Regulations.

Maps of known burrowing petrel breeding colonies will be provided to staff and staff will be trained in methods for minimising impacts on burrows, vegetation and soils. This is to ensure that the trampling of burrows is minimised, particularly during breeding season if shooting activities are to be undertaken.

Action	Responsibility
All hunting staff to be briefed on the potential impact of spotlighting Masked Owl	Eradication Team Leader
All hunting staff to be made aware of the location of burrowing petrel colonies and trained in methods for minimising impacts on burrows, vegetation and soils.	Eradication Team Leader
Any negative impacts are to be recorded and reported with advice sought to further mitigate future impacts	Eradication Team Leader

3.5 Bait Quantities, Label Requirements and APVMA Conditions

Pestoff 20R baits will be used as per the APVMA conditions and label requirements.

To further reduce the likelihood of accidental poisoning of non-target species, Australian Pesticides and Veterinary Medicines Authority permit conditions and brodifacoum label procedures for handling, transport, clean-up and disposal of pesticides will be followed.

Action	Responsibility
All conditions associated with bait handling, spreading and disposal to be adhered to.	LHIREP Manager
Handling, transport, clean-up and disposal of the pesticide *brodifacoum* must be undertaken in accordance with the Pestoff 20R label requirements and APVMA permit conditions.	LHIREP Manager

3.6 Collection of Biological Samples

Samples from deceased wildlife may be collected for two different reasons during LHIREP; 1) to confirm species and determine sex of non-target species killed, or 2) to determine the levels of brodifacoum in deceased individuals of the non-target populations.

Samples for brodifacoum testing

The collection of samples to assess the amount of brodifacoum within the non-target species is slightly more labour intensive than genetic samples, although very straightforward when abdomens are opened for assessment of haemorrhaging. Samples can be collected to confirm the cause of death on those carcasses where it is unclear, as well as providing information on toxic loads and potentially the longevity of the toxin within non target populations. It must be noted that sample information will have to be sent to Brisbane for testing at a NATA accredited analytical laboratory.

Livers provide the most appropriate tissue for brodifacoum samples to be collected from. These must be frozen once collected. Ten samples to be collected from code 2 and 3 carcasses (see Appendix 3) per species per month. The sample collection process will be in accordance with the 'NZ vertebrate pest residue database guidelines', copies of which will be held on Lord Howe Island and used as a reference by field staff.

Action	Responsibility
Genetic samples will be taken from all non-target species that are identified as likely to have been killed by brodifacoum poisoning.	Mitigation Team Manager
10 samples of code 2 & 3 non-target species carcasses to be collected each month to test for brodifacoum levels	Mitigation Team Manager
Information on non-target species mortality and cause of death will be collected, collated, and reported on a weekly basis to the SAC, Steering Committee, and LHIREP.	Mitigation Team Manager

3.7 Dog Training in Relation to Non-target Species Avoidance

Dogs used for detecting rodents on Lord Howe Island are specifically trained and certified to avoid impacts on non-target species during the Monitoring Phase of the program.

Only dogs that have undergone rigorous training and have met assessment criteria will be used on Lord Howe Island during this phase of the operation to ensure that impacts on other wildlife are minimised.

Dogs will undergo training for deployment to Lord Howe Island in late August 2017. A significant part of the training, in terms of both duration and cost, is the training for aversion to non-target species. Dogs are trained to be absolutely obedient and to be averse to the scents or presence of any animals other than rodents. The dogs undergo two levels of assessment based on criteria developed specifically for this project, and are certified by the Project Dog Training Coordinator before they are considered to have met the standard required for use on the island.

Action	Responsibility
All dogs to be trained to avoid non-target species. All dogs used on Lord Howe Island must meet the requirements of the training modules contained in the Lord Howe Island Pest Eradication Project Dog-Training Standards and be certified by the Project Dog Training Coordinator as having met those requirements prior to commencement of hunting operations	LHIREP Manager
Any impacts of dogs on non-target species to be recorded and reported	Eradication Team Leader

3.8 Non-target Species Impacts Mitigation Team

As part of the REP aerial baiting and hunting teams, a team led by a designated Mitigation Team Manager will be present on Lord Howe Island for the duration of the baiting operation and at least until 31st August 2017.

A core team of mitigation personnel will be supervised by the Mitigation Team Manager or Eradication Team Leader from the commencement of baiting. These staff will be employed with the specific task of implementing non-target mitigation measures on Lord Howe Island as prescribed in this plan. The baiting teams are expected to range from 22 -30 personal. This larger team allows more flexibility in implementing the core functions of the team, including the search and removal of animal carcasses through the settlement areas, walking trails and designated beach areas. The collection and removal of animal carcasses will be an important part of both non target mitigation and human health concerns through these areas. These teams will also participate in the initial hand broadcast baiting of the settlement areas on the island.

The mitigation team will be supported by other baiting REP staff when not required to undertake other duties. It is expected that an average of 10 personnel per day over the winter period will be required to adequately undertake carcass search and removal to minimise impacts on non-target species through designated areas. As such, it will be the responsibility of the Eradication Team Leader and Mitigation Team Leader to ensure that resources are allocated accordingly.

If non-target species mortalities from poisoning are high, additional staff resources will be allocated from the broader REP team, and/or any other personnel on Lord Howe Island to ensure that carcass search and removal efforts minimise non-target species impacts. Where impacts on non-target species are unacceptable and on the advice of the SAC additional staff must be appointed to assist with rodent carcass collection and removal efforts.

Staff involved in non target species mitigation work will receive induction and training as detailed in appendix 4.

Action	Responsibility
A Mitigation Team Leader will be appointed from the commencement of baiting until at least the end of the distribution of bait. The Mitigation Team leader will be responsible for coordinating and rostering team members, and for the collection and collation of information on non-target species mortality, documenting and reporting this information, and using this information to further inform carcass search and removal.	LHIREP Manager
Once baiting has occurred and been completed during the 2 baiting regimes, the teams will be dedicated solely to carcass search and removal and monitoring of non-target species mortality around the settlement areas and designated walking tracks and beaches..	Mitigation Team Leader
Additional personnel will be tasked with non-target species impact mitigation tasks as required to meet	Eradication Team Leader Mitigation Team Manager

the requirements of the plan, in accordance with baiting progress and non-target species mortalities and on advice from SAC. This includes the requirement for an average of 10 personnel per day over the winter period to be undertaking carcass search and removal activities.	
Non-target mitigation efforts, including carcass search and removal efforts (dates, person hours, location, etc) will be recorded and reported to project stakeholders. This information will also be used to inform systematic and targeted carcass search and removal activities across the island and to ensure that aerial baiting operations do not surpass search and collection efforts.	Mitigation Team Manager

3.9 Collection and Removal/Disposal of Carcasses

The removal of carcasses of both rodents and non-target species killed during the baiting phase of the REP project is proposed to minimise the incidence of secondary and tertiary poisoning of non-target species around the settlement areas only. It will be impossible to remove carcasses from the remote areas of the island.

The premise is that once a carcass is removed, the toxin it contained is no longer available to cause poisoning to no target species on the island, provided it is disposed of appropriately. The removal of dead carcasses from around the settlement area will also reduce the smell of decomposing rodents from around resident's homes and lodge accommodation. This will be confirmed by records maintained by the Mitigation Team Leader and reported to project stakeholders as required.

Trials conducted on Lord Howe Island for toxicity efficacy show that rats take 4 to 10 days to die (Wheeler et al in prep) and mice take 2-20 days to die from brodifacoum poisoning (O'Dwyer 2016). Searches of settlement baited areas will commence from about 3 days after bait has been laid in any area and search effort will continue in a targeted and systematic manner at the instruction of the Mitigation Team Leader. Following bait drops, observations by a mitigation team member will be made to determine the time taken until carcasses first appear, in order to confirm the lag time between bait being laid and the recommended commencement of carcass search and removal. Residents will also be advised to contact the REP team in order to have any exposed dead rodents removed from around the settlement area. A number of areas on the island (particularly in the southern and northern mountainous parts of the island) will be too steep or unstable to support a physical search and removal of carcasses. It is acknowledged that some target and non-target species may be scavenged in areas not accessible to staff.

Action	Responsibility
Baiting operations will be limited in scope and timed to ensure that baited settlement areas can be systematically and comprehensively searched and carcasses collected and disposed of to minimise risk to non-target species on the island.	LHIREP Manager; Mitigation Team Leader
Regular aerial searches and reconnaissance by	Mitigation Team Leader;

mitigation team members across the settlement area will be undertaken to ensure that carcass search and removal is also targeted to areas where high densities of carcasses are observed around the settlement areas.	Eradication Team Leader
Systematic, targeted and adequate carcass search and removal will be confirmed by records maintained by the Mitigation Team Leader and reported to project stakeholders.	Mitigation Team Leader

3.10 Non-target Species

Of the birds that forage in the terrestrial environment on Lord Howe Island, the Woodhen and Currawong provide the largest non-target risk due to their foraging and diet habits. Woodhens breed and forage in the settlement and elevated areas of the island and will scavenge dead rodents while currawongs will also feed on dead or moribund rodents that may have taken bait.. Both these species will be subject to captive management program during the baiting program.

Black/mallard ducks are known to take the Pestoff baits. As such, the carcasses remain toxic could possibly contribute to secondary or tertiary poisoning of non-target species. if carcasses will be found along the coast, as they primarily inhabit the coastline, but also on the plateau, where they also forage and roost. Black/mallard duck are primarily located around the airport around ponds to the east of the airport.

Given the distribution and behaviour of the primary non-target species susceptible to poisoning and the search effort will initially be focussed on the selected beaches until these areas have been systematically covered. Search and collection will then systematically move to higher elevation and other terrain until available carcasses are collected and removed.

Action	Responsibility
Following baiting of an area, systematic carcass search and removal will be targeted at coastal areas and the coastal escarpment in the first instance, followed by systematic coverage of higher elevations and all accessible terrain until all available carcasses are collected and removed.	Mitigation Team Leader

3.11 Search Methodology

The concentration of the search effort will be dependent on the progress of baiting. Due to the relatively small scale of Lord Howe Island, it is expected that baiting for each of the two bait drops (undertaken up to 21 days apart) will be completed in 3-4 days. Once the baiting has been completed, teams will begin systematic search grids through the settlement areas, beaches and high profile walking tracks for carcasses. As stated above, the aerial baiting effort will need to be limited in scope and sequencing to ensure that baiting does not surpass the capacity of carcass search and removal efforts.

In addition to systematic non target carcass search and removal coverage of the island, the Mitigation Team Leader will develop a search protocol to facilitate effective observation and detection of carcasses in the settlement terrains areas of the island. This protocol will be developed before the commencement of aerial baiting and will be adapted by the Mitigation Team Leader based on experience gained over the course of the carcass search and removal activities as required to ensure that they are effective. The protocol will also be informed by advice from the SAC and should include:

- The identification of systematic search grids through the settlement area to search for carcasses based on GPS grids during the baiting,
- Methods to maximise the likelihood of carcass discovery or detection, preferred distance between personnel, or adapted flora and fauna survey methodologies;
- Altered methods to support adequate detection in difficult terrain or vegetation, e.g. rocky or vegetated areas; and
- Prioritisation of areas based on their likelihood of supporting carcasses

All personnel undertaking search and removal activities will be trained by the Mitigation Team Leader in the implementation of the search protocol.

Action	Responsibility
A search protocol to facilitate effective observation and detection of carcasses from settlement areas, beaches and designated walking tracks will be developed prior to the commencement of aerial baiting. This protocol will be continually adapted and improved as required based on experience gained over the course of the carcass search and removal activities to ensure that they are effective. Advice will be sought from the SAC on the protocol.	Mitigation Team Leader
All personnel undertaking search and removal activities will be trained in the implementation of the search protocol.	Mitigation Team Leader

3.12 Carcass Disposal

Brodifacoum breaks down in the environment from the action of soil micro-organisms. As pellets and carcasses containing brodifacoum decompose, the toxin also breaks down. The baits and poisoned carcasses can remain toxic for at least seven months after being broadcast. The aim of carcass removal is to remove and dispose of poisoned animal carcasses to ensure that they are unavailable to be scavenged by woodhens and currawongs when they are realeased. Burial and or incineration at the Waste Management Facility is a practical means of disposal available in remote field situations encountered on Lord Howe Island.

All carcasses encountered during search and collection must be disposed of in an appropriate manner that ensures safe disposal and meets label requirements. A disposal protocol will be developed by the Mitigation Team Leader prior to the commencement of baiting that will ensure this objective is achieved. This will be based on 2 options for burial and incineration that exist on Lord Howe Island – in preferred order these are;

- use existing incinerator located at the Waste Management Facility (WMF) to incinerate carcasses (preferred option).
- purpose dug deep burial pits located at the WMF to appropriate depth to allow microbial breakdown of carcasses.

Opening of the skin and body cavity to check for haemorrhaging will also greatly assist decomposition of carcass by allowing better contact between soil and tissue rather than fur/feathers.

Action	Responsibility
A disposal protocol to facilitate effective disposal of carcasses will be developed before commencement of baiting. This protocol will be continually adapted and improved as required based on experience gained over the course of the carcass search and removal activities to ensure that they are effective. Advice will be sought from the SAC on the protocol.	Mitigation Team Leader
All personnel undertaking search and removal of carcasses activities will be trained in the implementation of the disposal protocol.	Mitigation Team Leader

3.13 Documentation

TARGET SPECIES (rodents and owls)

Dead rodents collected will not be recorded however, recording of the following points is mandatory for all non target species carcasses found:

- The date
- The search area – e.g. Lagoon Beach, walking tracks etc.
- The species, sex and carcass condition using standard categories
- The number of and GPS point of each deceased individual found.
- A field autopsy examination to establish whether internal haemorrhaging is evident and thus whether brodifacoum poisoning is the likely cause of death (by a suitably trained employee)
- The disposal method and location
- Any obvious signs of external trauma

NON TARGET SPECIES

For data collection and recording protocols refer to section 4.1.

Equipment list required for searching and burial

Equipment	Purpose
Gloves	Personal hygiene
Sharp knife	To check carcass for internal haemorrhage
GPS	Record location of carcasses and burial sites & search effort
Plastic bags/pack liners	For carrying carcasses to a disposal site
Note book & pencil	For recording data and labelling samples
VHF radio	For coordinating search efforts with other team members
Specimen vials and labels	Storing tissue samples

Pocket knife/scalpels and sharps containers	For sample acquisition
Solid blunt object (mallet, shovel, steel pipe etc)	For euthanasia

Action	Responsibility
Mitigation team members and other LHIREP staff will undertake carcass collection, recording and disposal. Searches will be based on baiting progress, focussed on recently baited areas and coordinated by the mitigation team manager. The level of resourcing will meet the requirements set out in this plan.	Mitigation Team Manager
All non target carcasses collected and disposed will be recorded and reported	Mitigation Team Manager
The level and area of search effort will be recorded and reported	Mitigation Team Manager
Monitoring of carcass disposal sites will occur	Mitigation Team Manager

3.14 Selected Island Beach and Walking Track Searches

Beach and walking track patrols will be undertaken to as required to assist with targeted and systematic carcass search and removal. Of particular attention will be the Lagoon foreshore, Neds Beach and Settlement Beach. Blinky Beach will also be monitored for non target carcasses. Walking tracks including but not restricted too, Transit Hill, Stevens Reserve and Foreshore Walk will also be monitored for carcasess. As a minimum, these will occur in the days immediately following each bait drop, however additional searches will be undertaken as required where non-target species mortality is reported. It is less likely to be effective in locating rodent carcasses, but may assist in the evaluation of the number of possible non-target carcasses. These searches will allow staff to locate carcasses, GPS point and location description and remove them for testing where deemed necessary.

Action	Responsibility
Undertake selected beach and walking trail searches of the island as required to assist with targeted and systematic carcass search and removal.	LHIREP Manager; Mitigation Team Leader

3.15 Euthanasia of Poisoned Wildlife

Euthanasia of poisoned wildlife is considered appropriate for the welfare of affected animals, and to enable mitigation personnel to collect and dispose of what will become a toxic carcass once an animal dies. The removal of these animals may reduce the threat of non-target species poisoning. Euthanasia will only be a feasible option for those animals that are very easily caught and restrained e.g. completely or nearly immobile animals. If an animal is still mobile and not easily caught, it should not be chased. All woodhens and currawongs will all be bought in for treatment with antidote Vitamin K in all instances.

In order to euthanize moribund non target species in New South Wales, necessary training and the appropriate ethics approval to euthanize non-targets is required. Personnel will be trained in euthanasia by blunt trauma/ cervical dislocation as this method is practical for remote field use. Unless a vet is present, it is recommended that all sick animals that can be accessed to be euthanased or rendered unconscious with a strong blow to the head, sufficient for immediate loss of consciousness and for them not to recover.

This method must be properly applied to be effective and humane; therefore training to ensure sufficient skill of the operator is essential. It is proposed that training be undertaken by a number of staff in order to meet these ethics requirements with visiting vets while on the island. These trained staff will then be assigned to search teams during the monitoring period. An appropriate mallet or similar instrument should be used and birds need to be restrained adequately with the head held against a solid surface and one blow with sufficiently force needs to be applied at an appropriate angle to the skull. If not performed correctly, various degrees of consciousness with accompanying pain can occur. All incidents of euthanasia must be documented and reported in weekly reports to SAC and the steering committee. Documentation must include details of the demeanour/condition of the bird prior to euthanasia, as well as details of the method and efficacy of euthanasia. This process will enable appropriately qualified and experienced personnel to make informed assessments and provide advice as required.

Action	Responsibility
Moribund poisoned target and non-target species to be euthanized by appropriately trained personnel and carcasses disposed as per disposal protocols	Mitigation Team Leader
All euthanasia of non-target species to be documented and reported	Mitigation Team Leader

3.16 Contingency Planning and Adaptive Management Measures

Given the residual uncertainty regarding the magnitude of the impact of baiting on non-target species, the efficacy of the mitigation measures proposed, and the risks associated with the action for threatened bird species, an adaptive management framework is critical to ensure impacts are effectively managed over the duration of the operation.

The reality of logistics associated with undertaking works on Lord Howe Island means that large scale approaches for mitigating the effects of the REP baiting operation must be planned and organised and the scope for implementing new measures is limited. However, if the operation is not managed effectively it could lead to long-term and devastating impacts on populations of threatened species, in particular the LHI Woodhen and LHI Currawong. As such, all efforts must be made to ensure that impacts are minimised and this will require the investigation and implementation of appropriate mitigation measures.

Within two weeks of the commencement of baiting, the Mitigation Team Leader on the advice of SAC and other relevant experts, will identify key threshold impact levels (e.g. number of seabirds strikes via helicopter flights, number of moribund currawongs or woodhens found), or as well as contingency measures that will be implemented should those thresholds be breached. Thresholds will be based on the acceptability of the level of mortality (if any) on populations of Providence Petrels (and other species where relevant), considering the ability of these populations to recover in the short and long-term and conservation advice and published information for these species.

The following contingency measures must be considered by the Mitigation Team Leader and the SAC and allocated to appropriate impact thresholds:

- Allocation of additional personnel to carcass search and removal, either from the LHIREP team, or transport of additional of trained personnel on the island;
- Modification of search procedures (including additional search protocols and disposal protocols;
- Temporary suspensions of aerial baiting operation until risks are mitigated, particularly for Providence Petrels.

If a contingency measure cannot be implemented due to logistical reasons, this must be adequately justified. Adopted contingency measures must be implemented.

Action	Responsibility
Within two weeks of commencement of baiting, the Mitigation Team Leader based on advice from SAC and other relevant experts will identify impact thresholds for Providence Petrels and corresponding contingency measures based on the content of this plan. These will be reported to project stakeholders, including the Steering Committee and DSEWPAC.	Mitigation Team Leader and SAC
Based on the results of non-target species mortality monitoring, the adoption of specific contingency measures must be implemented if requested by SAC or LHIREP	Mitigation Team Leader and SAC

3.17 Monitoring the Extent of Non-target Mortality

Monitoring of wildlife populations on Lord Howe Island will be consistent with LHIREP's guidelines. This will include:

For a period of at least 5 years following the completion of baiting:

- annual whole-of-island census and breeding success monitoring of the Lord Howe Island Woodhen population;
- annual census and breeding success monitoring of the Lord Howe Island Currawong.

Survey information for other species will be collected as per the ongoing Lord Howe Island Board monitoring regimes. The survey area for Woodhen and Currawong monitoring may be increased if resources are available, and the following monitoring regime will be implemented in relation to Lord Howe Island birds if resources permit:

- annual whole-of-island census and breeding success monitoring of Woodhen and populations for a period of at least five years following completion of aerial baiting as per current annual monitoring program .
- re-survey and continue to refine Woodhen and Currawong numbers and study areas annually for five years following the baiting.

Action	Responsibility
Implement the monitoring of non-target species.	LHIREP Manager

4 Reporting Requirements

4.1 Field Data and Sample Collection

The mitigation team manager will be responsible for the effective documentation of field data and sample curation. The SAC and LHIREP will provide guidance and may request additional data to be documented as the program proceeds. A Microsoft Excel spreadsheet will be used to store and collate all records relevant to the mitigation team work. Field data will be collected in record sheets, see Appendix 2, based on the required information contained in table 2 below.

Table 2 – Dead non-target species, required information for collection

Identifying No/Code	Species, date and finder code e.g. NGP_dd/mm/yy_LG_1
Date	Full dd/mm/yy format
Time	24 hr clock
Species	Common name
Live/Dead	
Euthanised	NA/Y/N - if yes, method.
Carcass code	Carcase condition codes as provided by BMS
GPS Easting	
GPS Northing	
Finder/Recorded by	Name and code e.g. Anthony Wilson (AW)
Location	Keep short - but provides verification of GPS if something goes awry
Necropsied	Y/N. If yes, comments? Brodifacoum confirmed?
Adult/Juvenile	
Sex	M-F-UN - if known, how determined? (necropsy/morphometric - GPs can be sexed in the field with bill measurements - would provide real time data)
Genetic Sample Collected	Y/N - if Y use ID code with a G in it?
Broadifacoum Sample collected	Y/N - if Y use ID code with a B in it?
Comments	Particularly info if found
Banded	Y/N if yes include number
Disposal method	Incineration/ burial
GPS tracklog ID	

4.2 Reporting Structure and Frequency

Weekly reports will be produced and provided by the Mitigation Team leader directly to the SAC, Steering Committee, and REP Project Manager. Reports will summarise non-target species mortality, the percentage of populations of threatened birds poisoned to date, and the efficacy of carcass search and removal operations. During the REP reports will be produced and reported by the Mitigation Team Leader. Once phase 2 (second baiting) of the REP commences, the reports will be compiled and reported directly to the above groups by the Eradication Team Leader who will also be filling the role of Mitigation Team Leader.

The Mitigation Team Leader, and following his departure from the island, the REP Manager shall be responsible for ensuring the comprehensive collection and documentation of the required information on non-target species mortality. Included in this is the accurate and comprehensive compiling of information in the non-target mortality spreadsheet and the curation and transfer of biological samples.

More frequent reports will be provided if requested. The reports will include:

1. Baiting progress – including baiting dates, quantities and broadcast areas;
2. Maps and locations of non-target carcasses;
3. Summary of non-target mitigation works undertaken;
4. Summary of samples collected to date;
5. Number and species breakdown of carcasses found;
6. An ongoing figure of carcasses collected since baiting commenced;
7. Incidental relevant information;
8. An updated spreadsheet containing the information described in section 4.1;
9. Details of any euthanasia events.

Action	Responsibility
Weekly reports will be provided to SAC, the LHIREP manager, the steering committee and in accordance with this plan.	Mitigation Team Leader

4.3 Interim and Final Reports

An interim and final report will be completed for the SAC, the steering committee and the LHI Board within 3 months following completion of baiting and once the mitigation team complete works on Lord Howe Island. The report will be completed by the LHIREP Project Manager. A draft of the report will be forwarded to SAC for final advice and comment. The report will summarise monitoring results collected on non-target species mortality, in particular the impacts on populations of threatened Lord Howe Island Woodhen and Currawong.

Action	Responsibility
An interim report and final report will be provided to SAC, the steering committee and LHI Board within 3 months following completion of baiting and in August 2017	LHIREP Manager

4.4 Acknowledgements

This non-target species impact mitigation plan has been produced with the significant input of the SAC members, Anthony Wilson and as well as members of the LHIREP.

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Appendix 2 – Indicative Field Data Recording Sheet

Team member:

Date	Time	Species	Carcass code	Scavenged?	Location	GPS easting	GPS northing	Brodifacoum Y/N/?	Samples collected	Notes

Carcass code: 1 - Alive, 2 - Good condition

3 Decomposed but organs intact

4 - Advanced decomposition, 5 - mummified or

Samples collected: (G)- genetic or (B) - tissue samples for brodifacoum testing

Notes to include: band numbers, euthanasia, disposal method, brood patch presence skeletal

Appendix 3 – Carcass Codes

Carcass Condition Classification (following Geraci and Lounsbury 2005)

CODE 1 – Live Animals

Useful for: morphometrics, biopsy, blood studies, toxicology, microbiology etc

CODE 2 – Carcass in Good Condition (Fresh)

Useful for: morphometircs, genetics, toxicology, nutritional analyses, gross pathology

Characteristics: normal appearance, usually with little scavenger damage; fresh odour, minimal drying and wrinkling of skin, eyes and mucous membranes; eyes clear; viscera intact and well defined (liver is a good indicator), gut contains little or no gas.

CODE 3 – (Decomposed but organs basically intact)

Useful for: molecular analyses, gross pathology, histopathology, toxicology,

Characteristics: carcass intact, , possible scavenger damage, mild odour, , mucous membranes dry, , eyes sunken or missing, muscles soft and poorly defined, blood haemolyzed, viscera soft friable but still intact,

CODE 4 – (Advanced decomposition)

Useful for: morphometrics, life history, DNA, paristology, gross pathology

Characteristics: carcass may be intact but collapsed, skin sloughing, severe scavenger damage likely, strong odour, muscles nearly liquefied and easily torn, viscera friable and difficult to dissect, gut gas filled,

CODE 5 – (Mummified or Skeletal Remains)

Useful for: morphometrics, gender and DNA analyses

Characteristics: skin draped over skeletal remains, any remaining tissues are dessicated.

Appendix 4 – Mitigation Team Training and Induction Checklist

- The aims of the non target mitigation program
- The methods to be employed (familiarity with the mitigation plan)
- Identification of seabird species (e.g. Provenance Petrels)
- What brodifacoum poisoning looks like (necropsy process)
- Genetic and brodifacoum sample collection, labelling and storage
- Data collection requirements
- Special Management Area briefings
- Briefing on behaviour around nesting birds
- Disposal methods for poisoned carcasses at the Waste Management Facility (WMF)
- Euthanasia – in which circumstances it will occur, methods to be used and equipment available
- Burrowing petrel colony locations and methods for determining reduction in collapsing burrows during carcass collection and Masked Owl eradication shooting programs.

Lord Howe
ISLAND BOARD

Lord Howe Island Rodent Eradication Project

NSW Species Impact Statement

February 2017

Appendix F - Masked Owl Package

F.1 Draft Masked Owl Eradication Plan

F.2 Masked Owl Research Report

F.3 Masked Owl Genetics Study

DRAFT Lord Howe Island Masked Owl Eradication Plan

Prepared for

The Lord Howe Island Board

By

Terence O'Dwyer and Nicholas Carlile

Office of Environment and Heritage, P.O. Box 1967, Hurstville, NSW 2220.

June 2016

Background and justification

Masked Owls (*Tyto novaehollandiae*), along with a number of other owl species, were introduced to Lord Howe Island in the 1920s to help control introduced Ship Rats (*Rattus rattus*). Of the owl species introduced, only Masked Owls remain on the island and the species is now considered to be a pest. A rodent eradication plan (REP) for Ship Rats and House Mice (*Mus musculus*) is proposed for Lord Howe Island in winter 2017. Concurrent with the REP, the Lord Howe Island Board proposes to also eradicate Masked Owls. Milledge (2010) previously performed an extensive study on the distribution and habitat use, movements, home ranges, population size, roost sites, and diet of the Lord Howe Island Masked Owl population and that research, as well as a recent workshop involving proponents for the owl eradication, are used to inform this currently proposed Masked Owl eradication plan (MOEP).

It was previously thought that Lord Howe Island Masked Owls were sourced from Tasmania (*Tyto n. castanops*), where the species is listed as threatened under Tasmania's *Threatened Species Protection Act 1995*. However, recent genetic studies have shown that at least some of the Lord Howe Island Masked Owl ancestry comes from the south-eastern Australian mainland (*Tyto n. novaehollandiae*) and not solely from Tasmania (Hogan *et al* 2013). While Masked Owls are also listed as threatened in NSW (*Threatened Species Conservation Act* 1995) and Victoria (*Flora and Fauna Guarantee Act 1988*), the Lord Howe Island Masked Owl is of limited conservation value because translocations to either the Tasmanian or mainland populations would compromise the genetic integrity of the recipient populations.

Currently, introduced rats and mice form the Lord Howe Island Masked Owl's main prey base but the owls also prey on native species including the Black-winged Petrel, the White Tern, the Sooty Tern and the Lord Howe Woodhen (Milledge 2010). Following rodent eradication programmes in other locales, predators of rats have maintained their previous abundance by switching to other available prey (e.g. Murphy and Bradfield 1992). It is feared, therefore, that if rats and mice are eradicated from Lord Howe Island, owls will switch their prey base to native species (Milledge 2010). Thus, it is imperative, that owls be eradicated prior to and concurrently with, the rodent eradication.

This MOEP will consist of several components including pre- and post-REP owl surveys, owl trapping and a shooting programme. These components are outlined below. The opportunity to, and utility of, translocating owls is also briefly discussed.

Management of the programme

It is recommended that a Project Manager be appointed and a Technical Advisory Group (TAG) be established to support the programme. The TAG will need to include expertise on masked owl ecology and bird capture as well as eradication expertise and local knowledge of the island. A detailed Operational Plan should be produced that clearly indicates who is responsible for decision-making and outlines specific roles within the project. The TAG will advise the Project Manager and provide input into and finalise the Operational Plan. The project manager and TAG should be appointed as soon as is practicable.

Pre- and post-REP population estimates

Pre-REP surveys will be performed to estimate the current distribution and size of the owl population and to provide a measure of the number of owls, general location of roost sites, and key areas that will be required to be targeted in the subsequent shooting programme. Simultaneous point surveys will follow the methods performed previously by Milledge (2010). Briefly, locations of point surveys will be selected to cover the slopes of the southern mountains and the northern hills of the island. The aim of the point surveys will be to provide a measure of owl density in two important areas of habitat. Measures of owl density will be then be extrapolated to the remainder of the island to inform an overall estimate of population size. The survey method will comprise a 45 minute listening period from dusk (with an agreed start time prior to the survey). Prior to the REP, the simultaneous point surveys will be performed every three months until baiting occurs, with the first survey to be performed as soon as is practicable. Surveys will then continue to be performed once every three months for two years in line with the post-eradication rodent monitoring.

Personnel

A total of sixteen people will be required to perform point surveys at eight locations across the island. Each team of two will have at least one person who is familiar with the survey method, call playback technique and the calls of the Masked Owl. Volunteers from within the Lord Howe community will be sought to perform these surveys where possible but people from off the island may also be involved.

Acoustic monitoring

Remote acoustic monitoring devices will be used to constantly monitor owl calls in remote areas of the island. The deployment and recovery of three units in selected locations throughout 2017 can inform both the population monitoring and eradication effort. Acoustic monitoring devices would be rotated throughout the island on a monthly basis (for recovery of recordings and refreshing of power source). The recovery of information from the recordings can either be through intensive replaying or the application of call-recognition software.

Eradication Methods

Secondary poisoning and trapping

There is the potential for a number of owls to succumb to secondary poisoning during the REP as a result of preying on rodents that have consumed brodifacoum. However, it cannot be presumed that all owls will die in this manner; poisoned rodents may be unavailable in some areas, and because rodenticides are currently used on Lord Howe Island to control rats and mice, prolonged exposure to poisons may have allowed the owls to evolve some tolerance. Milledge (2010) had only limited success trapping owls using drop-nets (Dho-Gaza net). Therefore, trials will be performed prior to the eradication programme to explore the suitability of ‘goshawk-type traps’, which will need to be set after dark and closed prior to dawn to avoid the capture of non-target species such as currawongs. All owls caught during this trial will be destroyed.

Timing and personnel

Trapping of owls for removal (if shown to be an effective method) will continue from three months before and for up to three months after the REP or longer if necessary until all owls not eliminated by shooting have been removed. Owls will be trapped with goshawk-type traps in two teams of two people.

Trapping with goshawk-type traps using live rats as bait will not be possible once the REP commences, as using live rats cannot be risked due to the possibility of their escape. However live trapping may need to be employed as an alternative to shooting post-REP, for example where a particular owl has become too wary to be lured in by call playback or where an owl has been detected in an area of terrain too difficult to allow shooting. In these cases alternative live baits such as guinea pigs or young chickens may be used.

Shooting programme

The proposed method of removing owls that are not eliminated through secondary poisoning and trapping is through a systematic shooting programme. Because it is inevitable that owls will begin preying on native fauna once rats and mice are removed, it is intended that the shooting programme begins as soon as possible after the REP begins without compromising the trapping programme.

Locations across the island will be chosen to provide clear vantage points and suitable overhead perches to enable the shooting of owls. Call playback will be used at these stations to attract owls, at which time they will be shot by experienced, qualified shooters who will be engaged to perform the shooting component. All shooters will be appropriately licensed in accordance with any New South Wales and Lord Howe Island Board requirements. The shooting programme (locations and expected number of owls to be targeted) will be informed by the pre-REP point surveys and acoustic monitoring results.

The shooting programme will cover all accessible habitat across the island. However, the first priority should be to target areas that will be difficult for shooters to access on foot. It is proposed that the helicopter(s) used for spreading bait be used to transport shooters to these inaccessible areas either, during the period between the first and second bait drops, or immediately after the second bait drop. It should be noted that the rodent eradication should be prioritised for helicopter use. When being transported to remote areas by helicopter during the day, shooters will carry adequate equipment to enable them to stay overnight as it will be unlikely that they can be picked up that night and inclement weather or other factors may also delay the return of the helicopter.

Timing and personnel

The shooting schedule will be informed by the population surveys and acoustic monitoring and it is proposed that two teams comprising two persons will perform shooting operations. Shooting in remote areas will begin as soon as is practicable after the first bait drop. The duration and timing of these forays will be dictated by weather and helicopter availability. Shooting forays in areas accessible by foot will also begin soon after the first bait drop once owls have had an opportunity to consume poisoned rodents. These forays will be performed at a frequency of three hours per night three nights per week. Shooting forays may need to continue at this frequency for six months after the REP and should include the period when owls are most responsive to calls (winter and spring, Milledge 2010)). After six months it should be possible to make an assessment of the necessity to continue at the same frequency or reduce either the number of shooting parties or the number of forays. The shooting schedule will be flexible throughout, however, to allow for breaks if, for example, owls become unresponsive to call-play back; previous culling programme found that, following a break, owls responded better to calls.

Firearms

Two firearms with different capabilities will be used in the shooting programme; a 12-guage shotgun for close range and a .17 HMR rifle for longer range shots. Longer-range capabilities will be required for occasions when owls do not closely approach the call play-back station. All necessary licencing and shooting operations will be overseen by the Lord Howe Island Board Firearms Officer.

Translocation

As indicated above, genetic analysis has found that the ancestry of Lord Howe Island Masked Owls indicates a mixture of Tasmanian and mainland Australian Masked Owl individuals (Hogan *et al* 2013). These owls are thus unsuitable for translocation into wild populations elsewhere in the species' range. Nevertheless, the owls are valued by some members of the Lord Howe Island community and the opportunity to transport some individuals to zoos or wildlife parks to maintain captive populations should be explored. Taronga and Melbourne zoos have been approached but these organisations are not able to accept live owls. However, other organisations, such as smaller zoos should be approached to investigate the potential for some owls to be relocated.

MOEP Schedule

Table 1. Proposed schedule of important activities for the Lord Howe Masked Owl Eradication Plan. Schedule presumes the REP will take place in July 2017.

	Point Surveys	Acoustic surveys	Trapping	Shooting
Persons	16	1	4	4
2016				
June	8 locations			
July				
August				
September	8 locations			
October				
November				
December	8 locations			
2017				
January		3 locations		
February		3 locations		
March	8 locations	3 locations		
April		3 locations	Trapping	
May		3 locations	Trapping	
June	8 locations	3 locations	Trapping	
July		3 locations	Trapping	3hrs per night/3x per week
August		3 locations	Trapping	3hrs per night/3x per week
September	8 locations	3 locations	Trapping	3hrs per night/3x per week
October		3 locations		3hrs per night/3x per week
November		3 locations		3hrs per night/3x per week
December	8 locations	3 locations		3hrs per night/3x per week
2018				
January				Less extensively as required
February				Less extensively as required
March	8 locations			Less extensively as required
April				Less extensively as required
May				Less extensively as required
June	8 locations			Less extensively as required
July				Less extensively as required

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DRAFT

RESEARCH TO INFORM THE ERADICATION OF THE INTRODUCED MASKED OWL POPULATION ON LORD HOWE ISLAND

FINAL REPORT, STAGES 1 AND 2

INCLUDING INFORMATION ON DISTRIBUTION AND HABITAT USE, MOVEMENTS, HOME RANGES, POPULATION SIZE, ROOST SITES, DIET AND RECOMMENDATIONS FOR ERADICATION

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November 2010

CARING FOR OUR COUNTRY

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Photos of Masked Owls, roost and nest sites, pellets and prey remains and of attaching the radio-transmitter packages were supplied by Nicholas Carlile, Ian Hutton, Greg James, David Newell, Jesse Rowland and Jack Shick.

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The project was undertaken under Scientific Licence S12928 issued by the NSW Department of Environment and Climate Change (now Department of Environment, Climate Change and Water, Banding Authority 484 issued by the Federal Department of the Environment, Water, Heritage and the Arts, permits issued by the Lord Howe Island Board and an Approval and Animal Research Authority issued by the NSW Department of Agriculture (now Department of Industry and Investment) Director-General‟s Animal Care and Ethics Committee.

TABLE OF CONTENTS

SUMMARY

The Lord Howe Island Board proposes to remove the introduced Masked Owl *Tyto novaehollandiae* population on Lord Howe Island coincident with eradication of rodents under the Rodent Eradication Plan, scheduled for implementation within the next 2-3 years.

A research project to inform the removal of Masked Owls by providing information on distribution, habitat use, movements, home ranges, population size, roost site characteristics, diet and breeding was commenced on the Island in June 2009 and continued until July 2010. Field work was undertaken during 7 field trips involving 147 days over the 13 month study period.

Methods used comprised community consultation, habitat examination, sound recording of local owls, call playback using mainland and local calls, drop-net trapping of owls, tracking of radio-tagged owls, recovery and analysis of regurgitated pellets, simultaneous point surveys, opportunistic searches for roost and kill sites and photographic recording of methodology, habitats, roost sites, pellet and kill sites and owl behaviour.

One male (Male 1) and two female (Females 1 and 2) Masked Owls were trapped and fitted with radio-transmitter packages in August and September 2009 and the two females were tracked throughout the study period. The transmitter on the male appeared to fail shortly after fitting.

Simultaneous point surveys of calling owls involving community participation were undertaken in the southern mountains in November 2009 and the northern hills in June 2010. These surveys indicated the presence of three and four pairs of Masked Owls respectively in the survey areas in the northern hills and southern mountains.

Masked Owls were recorded throughout the Island during the study, foraging in a variety of habitats from forest to cliffs, open pasture and gardens, but were confined to forest for roosting. Roost sites of Females 1 and 2 were mostly 100m away from forest edges and 0.5km or more away from areas of settlement. However, both females and a male owl were recorded roosting at forest edges or within the Settlement on occasions.

Nightly movements recorded for Females 1 and 2 while foraging and between successive roost sites showed that Female 1 was considerably more mobile and occupied a much larger home range than Female 2. Female 1 foraged and roosted mainly on the northern, western and southern slopes of Transit Hill but also ranged north to Stevens Reserve in the Settlement and south to Intermediate Hill and the lower western slopes of Mt Lidgbird. In contrast, Female 2 was mainly confined to the northern, western and southern slopes of Intermediate Hill

Twenty-two nightly foraging distances greater than 0.5km were recorded for Female 1 whereas only 15 were recorded for Female 2. The longest nightly foraging distance recorded for Female 1 was 2.5km whereas that for Female 2 was only 1.1km, and nine of Female 1"s foraging distances exceeded 1.0km with only one of Female 2"s exceeding that distance.

Both Female 1 and 2 changed roost sites on a nightly basis with Female 1 travelling up to 4.1 km between successive roosts, whereas the greatest distance between successive roosts recorded for Female 2 was 0.6km.

Female 1 occupied a home range of approximately 230ha during the study period compared with the home range of only approximately 75ha occupied by Female 2. The home range of Female 1 overlapped that of Female 2 although both spent most time foraging and roosting in discrete home range cores of approximately 39ha and 20ha respectively.

Female 1‟s movements were characterised by periods of occupation of a sector of her home range core interspersed with movements to, and shorter periods of occupation of, other sectors of the core or to areas of the home range several kilometres distant. Female 2 by contrast exhibited strong fidelity to her single small home range core, with almost 90% of recorded roost sites confined to this area.

When Females 1 and 2 co-occurred on Intermediate Hill, they appeared to mainly avoid each other when foraging and roosting. Nevertheless, they did occur in relatively close proximity at some times with the closest distance recorded between roost sites 250m and the closest distance between approximate foraging sites 350m. However, on all but one occasion when foraging sites were identified, Female 1 moved to Transit Hill to forage after roosting on Intermediate Hill.

The current size of the Masked Owl population on Lord Howe Island is estimated to be 20 pairs with probably a small number of immature individuals. However, this is regarded as a preliminary estimate and requires further investigation.

Roost sites of Females 1 and 2 were mainly in the canopies of slender Greybarks *Drypetes deplanchei* and large trunk and branch hollows of mature Scalybarks *Syzygium fullagari*. However, Female 1 used canopy roosts more often than trunk and branch hollows, whereas Female 2 used canopy roosts and trunk and branch hollow roosts equally. Female 1 also roosted frequently in trunk crevices of Banyans *Ficus macrophylla columnaris* and occasionally in hollows in arboreal Elkhorn Fern *Platycerium bifurcatum* clumps. The height of canopy roosts of both females reflected the canopy height at sites. Females 1 and 2 changed roosts on a nightly basis and also roosted at several sites on a number of occasions, suggesting a preference for particular sets of attributes.

No breeding, or indication of breeding, was recorded during the period of the study.

Analyses of prey remains in regurgitated pellets from Females 1 and 2 together with pellets from other owls found that 72% of pellets contained remains of Black Rats *Rattus rattus*, 28% the remains of House Mice *Mus musculus* and 23% the remains of birds. The main bird species represented were the Little Shearwater *Puffinus assimilis*, Black-winged Petrel *Pteradroma nigripennis* and Sooty Tern *Sterna fuscata*. Remains of Sooty Terns and White Terns *Gygis alba* were also prominent at kill sites. The analyses demonstrated that the Black Rat and House Mouse currently provide the Masked Owl‟s main prey base on the Island, with seabirds a moderately important seasonal component in the diet of individual owls.

The call playback method using both mainland and local Masked Owl calls proved effective in attracting Masked Owls on the majority of occasions it was used. However, at sites where the method was repeated up to six times over periods of six to twelve months, owls quickly became wary and the intensity of response rapidly diminished. Owls also became alarmed by use of a spotlight. There appeared to be some season variation in response to the call playback method, with the majority of intense and prolonged responses obtained in winter and spring. The presence of a pair of owls at a site during playback, and particularly if another pair also responded, was found to increase the intensity of response.

The drop-net trapping technique was successful in capturing one male and two female Masked Owls early during the study period, but owls at trapping sites quickly became wary of the method and no additional individuals were caught. However, radio-tracking of the two females was highly successful in providing the range of data described above.

Due to the Masked Owl"s current high level of dependence on the Black Rat and House Mouse on Lord Howe Island, combined with its ability to operate as a generalist, opportunistic predator, it is considered that the species is likely to present a major threat to the Island"s indigenous vertebrates following rodent eradication. This is because there is no certainty that owls will succumb to secondary poisoning

It is recommended that the Masked Owl population be removed from the Island simultaneously with rodent eradication and not prior to or independent of implementation of the Rodent Eradication Plan. Additional trapping techniques such as the use of “goshawk-type” traps are recommended to be trialled as a substitute for drop-net trapping due to the lack of success obtained with the latter method. Trialling of trapping methods should also be used to undertake further studies of individuals by radio-tracking to provide more accurate data on population size and other information to better inform the owl eradication program.

Eradication methods should include trapping for translocation of owls to zoos or euthanasia, and the use of call playback to attract individuals for shooting.

As a precursor to any translocation to Tasmanian or mainland zoos, it is recommended that the provenance of the Lord Howe population be investigated by DNA analysis to determine if mainland genes are present and to determine the level of genetic divergence.

The recommend strategies, actions and timing for removal of the Masked Owl from Lord Howe Island are presented in an owl eradication plan.

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

Approximately 100 individuals of five species of owls were released on Lord Howe Island by the Lord Howe Island Board (LHIB) between 1922 and 1930 (Hindwood 1940, Taronga Zoo and Lord Howe Island Board files) in an attempt to control the Black Rat *Rattus rattus* population. Black Rats had exploded on the Island shortly after numbers reached the shore from the SS Mokambo, which grounded off the northern coast in 1918 (Hindwood 1940, Hutton 1991). The owl species that were introduced comprised the eastern Australian race of the Southern Boobook *Ninox n. novaeseelandiae*, the Tasmanian race of the Masked Owl *Tyto novaehollandiae castanops*, the Australian Barn Owl *Tyto javanica*, the American Barn Owl *T. furcata* and the American Great Horned Owl *Bubo virginianus*. The majority of owls released comprised Tasmanian Masked Owls (approximately 80%, Hutton 1991) and this was the only species to become established.

In the 1970"s the Masked Owl"s predation of breeding seabirds (particularly the Providence Petrel *Pterodroma solandri*, Black-winged Petrel *P. nigripennis* and White Tern *Gygis alba*) and the Lord Howe Woodhen *Gallirallus sylvestris* prompted the LHIB to initiate a culling program by shooting, principally about settled areas and the Airstrip (Hiscox 1988-2007, **Fig. 1**). This program continued sporadically until 2007 but culling was most intensive between 1988 and 1998, when 95 individuals were shot (Hiscox 1988-2007, Milledge 2009, **Fig. 2**). The highest annual cull was 15 owls in 1997 and juveniles averaged 33% of annual totals between 1988 and 1997 (**Fig. 2**).

However, the culling program appeared to have little overall effect in reducing Masked Owl predation of seabirds and terrestrial bird species and the owl population continued to thrive. Current biodiversity conservation planning for the Island now proposes complete eradication of Masked Owls in conjunction with the Rodent Eradication Plan (REP), scheduled for implementation in 2013-2014 (DECC 2007, Lord Howe Island Board 2009).

It is possible that the rodenticide to be used by the REP to poison Black Rats and House Mice *Mus musculus* will cause the deaths of a number of Masked Owls from secondary poisoning. However, there is no conclusive evidence that owls will succumb as a result of the poisoning program and even if numbers are reduced, once their rodent prey base has been eliminated any remaining owl population is likely to pose a significant threat to breeding seabirds and endemic terrestrial bird species and subspecies.

As a first step in addressing this concern, the LHIB engaged Landmark Ecological Services in May 2009 to undertake a project involving research into the ecology of the Masked Owl on Lord Howe Island to inform an eradication program planned to coincide with implementation of the REP.

The Masked Owl research project aims to supply information on the species" distribution and habitat use, movements, home ranges, population size, roost site characteristics, diet, breeding biology and general behaviour, and provide recommendations for eradication, including effective methods for translocating or destroying individual owls.

Figure 1 **Locations of Masked Owl cull sites between 1988 and 2007**

Figure 2 Masked Owl cull data between 1988 and 2007

2.0 METHODS

Stages one and two of the project involved seven field trips to Lord Howe Island between:

- 28 June - 18 July 2009
- 18 August - 14 September 2009
- 20 October - 8 November 2009
- 8-19 January 2010
- 6 March – 7 April 2010 and
- 9 – 27 May 2010
- 15-31 July 2010

These constituted 47 winter days, 41 spring days, 10 summer days and 49 autumn days, representing a total of 147 field days.

Activities undertaken during field trips comprised:

- community consultation with residents who had previously undertaken owl culling and/or had information on owl occurrence and habits;
- examination of habitats where owls had previously been recorded (Hiscox 1988-2007, Hutton 1991, records of the Australian Museum; as summarised in Milledge 2009);
- sound recording of local Masked Owl vocalisations for use in call playback and eradication methods;
- trials of call playback to gauge owl response for informing trapping methodology and for use in eradication;
- trapping of owls using drop-netting (large Dho-Gaza nets) with banding and fitting of radio-transmitters;
- tracking of radio-tagged owls to provide data on movements, foraging ranges, characteristics of roost sites, recovery of pellets to provide data on diet, and behavioural characteristics;
- simultaneous point surveys in November 2009 and June 2010;
- opportunistic searching for roost sites and pellets and general observations of owl occurrence and behaviour; and
- photographic recording of methodology including trapping techniques, banding and fitting radio-transmitters and radio-tracking, and habitats, individual owls demonstrating roosting behaviour, roost sites, pellets, kill sites and potential nesting sites.

Preliminary activities such as community consultation and examination of habitats have been previously reported in Milledge (2009).

2.1 <u>Call playback</u>

The June-July 2009 field trip concentrated on trialling the call playback method at various locations throughout the Island, from Erskine Valley in the southern mountains to the Old Settlement area at the southern toe of the northern hills.

Initially short sequences (approx. 3 min) of mainland Masked Owl calls recorded on CD were broadcast through a Toa Mini 6w 12v transistorised megaphone coupled to a Sony Walkman CD player. Mainland Masked Owl call sequences were replaced later in playback sessions with those obtained from local Lord Howe Masked Owls in response to broadcasts of mainland calls, using the Toa Mini megaphone and a Sony MP3 player. Usually two to three call sequences were broadcast at a site, interspersed with two to three minute listening periods. A 50w spotlight was used on dark nights to locate individual owls once these had flown in to the playback site.

Additional call sequences were sometimes broadcast if distant vocal responses were obtained in attempts to attract these owls within visible range.

The method was also trialled during later field trips in August-September and October-November 2009 and March-April, May and July 2010 (including its use as part of the drop-net trapping method and simultaneous point surveys) to gauge seasonal variation in owl response and the effects on individual owls to over-exposure to the method.

Owl responses to call playback during trapping sessions were recorded as good, moderate, poor or nil according to the proximity of the owl(s) to the call playback site, intensity of vocalisation and length of time of responses.

2.2 Trapping, banding and fitting with radio-transmitters

Trapping was undertaken using a 10m x 12m drop-net (Dho-Gaza net) made according to specification from 150mm diagonal pattern, 6-strand black nylon braided mesh supplied by Oxley Nets (Port Melbourne).

The net was set in a clearing within forest or at the forest edge and suspended between the two tallest trees at a site to obtain maximum height. The top of the net was held in position and tensioned by major ropes at each end, with minor release ropes and weights (to accelerate the fall) controlled by an operator, also at each end. A third operator located at a suitable vantage point controlled playback from two megaphones positioned either side of the net and gave instructions to the net operators on when to drop the net if an owl flew in and became entangled. On most occasions, one or two mounted specimens of Masked Owls fixed to perches were positioned close to the net to act as decoys and one of the two megaphones was then located close to the decoys. Call playback was alternated between the two megaphones to entice owls to fly backwards and forwards across the net and increase the chance of entanglement.

A total of 15 sites were trapped during the study period (**Figure 3**) with several trapped on a number of occasions. Seven sites were trapped once, four sites were trapped twice, three sites were trapped three times and one site was trapped on four occasions (**Appendix 1**). The number of site trap nights totalled 28.

Captured owls were banded with numbered metal leg bands provided by the Australian Bird and Bat Banding Scheme and fitted with a GP1-16MS2 back-pack radio-transmitter package with 250mm aerial supplied by Titley Scientific (Brisbane). The transmitter broadcast in the 151MHz frequency range and contained a 12hr "mortality" switch that doubled the pulse rate if kept stationary for more than 12hrs. The package was attached to an owl with a harness modified from the design of Karl and Clout (1987) and included a three-strand cotton "weak link" designed to break if snagged, and eventually perish and shed the package once the battery had expired. The harness was fastened with small cable ties sealed with supaglue and a sheepskin pad was used to soften the package"s contact with the owl"s back. The total weight of the package and harness was 26g and the transmitter battery provided a minimum life of 12 months. Owls carrying transmitters were tracked using a three-element Sirtrack Yagi aerial.

Two female and one male Masked Owl were trapped in August and September 2009 and fitted with transmitter packages (**Table 1**). The male and the second female

Figure 3 **Locations of sites trapped for Masked Owls between August 2009 and July 2010**

Table 1 Details of Masked Owls trapped and fitted with radio-transmitters during August and September 2009

date	owl code, transmitter frequency, band no.	trapping location	Easting MGA	Northing MGA	comments
27.8.'09	Female 1 151.600 132-15891	forest edge along north eastern boundary of Middle Beach Common	507117	6511787	adult female captured after male of pair had escaped
10.9.'09	Male 1 151.540 121-51701	edge of forest on western edge of southern end of Golf Course	507445	6509778	adult male captured on dusk
10.9.'09	Female 2 151.480 132-15892	edge of forest on western edge of southern end of Golf Course	507445	6509778	adult female captured immediately after male removed from net

data from Appendix 1

captured in September appeared to be a pair as they came in to the trapping site together and the female was captured immediately after the male was extracted from the net (**Appendix 1**). The transmitter on the male failed or was damaged approximately one week after fitting, but the two females were tracked continuously during field trips up until the end of the last trip at the end of July 2010.

2.3 Radio-tracking to establish movements, home range size, roost characteristics and diet

During the August-September and October-November 2009 and January, March-April, May and July 2010 field trips, radio-tracking of Masked Owl Females 1 and 2 was undertaken whenever weather conditions permitted. Male 1 was tracked during the last week of the September 2009 field trip, after which its transmitter appeared to fail.

Diurnal tracking was undertaken on foot and enabled roost sites to be located and their MGA co-ordinates and characteristics to be recorded. Locations of roosts of the two females provided data on movements and the size and use of home ranges. Roost characteristics recorded included tree species, tree diameter at breast height (dbh) and roost type. In cases of canopy roosts, regurgitated food pellets were recovered on numerous occasions, providing information on diet. Pellets were air-dried and forwarded to Barbara Triggs, Genoa for analysis of mammal remains and to Dr Walter Boles, Australian Museum for analysis of bird material.

Nocturnal tracking was carried out during the evening from a vehicle using the Island road network and involved a series of stops at established points, usually between 2200 hrs and 2400 hrs, that provided wide coverage of the ranges of the two females. If a female was unable to be located from these points, tracking on foot along tracks was sometimes undertaken in an attempt to obtain a location. The nocturnal tracking method did not enable accurate positions to be established (such as can be obtained from triangulation) but allowed approximate foraging sites to be estimated that complemented the home range data provided by roost locations.

Figure 4 **Simultaneous point survey locations for Masked Owls in the southern mountains in November 2009 and in the northern hills in June 2010**

2.4 Simultaneous point surveys

Simultaneous point surveys of calling owls involving community participation were conducted on the nights of 1 November 2009 and 2 June 2010 from a series of locations selected to cover the areas of the mid and lower slopes of the southern mountains, and the northern hills respectively (**Fig. 4**). The aim of the point surveys was to provide a measure of owl density in two important areas of habitat that could be extrapolated to the remainder of the Island to inform an overall estimate of population size.

Prior to surveys, participants were briefed on the method and familiarised with the calls of local Masked Owls through playing a series of recordings. Survey point locations were pre-selected on the track system covering the areas and each point was allocated a team of two observers. A proforma (**Fig. 5**) was provided to each team to ensure standardisation of the procedure and the data collected. Observers synchronised watches and walked in to survey locations to be in position before dark.

The survey method comprised a 45 min listening period from dusk (agreed time prior to survey) followed by playback of a recorded sequence of owl calls and then a 5 min listening period. The playback sequence was then repeated followed by a further 5 min period of listening.

Observers transcribed all records of owl activity (calling, sightings) to a sketch map showing a north point and relevant visible landmarks, recording the time, direction of activity and estimated distance.

2.5 Opportunistic roost site and pellet searches

Opportunistic searches for potential tree hollow roost and nest sites, canopy roosts and pellets were undertaken whenever diurnal forest traverses involving radio-tracking and other activities were being conducted. This mainly involved noting locations of large, mature, hollow-bearing Scalybarks *Syzygium fullagari* and Greybarks *Drypetes deplanchei*, large mature Banyans *Ficus macrophylla columnaris*, and searching under canopy trees with tight, dense crowns or substantial horizontal branches for “whitewash” or faecal splashes on understorey vegetation and the leaf litter. Whitewash frequently revealed the presence of canopy roost sites or interaction perches, where owls spent time after leaving the roost in the evening, and where regurgitated pellets of food material were sometimes found. Old pellet remains, characterised by the bleached skulls of Black Rats, also sometimes indicated the locations of canopy roost sites or interaction perches not currently in use.

3. DISTRIBUTION AND HABITAT USE

The Masked Owl was recorded in all terrestrial habitats throughout Lord Howe Island during the study, foraging and roosting mainly in forest but also foraging in shrubland and grassland habitats and over exposed rocky areas including cliffs (**Figs 6 and 7**). Owls were also recorded foraging over highly modified vegetation including pasture and mown grassland at the Airstrip and Golf Course and through planted forests and gardens in the area of the Settlement. However, no records were obtained for shoreline or littoral habitats and no evidence was obtained of owls visiting the offshore islands, although no surveys were conducted on the latter.

Most detailed information on occurrence was obtained from radio-tracking of Females 1 and 2, particularly Female 1 which ranged from the area of the Settlement in the north to the western slopes of Mt Lidgbird above Far Flats in the south (**Fig. 7)**.

Figure 5 Proforma used for simultaneous point surveys of Masked Owls during November 2009 and June 2010

Lord Howe Island Masked Owl Project - simultaneous point survey method	
location:	MGAs E **N**
date:	**start time:**
observers:	
equipment checklist: watch (synchronised) head torch/spare batteries UHF radio (ch 10) GPS/compass clipboard, paper pen/spare pen/pencil CD player/MP3 player/pre-recorded CD	megaphone, lead **additional materials:** water, food insect repellent
method: 1) listen for 45 min from dusk (synchronised time) 2) use playback for standard time 3) listen for 5 min 4) use playback for standard time 5) listen for 5 min	**results:** map showing north point owl call and/or sighting direction owl call and/or sighting time call description approx. distance
map of compass points and approximate distances of owl call/observation records, orientated to north:	

Figure 6 **Recorded locations of Masked Owls (excluding records of radio-tracked females) between May 2009 and July 2010, plus past records from remote areas**

Old records showed some remote forested areas not surveyed during the study also provide habitat for owls, including the 873m summit of Mt Gower and the precipitous Little Slope on the mountain"s western side (**Fig. 6**).

The majority of roost sites, primarily representing roosts of Females 1 and 2 (**Fig. 7**), were in low to tall mature forest 100m or more away from edges and 0.5km or more from areas of settlement. However, Female 1 roosted in and adjacent to Stevens Reserve within the Settlement on several occasions and Female 2 was recorded at one canopy roost on the edge of pasture (**Figs 7, 10 and 11)**. A male Masked Owl was also detected roosting in a Kentia Palm *Howea forsteriana* in the grounds of a resort within the Settlement.

Radio-tracking indicated that Females 1 and 2 mainly foraged within low to tall forest, but although Female 1 apparently often crossed cleared land (**Figs 8 and 10**), no records of foraging were obtained in this habitat. However, Female 1 was recovered from a paddock on the edge of the Settlement in December 2009 (H. Bower pers. comm.), apparently suffering the effects of secondary rodenticide poisoning.

Observation or call records of other Masked Owls using cleared or disturbed habitats about the Settlement included a female killed by a vehicle at Somerset, a male foraging over the Airstrip and adjacent paddocks, and individuals in and about Stevens Reserve and the Cemetery (**Fig. 6**). Owl kill sites were observed in the wharf area and elsewhere along Lagoon Road, and at the Old Meteorological Station (**Figs 6 and 18**).

4. MOVEMENTS, HOME RANGES AND POPULATION SIZE

4.1 Movements

Two data sets illustrating nightly movements of Females 1 and 2 were derived from the diurnal location of roost sites and approximate locations obtained from nocturnal radio-tracking. These comprised estimated distances travelled from roosts to mid-nightly foraging sites, and distances measured between successive roost sites (**Appendices 7, 10, 12 and 14**).

The pattern of overall movements and distances travelled by the two females varied markedly, with Female 1 exhibiting greater mobility and covering a much wider area than Female 2 (**Tables 2 and 3, Figs 8-11**).

Female 1 alternated mainly between the northern, western and southern slopes of Transit Hill with occasional forays north west to the Settlement and south to Intermediate Hill and the lower western slopes of Mt Lidgbird (**Figs 7, 8 and 10**). However, Female 2 was confined almost entirely to the northern, western and southern slopes of Intermediate Hill (**Figs 7, 9 and 11**).

During the period of the study, radio-tracking of Female 1 revealed 22 movements of 0.5km or greater in nightly foraging, and 27 distances of 0.5km or greater between successive roost sites (**Tables 2 and 3, Figs 8 and 10**). Nine of the nightly foraging movements and 19 of the successive roost site distances were greater than 1km. By contrast, only 15 nightly foraging movements and ten successive roost site distances of greater than 0.5km were detected for Female 2 (**Tables 2 and 3, Figs 9 and 11**). Only one of Female 2"s nightly foraging movements and no successive roost site distances exceeded 1km.

Figure 7 **Locations of roost sites and approximate foraging sites of Masked Owl Females 1 and 2 between August 2009 and July 2010**

Table 2 Distances of 0.5km or greater travelled by Masked Owl Females 1 and 2 in nocturnal movements between August 2009 and July 2010

date	first location	second location	distance between locations, km
Masked Owl Female 1			
8.9.'09	Intermediate Hill	Transit Hill	2.2
10.9.'09	Intermediate Hill	Intermediate Hill	0.5
11.9.'09	Intermediate Hill	Transit Hill	2.5
18.9.'09	Intermediate Hill	Transit Hill	2.4
19.9.'09	Intermediate Hill	Transit Hill	0.9
23.9.'09	Intermediate Hill	Transit Hill	0.9
21.10.'09	Transit Hill	Intermediate Hill	1.7
30.10.'09	Transit Hill	Transit Hill	0.5
4.11.'09	Intermediate Hill	Intermediate Hill	0.6
5.11.'09	Transit Hill	Intermediate Hill	1.9
14.3.'10	Intermediate Hill	Transit Hill	1.6
21.3.'10	Valley of the Shadows	Transit Hill	0.8
23.3.'10	Mt Lidgbird	Mt Lidgbird	1.6
27.3.'10	Transit Hill	Transit Hill	0.8
28.3.'10	Transit Hill	Settlement	1.1
29.3.'10	Transit Hill	Transit Hill	0.6
2.4.'10	Valley of the Shadows	Settlement	1.1
3.4.'10	Transit Hill	Transit Hill	0.5
4.4.'10	Transit Hill	Transit Hill	0.5
5.4.'10	Transit Hill	Transit Hill	0.5
6.4.'10	Transit Hill	Transit Hill	0.5
11.5.'10	Transit Hill	Transit Hill	0.5
Masked Owl Female 2			
21.10.'09	Intermediate Hill	Intermediate Hill	1.1 (0.5 + 0.6)
30.10.'09	Intermediate Hill	Intermediate Hill	0.5
4.11.'09	Intermediate Hill	Intermediate Hill	0.5
14.3.'10	Intermediate Hill	Intermediate Hill	0.8
26.3.'10	Intermediate Hill	Intermediate Hill	0.6
27.3.'10	Intermediate Hill	Intermediate Hill	0.6
29.3.'10	Intermediate Hill	Intermediate Hill	0.6
4.4.'10	Intermediate Hill	Intermediate Hill	0.5
13.5.'10	Intermediate Hill	Intermediate Hill	0.8
14.5.'10	Intermediate Hill	Intermediate Hill	0.6
15.5.'10	Intermediate Hill	Intermediate Hill	0.7
21.5.'10	Intermediate Hill	Intermediate Hill	0.5
22.5.'10	Intermediate Hill	Intermediate Hill	0.9
23.5.'10	Intermediate Hill	Intermediate Hill	0.5
16.7.'10	Intermediate Hill	Intermediate Hill	0.5

data from Appendices 12 and 14

Table 3 Distances of 0.5km or greater between successive roosts sites of Masked Owl Females 1 and 2 between August 2009 and July 2010

date	first roost site location	second roost site location	distance between locations, km
Masked Owl Female 1			
28-29.8.‟09	Intermediate Hill	Transit Hill	1.9
29-30.8.‟09	Transit Hill	Intermediate Hill	2.0
30-31.8.‟09	Intermediate Hill	Transit Hill	1.9
31.8-1.9.‟09	Transit Hill	Intermediate Hill	1.3
1-2.9.‟09	Intermediate Hill	Transit Hill	1.4
2-3.9.‟09	Transit Hill	Intermediate Hill	1.7
3-4.9.‟09	Intermediate Hill	Transit Hill	1.7
4-5.9.‟09	Transit Hill	Valley of the Shadows	0.5
5-6.9.‟09	Valley of the Shadows	Intermediate Hill	2.1
8-9.9.‟09	Intermediate Hill	Transit Hill	1.9
9-10.9.‟09	Transit Hill	Intermediate Hill	1.9
3-4.11.‟09	Transit Hill	Intermediate Hill	2.0
4-5.11.‟09	Intermediate Hill	Transit Hill	2.0
6-7.11.‟09	Transit Hill	Transit Hill	0.6
14-15.3.‟10	Intermediate Hill	Valley of the Shadows	1.8
15-16.3.‟10	Valley of the Shadows	Transit Hill	0.8
17-18.3.‟10	Transit Hill	Transit Hill	0.8
21-22.3.‟10	Valley of the Shadows	Mt Lidgbird	3.2
23-24.3.‟10	Mt Lidgbird	Mt Lidgbird	1.6
24-25.3.‟10	Mt Lidgbird	Transit Hill	4.1
26-27.3.‟10	Transit Hill	Transit Hill	0.6
27-28.3.‟10	Transit Hill	Transit Hill	0.5
2-3.4.‟10	Valley of the Shadows	Transit Hill	0.5
12-13.5.‟10	Transit Hill	Settlement	1.4
14-15.5.‟10	Settlement	Transit Hill	1.2
24-25.7.‟10	Valley of the Shadows	Transit Hill	0.5
28-29.7.‟10	Transit Hill	Intermediate Hill	1.6
Masked Owl Female 2			
2-3.11.‟09	Intermediate Hill	Intermediate Hill	0.5
3-4.11.‟09	Intermediate Hill	Intermediate Hill	0.5
4-5.11.‟09	Intermediate Hill	Intermediate Hill	0.5
3-4.4.‟10	Intermediate Hill	Intermediate Hill	0.5
4-5.4.‟10	Intermediate Hill	Intermediate Hill	0.5
5-6.4.‟10	Intermediate Hill	Intermediate Hill	0.5
21-22.5.‟10	Intermediate Hill	Intermediate Hill	0.5
22-23.5.‟10	Intermediate Hill	Intermediate Hill	0.6
25-26.5.‟10	Intermediate Hill	Intermediate Hill	0.5
28-29.7.‟10	Intermediate Hill	Intermediate Hill	0.6

data from Appendices 7 and 10

Figure 8 **Nocturnal movements of 0.5km or greater by Masked Owl Female 1 between September 2009 and July 2010**

Figure 9 **Nocturnal movements of 0.5km or greater by Masked Owl Female 2 between September 2009 and July 2010**

Figure 10 **Distances of 0.5km or greater between successive roosts sites of Masked Owl Female 1 between September 2009 and July 2010**

Figure 11 **Distances of 0.5km or greater between successive roosts sites of Masked Owl Female 2 between September 2009 and July 2010**

The longest nightly foraging movement and successive roost site distances recorded for Female 1 were 2.5km and 4.1km respectively (**Tables 2 and 3**), whereas the longest nightly foraging movement and successive roost site distance recorded for Female 2 were 1.1km and 0.6km respectively.

Mean nightly foraging movement and successive roost site distances recorded for Females 1 and 2 were 0.62/0.62km and 0.38/0.25km respectively (n = 49/79 for Female 1, n = 46/60 female 2; from **Appendices 7, 10, 12 and 14**).

In all cases where Females 1 and 2 were able to be radio-tracked to specific trees on successive days, both changed roost sites on a nightly basis, although it is possible that this was a response to disturbance from the researcher.

The pattern of foraging and roost site selection by Female 1, in contrast to that of Female 2 which was confined to an area of approximately 75ha on Intermediate Hill (**Fig. 13**), varied throughout the study period. After capture in late August 2009 and through to early September, Female 1 alternated on a mainly nightly basis between the western slopes of Transit Hill and the northern, western and southern slopes of Intermediate Hill (a distance of approximately 2km), with one excursion to the northern slopes of Transit Hill (**Fig. 10, Appendix 5**). From mid to late September, Female 1 was confined to Intermediate Hill but in late October to early November was restricted to the western and southern slopes of Transit Hill, with one foray to Intermediate Hill. Then during mid-January 2010, Female 1 spent most time on the northern slopes of Transit Hill with only one excursion to its western slopes. This pattern was reversed in early to mid-March, when most time was spent on the western slopes of Transit Hill with one excursion to its northern slopes and one visit to Intermediate Hill. In mid to late-March, Female 1 spent most time on the northern slopes of Transit Hill but in late March also travelled 3.2km south in one night to the lower western slopes of Mt Lidgbird, spending three days there and then covering a distance of 4.1km between roost sites on the return journey to the western slopes of Transit Hill (**Table 3, Fig.10**). Female 1 spent early April and mid-May on the northern and western slopes of Transit Hill, but in mid-May two days and nights were also spent in Stevens Reserve in the Settlement. In mid to late July, Female 1 foraged and roosted on the northern, western and southern slopes of Transit Hill with one foray south to Intermediate Hill.

Female 2‟s movements showed little variation within her restricted range, although roost and foraging sites were predominantly located on the north western and western slopes of Intermediate Hill. Foraging excursions to the northern and north eastern slopes of Intermediate Hill occurred mainly when storms buffeted the Island from the west and south west. This pattern of movement to sheltered, lee slopes in stormy weather was also observed with Female 1 on Transit Hill, when her foraging was confined to the eastern slopes of the northern ridge during westerly and south westerly gales.

4.2 Home ranges

As noted above (s.4.1), radio-tracking showed that Females 1 and 2 occupied home ranges of considerably different size during the study period (**Figs 7, 12 and 13**). These home ranges involved substantial overlap (**Fig. 14**) but when this occurred it appeared to involve relatively discrete use of foraging and roosting habitats.

On the basis of roost and foraging sites, it was estimated that Female 1 ranged over an area of approximately 230ha between the Settlement and the western slopes of Mt Lidgbird (**Fig. 12**). Similarly, the home range of Female 2 was estimated at only

Figure 12 **Estimated home range and home range core of Masked Owl Female 1 between August 2009 and July 2010**

Figure 13 **Estimated home range and home range core of Masked Owl Female 2 between September 2009 and July 2010**

Figure 14 **Overlap of estimated home ranges with discrete home range cores of Masked Owl Females 1 and 2 between August 2009 and July 2010**

approximately 75ha on the northern, western and southern slopes of Intermediate Hill (**Fig. 13**).

Female 1 mostly used a section of the northern part of its range for roosting and foraging. This comprised the crest and eastern slopes of the main northern ridge of Transit Hill, extending north to the Clear Place and the Valley of the Shadows, and the western and southern slopes of Transit Hill. A polygon drawn around roost and foraging sites in this area was designated the home range core (**Fig. 12**) and occupied an area of approximately 39ha.

Female 2 mainly roosted and foraged over the western and south western slopes of Intermediate Hill and a polygon drawn about roost and foraging sites in this area defined a home range core of approximately 20ha (**Fig. 13**).

Overlap of the home ranges of Females 1 and 2 occurred in August, September and November 2009 and March and July 2010, when Female 1 was recorded roosting on Intermediate Hill on 17 occasions. These records all represented intrusions into the home range of Female 2 (presuming Female 2 occupied a home range on Intermediate Hill prior to capture in September). On the nine days when both females were tracked to roost sites, these were placed between approximately 250m and 730m apart (mean 460m; **Table 4**, **Fig. 15**). On the six occasions when both were tracked to foraging locations later in the night, Female 1 had moved north to forage on Transit Hill on five of these occasions, covering distances between approximately 900m to 2150m. However on the other occasion, Female 1 foraged on Intermediate Hill and may have crossed the path of Female 2 to a location approximately 350m away (from Female 2) later that night.

Table 4 Records of overlap of home ranges of Masked Owl Females 1 and 2 on Intermediate Hill between September 2009 and July 2010, with distances between roost and foraging sites

	distance between Female 1 and 2 roost site, m	**distance between Female 1 and 2 foraging site, m**	**comments**
date			
11.9.'09	730	(1500)	foraging on Transit Hill
12.9.'09	250	-	
13.9.'09	290	-	
18.9.'09	270	(2000)	foraging on Transit Hill
19.9.'09	590	(1000)	foraging on Transit Hill
23.9.'09	540	(900)	foraging on Transit Hill
4.11.'09	610	350	foraging on Intermediate Hill
14.3.'10	440	(2150)	foraging on Transit Hill
29.7.'10	400	-	
mean	460	1320	

data from Appendices 5 and 8 and Fig. 15

4.3 Population size

It is difficult to provide a reliable estimate of the size of the Masked Owl population on Lord Howe Island at present, due mainly to the problem of reconciling the difference in size and level of overlap between the home ranges of Females 1 and 2.

The results of the simultaneous point surveys (**Appendices 3 and 4**) suggest that there were three and four pairs respectively in the areas surveyed in the northern hills and southern mountains (**Figs 16 and 17**), both apparently outside the ranges of Females 1 and 2. These data, together with the species" occurrence throughout the Island and assuming an average home range size of approximately 150ha with a home range core of approximately 30ha (means of ranges of Females 1 and 2) plus opportunistic observations such as the simultaneous occurrence of three pairs at a trapping site at Rocky Run in August 2009 (**Appendix 1**), enable a preliminary estimate to be made of a population of 20 pairs plus a small number of immature birds. This estimate assumes that pair bonds are maintained throughout the year and that male ranges correspond approximately with those of females.

5. ROOST SITE CHARACTERISTICS

Roost sites of Females 1 and 2 (**Figs 7, 12 and 13**) were in varying sized trees of a small number of species, at a range of heights above the ground and in varying positions in the tree, comprising the canopy foliage, trunk crevices or trunk/branch/ epiphyte hollows.

Female 1 roosted most often in the canopies of relatively slender Greybarks and a Maulwood *Olea paniculata*, although roosts were frequently in trunk crevices of a large mature Banyan and occasionally in trunk and branch hollows of large mature Scalybarks and in hollows in clumps of the epiphytic Elkhorn Fern *Platycerium bifurcatum* (**Table 4**). Female 2 roosted most frequently in canopies of both slender Greybarks and Scalybarks, but selected roost sites in trunk and branch hollows more often than Female 1, favouring large mature Scalybarks (**Table 4**).

No evidence was obtained that Females 1 and 2 used caves or cliff overhangs for roosting, although possibly the only rock sites offering sufficient shelter occurred in some sea caves.

Female 1 selected a greater variety of roost sites than Female 2 in relation to tree species, height above ground and position in the tree (**Table 5**), which appeared to reflect the larger home range and wider use of habitats by the former. Canopy roost heights reflected the canopy height at a site, with both females apparently preferring to roost as high as possible providing some canopy cover was available.

Both Females 1 and 2 changed roost sites on a nightly basis, but each used a number of favoured sites on several occasions (**Table 6)**. Favoured roosts used by Female 1 were mostly in canopies of slender Greybarks and in trunk crevices in a large Banyan, although a large Maulwood was used on several occasions. Female 2 also favoured canopies of slender Greybarks and equally the trunk/branch hollows of mature Scalybarks (**Table 6**).

6. DIET

Regurgitated pellets (and fragments of pellets) of food remains were recovered from under canopy roosts and regurgitation perches in the northern hills, about the Settlement area, in the Valley of the Shadows, on Transit Hill, on Intermediate Hill and adjacent to the Boat Harbour Track (**Fig. 18**). Most were collected in three main areas representing:

i) roost sites of Female 1 on the north western slopes of Transit Hill and the Valley of the Shadows,

Figure 15 **Proximity of roost sites of Masked Owl Females 1 and 2 when both females roosted on Intermediate Hill in September and November 2009 and March 2010**

Figure 16 **Results of simultaneous point surveys for Masked Owls in the southern mountains in November 2009**

Figure 17 **Results of simultaneous point surveys for Masked Owls in the northern hills in June 2010**

Table 5 Characteristics of roost sites used by Masked Owl Females 1 and 2 between August 2009 and July 2010

Masked Owl	tree species	dbh* range/ mean# cm	roost height above ground range/ mean# m	number of roosts#			
				canopy foliage	under-storey	trunk crevice	trunk/ branch/ epiphyte hollow
Female 1	Greybark	17-71/ 44	2-16 9	11			
	Elkhorn cluster in Greybark	23-39/ 31	14-15 15				2
	dead fallen Greybark	-	-		1		
	Banyan	290+	14-20 17	2			
	Banyan	300+	15 15			7	
	Scalybark	73-149/ 106	8-14 10				4
	dead Scalybark	98	12				1
	Maulwood	79	13	3			
	canopy/ understorey roosts			17 (55%)			
	hollow roosts (incl. crevice)			14 (45%)			
	total roosts			**31**			
Female 2	Greybark	25-60/ 39	10-18/ 15	10			
	Greybark	58	12				1
	Scalybark	31-74/ 45	11-18 14	5			
	Scalybark	99-148/ 116	8-12 10				10
	Blackbutt	35	17	1			
	canopy roosts			16 (59%)			
	hollow roosts			11 (41%)			
	total roosts			**27**			

* dbh – trunk diameter at breast height
# includes repeated uses of same roosts
tree and epiphyte species:

Blackbutt *Cryptocarya triplinervis*
Greybark *Drypetes deplanchei*
Banyan *Ficus macrophylla columnaris*
Maulwood *Olea paniculata*
Elkhorn *Platycerium bifurcatum*
Scalybark *Syzygium fullagari*

data from Appendices 5, 8, 15 and 16

Table 6 Characteristics of roost sites used repeatedly by Masked Owl Females 1 and 2 between August 2009 and July 2010

Female Masked Owl	tree species	dbh* cm	roost height above ground m	canopy foliage	trunk crevice	trunk/ branch hollow	roost dates
1	Scalybark	100	8			+	31.8.‟09 9.3.‟10
	Banyan	300+	15		+		5.9.‟09 15.3.‟10 21.3.‟10 2.4.‟10 24.5.‟10 22.7.‟10 24.7.‟10
	Greybark	39	12	+			31.10.‟09 12.1.‟10 9.3.‟10 4.4.‟10
	Greybark	43	5	+			6.11.‟09 15.11.‟09
	Greybark	57	10	+			7.11.‟09 27.3.‟10
	Maulwood	79	13	+			11.5.‟10 20.5.‟10 26.7.‟10
	total roost sites			**6**			
2	Scalybark	115	10			+	23.9.‟09 13.3.‟10 1.4.‟10 17.7.‟10
	Scalybark	108	12			+	11.1.‟10 25.7.‟10
	Greybark	32	15	+			10.11.‟09 12.1.‟10 11.3.‟10
	Greybark	40	18	+			16.5.‟10 18.7.‟10
	total roost sites			**4**			

* dbh – trunk diameter at breast height
tree and epiphyte species:

Greybark *Drypetes deplanchei*
Banyan *Ficus macrophylla columnaris*
Maulwood *Olea paniculata*
Scalybark *Syzygium fullagari*

data from Appendices 5, 8, 15 and 16

ii) roost sites of Female 2 on the south western slopes of Intermediate Hill, and
iii) regurgitation perches of one or a pair of owls on the Boat Harbour Track.

Analysis of 43 fresh (intact) pellets from these locations showed that 31 contained remains of Black Rats, 12 contained remains of House Mice and 10 contained remains of birds (including Little Shearwater *Puffinus assimilis*, Black-winged Petrel and Sooty Tern *Sterna fuscata*), representing 72%, 28% and 23% of the total respectively (**Table 7**).

Examination of prey species remains in fresh pellets from Female 1 and 2 and the Boat Harbour Track regurgitation site (**Table 7**) indicated that the diets of individual owls varied. Remains in Female 1 pellets were mostly Black Rats and birds with some House Mice, remains in Female 2 pellets (although a small sample) were approximately equal Black Rats, House Mice and birds, whereas remains in pellets from the Boat Harbour Track owl(s) were predominantly Black Rats with only a few House Mice. These prey species and proportions probably reflected the characteristics of the home ranges of the individual owls concerned as the home range of Female 1 (**Fig. 12**) included a number of seabird colonies and disturbed habitat whereas the range of Female 2 (**Fig. 13**) and presumably that of the Boat Harbour Track owl(s) (**Fig. 18**) appeared more confined to intact forest, without known seabird breeding areas.

Table 7 Occurrence of prey species remains in fresh (intact) Masked Owl pellets collected between July 2009 and July 2010

	numbers of pellets containing prey species remains				
prey species	**Female 1**	**Female 2**	**unknown owl(s)***	**total pellets**	**% total pellets**
Little Shearwater	2			2	
Black-winged Petrel	3			3	
Lord Howe Wood-hen		1		1	(all bird species) 23
White Tern	1			1	
Sooty Tern	1	1		2	
unknown bird	1			1	
House Mouse	5	3	4	12	28
Black Rat	8	2	21	31	72
total pellets	18	3	22	43	

* from two adjoining regurgitation perches adjacent to Boat Harbour Track
data from Appendices 18, 19 and 20

Fragmented pellet material, although biased due to rat skulls and large bird bones persisting for longer in the litter layer than other food remains, emphasised the overall importance of the Black Rat in the Masked Owl‟s diet (**Appendix 17**). For example, a total of 26 Black Rat skulls together with other Black Rat bones were recovered from under one roost site of Female 1 (**Appendix 18**). Occasional House Mice skulls and bones, bones of one Flesh-footed Shearwater *Ardenna carneipes*, skulls and bones of several Black-winged Petrels and bones of an unidentified mammal were also found in fragmented material under other roost sites (**Appendix 17**).

Figure 18 **Locations of Masked Owl pellet collections and kills between July 2009 and July 2010**

In addition, a number of owl kill sites containing bird remains were recorded opportunistically during traverses across the Island. Although owls were not observed making these kills, remains were characterised by the removal of heads and wings in situ, together with plucked body feathers. Kill sites contained the remains of Buff-banded Rails *Gallirallus philippensis*, Sooty Terns and White Terns, with one site containing the remains of more than 20 of the latter species (**Appendix 17**).

7.0 DISCUSSION

7.1 Effectiveness of methods

7.1.1 Call playback

The use of call playback employing both mainland and local Masked Owl call sequences during the study period (s.2.1) was effective in attracting owls to within observable distances on most occasions (see comments, **Appendix 1**; **Table 8**). However, responses appeared to be affected by the time of year, the number of times individual owls had been exposed to the method and whether additional owls had been attracted to the site.

It was found that the intensity of response (duration, strength of vocalisation) and distance of approach by the owl(s) to the playback operator was generally diminished by repeated use of the method. Owls at sites that had been subjected to playback more than once, and particularly those that had been exposed five or six times, usually did not approach closer than about 30m or more to the operator, gave only a short call or series of short calls in response and left the site after 5 mins or less.

Table 8 Masked Owl responses to call playback used at trapping sites by season between August 2009 and July 2010

	spring 2009	summer 2009-2010	autumn 2010	winter 2010
response				
good	6	-	0	6
moderate	3	-	2	0
poor	2	-	4	1
nil	3	-	0	1
total call playbacks	14	-	6	8

data from Appendix 1

Owls also appeared to be adversely affected by use of the spotlight and usually flew off shortly after the light was played on them.

Wariness towards the method was acquired rapidly, as demonstrated by responses to its initial use during trials in June-July 2009 and subsequently when trapping at the same sites. In the first instances, individual owls approached low and close to within a few metres of the operator but this behaviour was never repeated during later playback sessions at the same sites.

The assessment of seasonal effects on owl response to call playback was affected by the lack of its use in summer and repeated exposure to the method. However, most responses ranked as “good” occurred in winter and spring and only “moderate” and “poor” responses were obtained in autumn (**Table 8**).

Records where two or more pairs of owls responded at a site on the one night all occurred in winter and spring (August, September and October 2009; **Appendix 1**), suggesting that these seasons represent the optimum time for response to call playback. Responses were also most intensive when more than one owl was attracted by playback and particularly when two or more pairs were present.

7.1.2 Drop-net trapping

Trapping using the drop-net technique was successful in capturing three Masked Owls (Male 1, Females 1 and 2) in August and September 2009 (s.2.2), but in numerous subsequent applications the method failed to secure any additional birds (**Appendix 1**). On a few occasions owls rebounded off the net due to malfunction of the dropping mechanism or escaped when the net snagged on adjacent vegetation, but in most instances individuals or pairs perched high overhead in the canopy and although often vocalising strongly and moving between high perches, would not fly low enough to become entangled. This was despite the use of mounted decoy owls and the provision of suitable perches close to the net.

A significant problem in setting the net was the scarcity of suitable trapping sites, which required clear gaps in the forest, or forest edges, where trees of an appropriate height were available on either side to enable the net to be raised level with the canopy. The presence of low perches near the net, that may have previously been used by owls when hunting, was also considered desirable but was seldom able to be achieved in practice.

However, probably the major problem contributing to the overall lack of success with the drop-net technique was a rapidly acquired wariness by owls to the use of call playback (s.7.1.1), together with their ability to detect human presence and familiarisation with the operation of the method generally (see comments **Appendix 1**).

Other problems experienced with the operation of drop-netting included seabirds such as Flesh-footed Shearwaters becoming entangled in the net and cattle inspecting the procedure at sites where the forest bordered pasture.

7.1.3 Radio-tracking

The use of radio-tracking in detecting roost sites, describing home ranges and establishing nightly and longer term movements of Masked Owl Females 1 and 2 proved highly successful.

The females appeared to readily accept the fitted harness and transmitter package and quickly preened the body feathers over both so that only the end of the aerial was visible along the upper surface of the tail. Although the male"s transmitter appeared to fail soon after fitting (s.2.2), both the females" transmitters performed to expectations and were continuing to emit a strong signal 12 and 11 months later when field work finished in July 2010.

The detection of roost sites enabled data to be collected on their characteristics and also resulted in information on the females" diet being provided through the recovery of regurgitated pellets.

7.2 Movements, home ranges and population size

The results from radio-tracking Females 1 and 2 suggest that some female Masked Owls on Lord Howe Island remain relatively sedentary within a small area whereas others range over a substantial area of the Island. Whether this is related to age and/or breeding status is unknown, as neither of the females bred during the 12 months of the study. No information was obtained on movements of males.

Female 1 undertook several relatively long movements over a 24hr period including one of 4.1km, one of 3.2km and several over 2km between roost sites. The pattern of Female 1"s movements showed periods of restriction to a home range core of approximately 39ha on Transit Hill, when nightly movements were minimal, interspersed with excursions to the north and south.

A comparison of the areas of the home range cores of Females 1 and 2 with their overall home range areas suggest that female owls in the Lord Howe population roost and forage within a core area of approximately one fifth to a quarter the area of their home range. However, the confinement of Female 2 to a home range of only approximately 75ha on Intermediate Hill compared with the considerably larger approximately 230ha home range of Female 1 makes it difficult to estimate an average home range area for the population. It is also apparent that home ranges overlap, although the home range cores of Females 1 and 2 were discrete.

Territoriality appears to have been relaxed to some extent in the population, with Females 1 and 2 exhibiting an overlap of home ranges, and roosting and apparently foraging in relatively close proximity on occasions (s.4.2). Records of two and three pairs of owls at call playback sites (s.7.1, **Appendix 1**) also suggests relaxation of territoriality.

A preliminary conclusion from these data is that home ranges of Masked Owls on the Island are subject to substantial overlap. Females and probably pairs maintain relatively small home range cores that, judging from the vigorous responses to call playback (s.7.1.1), are defended against other owls at some times. Intrusion of other owls into home range cores also appears to be tolerated.

As already noted (s.4.3), the information obtained from radio-tracking Masked Owl Females 1 and 2 alone makes it difficult to deduce the species" current population size on the Island, and the estimate of 20 pairs plus a number of immature birds relies on additional data from the simultaneous point surveys and opportunistic observations. However, this figure should be regarded as provisional and monitoring of additional owls, particularly males, is required to provide a more accurate estimate.

7.3 Social organisation and behaviour

Due to the apparent early failure of the transmitter fitted to Male 1, little information was obtained on its relationship with Female 2, which was probably its mate (s.2.2). However, when the male was tracked to roost sites on the second and third day after capture, these were located on the eastern periphery of Female 2"s home range.

Females 1 and 2 always apparently roosted alone, as no accompanying owls were observed on the numerous occasions when they were disturbed at roost sites or on the less numerous occasions when they did not flush (Appendices 5 and 8).

Most records of an owl remaining undisturbed in a canopy roost when approached during radio-tracking involved Female 2, which generally appeared less wary and more tolerant of human presence than Female 1.

The change of roost sites recorded for both females with successive roost detections may have reflected sensitivity to human disturbance, but its occurrence without exception and involving occasions when both females were not flushed from the first site (Appendices 5 and 8) suggests that nightly change of site is normal behaviour.

As noted (s.4.1), the owls" hunting behaviour appeared to be adversely affected by strong wind as both females moved to the lee sides of hills and ridges to forage during storms. This is an expected reaction from a predator highly dependent on hearing to detect prey.

7.4 Roost site characteristics

Sites selected by Masked Owl Females 1 and 2 for roosting on Lord Howe occurred in a variety of niches and indicate that the species is able to occupy the majority of forest habitats across the Island. The main attributes required for roosts appear to be darkness and maximum height above the ground, preferably providing an optimum vantage point.

Greybarks appear to offer the best sites for canopy foliage roosts, as demonstrated by their frequent use by both females. This is because the tree typically possesses a tight, dense crown providing a perch in a relatively dark, shaded position and is often emergent in a stand, enabling wide views of the surrounding environment.

The large trunk or branch hollows favoured for hollow roosts are mainly provided by mature and senescent Scalybarks, with the mean dbhs of trees used by Females 1 and 2 both exceeding 100cm and the heights of hollows above ground averaging 10m.

However, trees such as mature Banyans also provide suitable roost sites in the dark crevices present high in their trunks, and hollows that are formed in epiphytic Elkhorn fern clumps growing in the crowns of tall canopy trees offer similar darkness and height.

Despite the range of sites used, the repeated use of a relatively small selection of sites by both females suggests that roost sites possessing the best combinations of essential attributes are favoured, and home range cores may be defined by the occurrence of trees exhibiting these characteristics.

7.5 Lack of breeding

As noted (s.7.2), Females 1 and 2 did not breed during the 12 month study period and no evidence of other owls breeding, such as male display flights, pre-laying calling or the presence of fledged young was detected. The vigorous, sustained responses to call playback obtained throughout the study period (**Appendix 1**), usually indicative of breeding activity in mainland Masked Owls, were considered to represent defence of the home range core rather than the former.

It is possible that fitting of the transmitter packages inhibited breeding in Females 1 and 2, but this appears unlikely as their other behaviour appeared normal and owls fitted with transmitter packages on mainland Australia are known to have bred successfully (R. Kavanagh pers. comm.).

It is also possible that the Lord Howe Masked Owl population regulates breeding in accordance with population density, which could have been at maximum carrying capacity during the study due to the lack of recent culling (s.1). However, Masked Owls do not breed in all years in their mainland range (Higgins 1999) and this is considered most likely to have been the case during the study period.

It is considered likely that when Masked Owls do breed on Lord Howe they mainly use the large trunk and branch hollows in mature and senescent Scalybarks that occur at high densities in stands throughout the Island. The only documented record of breeding is a clutch of eggs taken from an 81cm dbh Scalybark on the edge of a stand at Rocky Run in May 1969 (Milledge 2009). Masked Owl Females 1 and 2 probably nest in one or more of the hollows in the 73-149cm dbh Scalybarks where they were recorded roosting during the study.

7.6 Diet

The analysis of prey remains from pellets and kill sites demonstrates that the Masked Owl operates as a generalist, opportunistic predator on Lord Howe Island. However, the high proportion of pellets found to contain Black Rat and House Mouse remains (73% and 28% respectively) indicates that introduced rodents currently contribute the major component of the prey base on the Island. Individual owls such as Female 1, with home ranges containing seabird colonies, take a substantial number of breeding seabirds and their young when these are available, and terrestrial birds such as the Lord Howe Woodhen and Buff-banded Rail are also occasionally taken.

The Masked Owl‟s high level of dependence on rodents combined with its ability to operate as a generalist, opportunistic predator supports the concern that the species is likely to pose a threat to a range of the Island‟s indigenous vertebrates (s.1), many of which are listed as Endangered or Vulnerable under State and Commonwealth legislation, once rodents are eradicated and unless owls are removed simultaneously.

Species likely to be particularly at risk following rodent eradication include small to medium-sized seabirds such as the Little Shearwater, Black-winged Petrel, White Tern and Black Noddy *Anous minutes*, and juveniles and immatures of the larger shearwaters *Ardenna* spp, Providence Petrel, Buff-banded Rail, Lord Howe Woodhen and Lord Howe Currawong. Other species that may also be threatened include the Emerald Dove *Chalcophaps indica*, Sacred Kingfisher *Todiramphus sanctus* and possibly the Lord Howe Gecko *Christinus guentheri* and Large Forest Bat *Vespadelus darlingtoni*, although there is no evidence that any of these four species are taken at present.

The high level of predation on the Black Rat also highlights the importance of removing the owl population coincident with implementation of the REP, and not prior to or independently of the latter. Removal of its major predator could result in a rapid and substantial increase in the Black Rat population in areas of intact native forest, with highly detrimental effects on biodiversity.

7.7 Implications of implementation of the Rodent Eradication Plan with respect to Masked Owls

It is apparent that Masked Owls are susceptible to secondary poisoning from rodenticides, as three individuals (including Female 1, s.3) exhibiting symptoms of anti-coagulant toxicity have been recovered over the past year from the area of the Settlement and North Bay (Appendix 2, H. Bower pers. comm.). These owls were apparently affected as the result of taking rats poisoned by baits laid to control damage in palm seed collection areas and around tourist resorts in the Settlement.

However, baits currently laid on the Island contain high levels of toxin and it is not known what impact the low dosage level of the rodenticide proposed for use in the REP will have on individual owls. Some owls may survive secondary poisoning during implementation of the Plan, as the doses may prove to be sub-lethal. In addition, other owls may have developed an immunity to the rodenticide due to its extensive past and current use about the Settlement. Further, dying rats may not be available to owls in some areas such as seabird colonies, as they may retreat underground to die. These uncertainties emphasis the importance of actively removing all owls simultaneously with rodent eradication and not adopting the high risk strategy of assuming that the total owl population will succumb to secondary poisoning.

7.8 Suitability of methods for Masked Owl eradication

Use of the call playback method employing either mainland or local call sequences appears suitable for attracting owls for shooting, and winter-spring appears to be the optimum time for its application. However, due to the wariness rapidly acquired by owls from repeated exposure to the method (s. 7.1.1), it is recommended that call playback not be used on the Island for up to one year prior to initiation of any shooting program.

Trapping of owls either for euthanasia or translocation using the drop-net technique (s.2.2) is not recommended except in particular circumstances. This is because it is time-consuming, requires up to three persons for operation and because owls quickly become wary of the use of the call playback method, human presence and also the location of the net if they have escaped from a previous trapping attempt. The use of drop-netting to capture owls for removal only appears appropriate at sites not previously trapped and that are highly favourable for its operation, such as in an open space where the adjacent canopy is low and perches suitable for owls to land are limited and in positions where they can be “covered” by the net.

Other methods of trapping owls for removal should be trialled, such as the use of “goshawk-type” traps using live rats as bait, as recommended below (s.8).

Additional techniques that could be investigated include trapping adults at hollow roost or nest sites with a hoop net once they have entered the hollow, but this method would require birds to be carrying transmitter packages (to enable location of the roost or nest) and would have limited application.

7.9 Status and origins of Lord Howe Masked Owl population

The study revealed that the Masked Owl occurs on Lord Howe Island at an apparent density of ten times or greater that found in Tasmania or on mainland Australia. This is based on an average home range on Lord Howe of 150ha (s.4.3) compared with a home range of 1,000-2,500ha in Tasmania and on the mainland (Kavanagh and Murray 1996, McNabb *et al.* 2003, Young 2006, Kavanagh *et al.* 2009). There also appears to have been no overlap of home ranges reported from Tasmania or on the mainland (Higgins 1999) such as occurs on Lord Howe.

Population limiting factors on the Island appear to be few as large hollow-bearing trees suitable as roost and nest sites are frequent and widespread, there are no predators (apart from humans) and the Black Rat and House Mouse populations provide an abundant and available food supply. The Island"s carrying capacity for owls is probably only limited by the area of forest and the level of individual pairs" tolerance of territorial or home range overlap.

The Masked Owl occupies, and in particular forages in markedly different habitats on Lord Howe Island from those used in Tasmania and on the mainland, where it hunts mainly in open dry sclerophyll forest and woodland dominated by eucalypts with typically open understoreys (Higgins 1999). The rainforest on the Lord Howe is much more structurally complex these open communities, being characterised by a closed canopy with emergent figs (Banyans), a dense understorey dominated by palms and vines and a well-developed litter layer. The Masked Owl population on the Island has adapted well to this environment over the approximately 90 years of its isolation, although it is not yet established whether this has resulted in significant changes to plumage or morphology.

It has been reported that Lord Howe Masked Owls are paler and smaller than the Tasmanian race from which they originated (McAllan *et al.* 2004), but statistically valid data to support this claim are lacking. Also, pale morph individuals are not uncommon in the generally darker, chestnut-plumaged Tasmanian population (M. Todd pers. comm.), an occurrence poorly documented in the ornithological literature. In explanation of the claimed divergence, it has been suggested that some individuals of the eastern Australian mainland race of the Masked Owl *Tyto n. novaehollandiae* may also have been included in introductions to the Island (McAllan *et al.* 2004), but there appears to be no evidence for this (Hindwood 1940).

However, the limited morphological data available for the Lord Howe population indicate that it has undergone some differentiation in relation to size since isolation. Means of weights and wing measurements of male and female Lord Howe Masked Owls are all smaller than those for the Tasmanian race (**Table 9**). Such a size

Table 9 Biometrics of mainland and Tasmanian races and Lord Howe Island population of the Masked Owl

race/population	male wt (g)	female wt (g)	male wing (mm)	female wing (mm)
mainland				
range[1]	352-602	476-706	292-323	320-356
mean[1]	**476**	**630**	**308**	**335**
Tasmanian				
range[1]	395-805	702-945	312-336	345-377
mean[1]	**632**	**841**	**323**	**364**
Lord Howe Island				
AM 0.47092[2]	510		316	
AM 0.70581[2]	508		325	
AM 0.54878[2]		655		
AM 0.56577[2]				325
AM 0.66004[2]		760		372
Somerset[3]		845		380
132-15891[4]		810		350
121-51701[4]	552		310	
132-15892[4]		820		345
mean	**523** (n=3)	**778** (n=5)	**317** (n=3)	**354** (n=5)

sources:
1 Higgins 1999
2 Australian Museum collection
3 roadkill, frozen specimen LHI
4 owls trapped this study, ABBBS band nos

reduction could be due to the substantially smaller size of the main prey species, the 200g Black Rat and 20g House Mouse, compared with the major prey species in Tasmania that range from 200-600g in weight and where bandicoots, possums and European Rabbits *Oryctolagus cuniculus* are frequently taken (Mooney 1993). It could also be due to the operation of Bergmann"s Rule, where species tend to be smaller in the areas of their ranges closest to the Equator.

8. RECOMMENDATIONS FOR FURTHER RESEARCH

To better inform the proposed eradication of Masked Owls from Lord Howe Island, more efficient and reliable trapping techniques should be investigated together with undertaking additional radio-tracking of individual owls, particularly males. Further radio-tracking is required to supplement and substantiate the information on movements, home ranges and population size obtained to date and to provide some data on breeding and recruitment. More effective trapping methods are required to capture additional owls for radio-tracking and for translocation or euthanasia during the proposed eradication program.

One trapping method that warrants consideration is the use of "goshawk-type" traps employing live rats as bait. This method has the advantage of being relatively time-efficient as it requires only one or two operators, is likely to work in locations unsuited for netting and would not alarm owls through human presence. The method has been used successfully to capture Masked Owls in Tasmania (D. Young pers. comm.).

Information on the provenance and genetic divergence of the Lord Howe population is also required for investigating the suitability of translocating captured birds to Tasmania or mainland Australian zoos during the proposed eradication program. Drs Fiona Hogan and Raylene Cooke of Monash and Deakin Universities respectively have developed methods for extracting DNA from feathers of large owls for genetic analysis (Hogan *et al.* 2008) and are prepared to supervise a University honours project using these techniques that would provide data on provenance, divergence and possibly population size. It is recommended that such a project receive the full support of the LHIB. In this regard, it would also be useful to establish preliminary contact with the Tasmanian authorities likely to be involved in any translocation to zoos should this option be adopted during the eradication program.

9. RECOMMENDATIONS FOR ERADICATION

As discussed (s.7.7), it is considered possible that deaths of some owls will occur from secondary poisoning following the application of rodenticide across the Island during the proposed REP. The cause of death may be direct, or from starvation through weakened condition from loss of the main prey base.

However, to achieve total removal of the Lord Howe Masked Owl population it is recommended that the following strategies be used coincident with implementation of the REP to account for owls that do not succumb to secondary poisoning or starvation. The strategies should be applied during both stages of the four-year REP.

During the two-year lead-in or first stage of the REP:

1. Trapping of owls should commence to enable the initiation of a translocation program to Tasmanian (and/or mainland Australian) zoos and to provide a selection of individuals for radio-tracking to assess the impacts of secondary poisoning following the application of rodenticide during the second stage of the REP. Trapping techniques could include:
   a) use of the drop-net method in favourable locations,
   b) use of “goshawk-type” traps involving the use of live rats, and
   c) use of a hoop net at roost and nest sites.

Coincident with and following application of rodenticide in the second stage of the REP:

2. Monitoring of radio-tagged owls should be undertaken to gauge the effects of secondary poisoning.
3. Individual owls should be trapped throughout the Island employing the methods described above and either translocated or euthanased.
4. Individual owls not able to be trapped should be removed using call playback and shooting at locations throughout the Island.
5. Monitoring for the presence of owls, using call playback at selected sites across the Island, should be undertaken for at least one year following completion of the REP to ensure that complete removal of the Masked Owl population has been achieved.

These strategies require that the following actions be undertaken prior to and during the first stage of the REP, and prior to initiation of owl and rodent eradication:

i) the use of “goshawk-type” traps baited with live rats should be investigated for their effectiveness in catching owls (due to the current lack of success with the drop-net method); the use of live rats will require approval from an Animal Care and Ethics Committee (ACEC) and application for an approval should be initiated promptly due to anticipated time delays in this process;

ii) the genetics of the Lord Howe Masked Owl population should be investigated by DNA analyses of feathers and other material from recently captured/killed specimens to assess the efficacy of translocation; this should establish whether mainland Masked Owl genes are present, the level of divergence or sub-speciation in the Island population and may allow a calculation of population size;

iii) liaison with the relevant Tasmanian (and mainland) authorities should be undertaken with respect to establishing a protocol for translocation of captured owls, together with an agreement on costs likely to be involved with transport and associated issues;

iv) the use of call playback should be avoided on the Island for at least 12 months before the start of owl removal to avoid habituation (and diminishing of response) of owls to the method; otherwise use of this method for drop-net trapping and shooting are likely to be compromised;

v) a program involving the monitoring of a number of radio-tagged owls in home ranges across the Island should be undertaken during the first stage of the REP and preferably prior to this to provide additional information on owl movements, home ranges, breeding and population size and recruitment; this will facilitate assessment of the impact of secondary poisoning and the effectiveness of other methods of owl eradication.

Table 10 summarises the strategies, actions and timing of the recommended owl eradication plan.

Table 10 Proposed eradication plan for the Lord Howe Island Masked Owl population

timing	strategy/action
prior to implementation of four-year REP*	i) application to ACEC for approval to use "goshawk-type" traps with live rats; ii) construction of "goshawk-type" traps and trial of use with live rats; iii) trapping of owls for fitting with radio-transmitter packages; iv) tracking of radio-tagged owls to provide additional information on movements, home ranges, breeding and population size and recruitment; v) conducting DNA analyses of owl feathers and other material to establish genetic provenance and divergence of Lord Howe population; and vi) liaison with Tasmanian (and mainland) authorities and zoos to arrange necessary approvals, licences, quarantine costs etc. for translocation of trapped owls to Tasmania (and/or mainland, dependent on outcomes of v) above).
during first (two-year lead-in) stage of REP	i) trapping of individual owls for: a) translocation to Tasmania(and/or mainland) to aid in recovery planning (subject to outcome of v) above); and b) fitting with radio-transmitter packages; ii) monitoring of radio-tagged owls to provide additional information on movements, home ranges, breeding and population size and recruitment.
coincident with and following application of rodenticide in second stage of REP	i) monitoring of radio-tagged owls to assess impacts of secondary poisoning; ii) trapping and translocation or euthanasia of individual owls; and iii) use of call playback for shooting individual owls that have not succumbed to secondary poisoning or could not be trapped.
one year following completion of REP	monitoring of selected sites across Island using call playback to ensure complete removal of owl population

* REP – Rodent Eradication Plan

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Appendix 1 Locations of sites trapped for Masked Owls between August 2009 and July 2010, with comments on captures and owl responses to trapping method

date	trapping site location	Easting MGA	Northing MGA	comments
26.8.'09	forest along road between Airport and Waste Management Facility	507270	6510500	adult female came in in response to call playback, perched high overhead, vocalised strongly, would not descend; **good response**
27.8.'09	forest edge along north eastern boundary of Middle Beach Common	507117	6511787	one pair of owls came in in response to call playback, vocalised strongly from perches on forest edge, male flew in but bounced out of net, **female then flew into net shortly after, captured, banded, fitted with transmitter – Female 1**; **good response**
28.8.'09	forest edge on western boundary of paddock behind Pinetrees Resort	506662	6511684	no response to call playback apart from two distant short vocalisations; **poor response**
28.8.'09	forest north east of LHIB Research Station	506456	6512138	no response to call playback; **nil response**
29.8.‟09	forest edge at north western corner of Old Settlement area	505140	6513010	one pair of owls came in in response to call playback, perched high overhead, female(?) most responsive, vocalised continuously but relatively quietly, male(?) perched off, vocalised intermittently, would not descend; **good response**
31.8.‟09	inside forest at southern edge of clearing, Rocky Run	508627	6508951	one pair of owls heard calling prior to playback, came in immediately in response to playback, perched high overhead, another pair of owls flew in later, interactive aggressive calling between two pairs, a further pair of owls came in to periphery towards end of call playback, total 3 pairs of owls, owls would not descend; **good response**
1.9.‟09	forest edge on southern banks of lower reaches of Soldier‟s Creek	507430	6508990	one owl came in after 20 min in response to call playback, perched high overhead, vocalised intermittently, would not descend; **moderate response**
1.9.‟09	forest along road between Airport and Waste Management Facility	507181	6510607	one owl responded towards end of call playback period, low key and from off to side, appeared aware of procedure; **poor response**
2.9.'09	forest edge along north eastern boundary of Middle Beach Common	507117	6511787	2nd time site trapped; previous capture site; no owl responses (captured Flesh-footed Shearwater); **nil response**

cont. Appendix 1 Locations of sites trapped for Masked Owls

date	trapping site location	Easting MGA	Northing MGA	comments
3.9.‟09	inside forest edge at north western corner of Old Settlement area	505079	6513043	one pair of owls calling before call playback, female came in with call playback, perched high overhead, gave sustained aggressive vocal response, male(?) less responsive, called intermittently from periphery of site, owls would not descend; **good response**
6.9.‟09	inside forest edge at north western corner of Old Settlement area	505079	6513043	2nd time site trapped; as on 3.9.‟09 one pair of owls calling before call playback, female came in with call playback, perched high overhead, gave sustained aggressive vocal response but would not descend, male(?) not seen; **good response**
7.9.‟09	Old Cemetery, behind Ned‟s Beach	506270	6512680	no response to call playback; **nil response**
9.9.‟09	forest edge at southern edge of clearing, Rocky Run	508628	6508991	one pair of owls calling prior to playback, came in almost immediately in response to playback, perched high overhead, gave sustained aggressive vocal response but would not descend, another owl flying about periphery of trapping site called several times, did not come in; **good response**
10.9.‟09	edge of forest on western edge of southern end of Golf Course	507450	6509780	**one male owl came in to two mounted owl decoys at dusk, prior to use of call playback, flew into net with first call playback, captured, banded, fitted with transmitter – Male 1, female came in while male being extracted, flew into net once male had been extracted, decoys set up and call playback used again, captured, banded, fitted with transmitter – Female 2**, at least one other owl calling to north during playback; **good response**
11.9.‟09	forest along road between Airport and Waste Management Facility	507181	6510607	2nd time site trapped; one owl came in high overhead in response to call playback, although decoys used gave brief aggressive vocal response and flew off, appeared well aware of procedure; **moderate response**

cont. Appendix 1 Locations of sites trapped for Masked Owls

date	trapping site location	Easting MGA	Northing MGA	comments
26.10.‟09	forest edge at north western corner of Old Settlement area	505140	6513010	2nd time site trapped; female came in in response to call playback, although used decoys female perched high overhead, gave few short vocalisations and flew off, two other owls (one male of pair?) vocalised in distance upslope to north east and across paddock to east; **moderate response**
28.10.‟09	forest edge on southern banks of lower reaches of Soldier‟s Creek	507430	6508990	2nd time site trapped; one owl (male?) came in after 20-30 min in response to call playback, although decoys used perched high overhead and would not descend, aggressive, persistent vocalisations; **good response**
29.10.‟09	edge of forest on western edge of southern end of Golf Course	507450	6509780	2nd time site trapped; one pair of owls came in to call playback fairly quickly, after 15 min, although decoys used pair would not come in close or descend, male most aggressive and vocal, gave sustained and vigorous response, not banded so not Male 1, female less vocal and hung back, Female 2 previously trapped and tagged at site present in vicinity but did not come in close; **good response**
30.10.‟09	disturbed forest adjacent to Pandanus Resort	506625	6512356	no response to call playback despite use of decoys; **nil response**
3.11.‟09	forest edge at southern edge of clearing, Rocky Run	508628	6508991	2nd time site trapped; a few wake-up scream calls upslope prior to call playback, little response to call playback and use of decoys apart from one full scream from adjacent forest, no owls seen; **poor response**
12.3.‟10	edge of forest on western edge of southern end of Golf Course	507450	6509780	3rd time site trapped; call playback attracted one owl, perched up high in canopy, vocalised but not strongly, would not come in close despite decoy being used, second owl also came in and vocalised but also not strongly, sat off in canopy, pair moved around site in canopy and remained throughout playback periodically, vocalised sporadically; **moderate response**
14.3.‟10	forest along road between Airport and Waste Management Facility	507181	6510607	3rd time site trapped; call playback elicited one short vocal response from an owl on forest edge, flew in high overhead but did not perch or vocalise further; **poor response**

cont. Appendix 1 Locations of sites trapped for Masked Owls

date	trapping site location	Easting MGA	Northing MGA	comments
15.3.‟10	edge of forest on western edge of southern end of Golf Course	507450	6509780	4th time site trapped; call playback attracted one pair of owls, but perched about 100m away, up high in canopy, appeared fairly wary, did not come in, vocalised softly but became disinterested fairly quickly; **poor response**
30.3.‟10	eastern end of paddock in forest to north of main road running parallel with Airstrip	507495	6510910	call playback did not appear to attract any owls, a few screams heard several hundred metres to west but owl(s) did not come in; **poor response**
19.5.‟10	swampy clearing in forest behind shelter sheds, North Bay	504160	6513220	call playback attracted one owl, sat on opposite side of clearing and gave a few low chatters, then floated in, hit top of net but when net released it caught up on adjoining foliage and owl bounced out; **moderate response**
22.5.‟10	forest edge at north western corner of Old Settlement area	505140	6513010	3rd time site trapped; call playback and use of decoy failed to attract any owls, none detected in vicinity but one owl called upslope in distance early in evening; **poor response**
23.7.‟10	forest edge at southern edge of clearing, Rocky Run	508628	6508991	3rd time site trapped; call playback and use of decoy attracted one pair of owls almost immediately, both owls came in close but perched high up, left but returned several times, one gave loud aggressive scream on two occasions, one flew over top of net but did not come down low, relatively persistent response over about 1 hr; **good response**
27.7.‟10	eastern end of paddock in forest to north of main road running parallel with Airstrip	507495	6510910	2nd time site trapped; call playback and use of decoy attracted Female 1, came in from north east and sat up high, vocalised loudly, aggressively in response to playback but would not come down, shortly after another owl came in from area of Airstrip to south, vocalised several times but not loudly, Female 1 persisted for about 40 min, responded loudly to playback, second owl left after about 10 min, did not appear particularly interested, did not interact with Female 1; **good response**

Appendix 2 Recorded locations of Masked Owls (excluding records of radio-tracked females) between May 2009 and July 2010, plus past records from remote areas

date[1]	record type[3], no. owls	location[1]	recorder[2]	Easting MGA	Northing MGA
16.5.‟09	road killed specimen, 1	Somerset	HB	506260	6512670
30.6.‟09	call, observation, 1	LHIB Research Station	DM	506403	6512132
30.6.‟09	call, observation, 1	Stevens Reserve	DM	506245	6512313
2.7.‟09	call, observation, 1	Rocky Run Creek	DM	508644	6508967
6.7.‟09	call, observation, 2	western end of Old Settlement area	DM	505130	6513015
6.7.‟09	call, observation, 2	Soldiers Creek	DM/HB	507790	6509141
10.7.‟09	pellets	Boat Harbour Track	BT/DM	508856	6508741
12.7.‟09	call, observation, 1	Airport-Waste Management Depot	DM	507202	6510600
13.7.‟09	call, observation, 1	Erskine Valley	DM	507475	6506445
26.8.‟09	kill site	Wharf area, Lagoon Road	DM	505525	6512525
1.9.‟09	call, observation, 1	Soldiers Creek	DM/NC/DN	507430	6508990
12.9.‟09	radio signal (Male 1)	under Transit Hill summit	DM	508400	6509200
26.10.‟09	call, 1	Kim‟s Lookout gully	DM	505150	6513350
26.10.‟09	call, 1	eastern end of Old Settlement area	DM	505500	5412880
1.11.‟09	call, observation, 2-3	Barra Flats, Mt Lidgbird	HB/SB	507015	6506899
1.11.‟09	call, 2-3	Erskine Valley	HB/SB	507300	6506880
1.11.‟09	call, 1	Erskine Valley	HB/SB	507800	6506750
1.11.‟09	call, 2-3	Erskine Valley	HB/SB	507370	6506700
1.11.‟09	call, 2	Erskine Valley	HB/SB	507420	6506530
1.11.‟09	call, 1	Erskine Valley	DM, NC	507600	6506800
1.11.‟09	call, 1	Erskine Valley	DM, NC	507440	6506800
1.11.‟09	call, observation, 2-3	Get-up Place, Mt Gower track	NC	507800	6505984
1.11.‟09	call, observation, 1-2	Goat House Cave area	DO/SC	508500	6507900
1.11.‟09	call, 1	Goat House Cave area	DO/SC	508720	6507840
1.11.‟09	call, 1	Goat House Cave area	DO/SC	508280	6507700
1.11.‟09	call, observation, 2-3	Sugarloaf Point-Red Point area	RH/SM	508999	6507388
1.11.‟09	call, 1	Sugarloaf Point-Red Point area	RH/SM	508980	6507730
1.11.‟09	call, 2	Sugarloaf Point-Red Point area	RH/SM	508820	6507750

cont. Appendix 2 Recorded locations of Masked Owls

date[1]	record type[3], no. owls	location[1]	recorder[2]	Easting MGA	Northing MGA
1.11.‟09	call, 2	Sugarloaf Point-Red Point area	RH/SM	508600	6507600
2.11.‟09	observation, 1	Middle Beach Road	NC	506523	6512076
7.11.‟09	kill site	Aquatic Club area, Lagoon Road	HB/DM	506200	6511900
14.11.‟09	dead specimen	Golf Course area	JR	507586	6509745
23.12.‟09	dead specimen	North Bay	HB	504196	6512778
13.1.‟10	call, 1	Dawson‟s Ridge	DM	504800	6513220
15.1.‟10	kill site	Old Meteorological Station	DM	506790	6512430
5.3.‟10	observation, 2	Malabar Hill	JS[2]	505877	6513409
16.3.‟10	observation, 1	Airstrip	NC/DM	507650	6510450
27.3.‟10	observation, call, 2	Mt Eliza track	DM/HB	503964	6513275
16.5.‟10	call, 1	Smoking Tree Ridge	DM	508460	6508900
19.5.‟10	call, observation, 1	North Bay-Old Gulch track area	DM/HB	504160	6513220
2.6.‟10	call, 1	Kim‟s Lookout area	HB	505050	6513560
2.6.‟10	call, 1	Cemetery area	SB/DK/EK	506200	6512780
8.7.‟10	pellet	Kim‟s Lookout area	RA/DO	504680	6513480
past records from remote areas					
1979(?)	specimen AM	Little Slope, Mt Gower	BM	506400	6505270
12.3.‟79	specimen AM	Muttonbird Point	BM	508700	6509800
2000(?)	observation	Mt Gower summit	AB	507250	6505500
3.2.‟01	observation	Razorback, Mt Gower	NC	506880	6505050
27.11.‟08	observation, photo	Far Flats	IH/JS[1]	507150	6507500

[1] date given for first record only at a location

[2] recorder:
AB – Adam Bester
BM - Ben Miller
BT – Bruce Thompson
DK – Dave Kelly
EK – Ethan Kelly
DO – Damian O‟Dwyer
DM – David Milledge
DN – Dave Newell
HB – Hank Bower
IH – Ian Hutton
JR - Jesse Rowland
JS[1] – Jack Shick
JS[2] – Jai Shick
NC – Nicholas Carlile
RA – Rob Abram
RH – Rachel Heaton
SC – Suryo Cunningham
SB – Sue Bower
SM – Stuart Macdonald

[3] record type
AM – Australian Museum

Appendix 3 Results of simultaneous point survey of Masked Owls in the southern mountains area, 1 November 2009

owl survey point	Easting MGA	Northing MGA	owl activity pre-call playback, 1915-2015hrs	owl activity with call playback, 2015-2025hrs*	owl activity post call playback, 2025-2100hrs	owl activity with call playback, 2100-2110hrs*	owl activity post call playback, 2110-2135hrs
Barra Flats	507015	6506899	1 owl observed flying NNE; continuous calling NE to SW, Erskine Valley, 2-3 owls	owls calling E to SE, Erskine Valley	continuous calling NE to SE, Erskine Valley, 2-3 owls	owls calling NE to E, Erskine Valley	continuous calling NE to ESE, Erskine Valley, 2-3 owls; **total 2-3 owls**
Goat House Cave ridge (no call playback)	508500	6507900	occasional calling WSW to SW and ESE to SE, Dinner Run area, 1-2 owls	nil	1 call to SE	1 owl observed overhead	1 call to SE, 1-2 owls; **total 2 possibly 3 owls**
Sugarloaf Point – Red Point	508999	6507388	continuous calling N to SSW, Dinner Run area, 2-3 owls	nil	continuous calling WNW to SW, 1 call SSE, Dinner Run area, 2-3 owls	1 owl observed adjacent to point; 2 calls WSW	continuous calling W to SW, 1 call SSE, Dinner Run area, 2-3 owls; **total 3-4 owls**
Get –up Place, Gower Track	507900	6505984	continuous calling NNW to NW, Erskine Valley, 2-3 owls	nil	continuous calling NNW to NW, Erskine Valley, 2 owls	1 owl observed flying SSE	1 call; **total 2-3, possibly 4 owls**
Eddies Cave (no call playback)	507739	6505893	continuous calling NW to NNE, Erskine Valley, 2-3 owls	nil	continuous calling NW to NNE, Erskine Valley, 2-3 owls	continuous calling NW to NNE, Erskine Valley, 2-3 owls	continuous calling NW to NNE, Erskine Valley, 2-3 owls; **total 3, possibly 4 owls**

* call playback not used at Goat House Cave ridge and Eddies Cave sites

Appendix 4 Results of simultaneous point survey of Masked Owls in the northern hills area, 2 June 2010

owl survey point	Easting MGA	Northing MGA	owl activity pre-call playback, 1730-1815hrs	owl activity with call playback, 1815-1825hrs*	owl activity post call playback, 1825-1900hrs	owl activity with call playback, 1900-1910hrs*	owl activity post call playback, 1910-1935hrs
Catalina Monument, Malabar Hill (no call playback)	505800	6513250	1 owl called to SW, Old Settlement area, 2 min prior to start; continuous calling to W, mid Kim‟s Lookout gully, 2 owls	calling to SE towards cemetery, 1 owl	nil	nil	n/a; **total 4 owls**
Malabar Hill (no call playback)	505750	6513560	faint calls to W, Dawson‟s ridge area, 1 owl; faint calls to SW, vicinity of Kim‟s Lookout gully, 1 owl	nil	nil	nil	n/a; **total 2 owls**
Kim‟s Lookout	504900	6513480	calling to E, Malabar hill area, 1 owl; calling to SE, Old Settlement area, 2 owls; calling to S, Old Settlement area, 1 owl, calling to SW, Dawson‟s Ridge area, 1 owl	response over cliff edge, 1 owl; response to S, 1 owl	nil	nil	n/a; **total 5 owls**
Dawsons Ridge, Max Nichols Memorial Track	504800	6513250	calling to NE, E, below Kim‟s Lookout, 2 owls	nil	nil	nil	n/a; **total 2 owls**
western end of Old Settlement area (no call playback)	505200	6513000	calling to W, N, NE, E, Kim‟s Lookout Gully, 3 owls	calling to SW, 1 owl	calling to E, 1 owl	nil	n/a; **total 3 owls**

cont. Appendix 4 Results of simultaneous point survey of Masked Owls in the northern hills area, 2 June 2010

owl survey point	Easting MGA	Northing MGA	owl activity pre-call playback, 1730-1815hrs	owl activity with call playback, 1815-1825hrs*	owl activity post call playback, 1825-1900hrs	owl activity with call playback, 1900-1910hrs*	owl activity post call playback, 1910-1935hrs
eastern end of Old Settlement area (no call playback)	505450	6512860	2 owls called to NW, Kim"s Lookout area, 22 min prior to start; calling to NW, NE, 2-3 owls	called to NW, 1 owl; called to W, 1 owl	nil	nil	n/a; **total 3, possibly 4 owls**

***** call playback only used at Kim"s Lookout

Appendix 5 Locations of roost sites of Masked Owl Female 1 between August 2009 and July 2010

date	roost site location	Easting MGA	Northing MGA	roost type, distance between roosts over 24hrs, comments
28.8.'09	forest on high ridge on western side of Intermediate Hill, south western aspect	507835	6509503	canopy roost, tree not identified, flushed to two other canopy perches close by as approached, approx. 2.4km distant from capture site on previous night
29.8.'09	forest on high bench on western side of Transit Hill, south western aspect	507200	6511300	canopy roost, tree not identified, approx. 1.8km distant from last roost site
30.8.'09	forest in high gully on western side of Intermediate Hill, south west aspect	507900	6509400	canopy roost, tree not identified, approx. 1.9km distant from last roost site
31.8.'09	forest on high bench on western side of Transit Hill, south western aspect	507256	6511198	canopy roost, tree not identified, flushed to one canopy perch close by and then to a hollow in 100cm dbh Scalybark, approx. 1.9km distant from last roost site
1.9.'09	forest in small mid-slope gully on northern side of Intermediate Hill	507886	6510069	canopy roost, tree not identified, approx. 1.3km distant from last roost site
2.9.'09	forest on high bench on western side of Transit Hill, south western aspect	507200	6511300	canopy roost, tree not identified, approx. 1.25km distant from last roost site
3.9.'09	forest on high ridge on western side of Intermediate Hill, south western aspect	507842	6509724	hollow roost in 98cm dbh Scalybark, would not flush from roost, approx. 1.6km from last roost site
4.9.'09	forest on high bench on western side of Transit Hill, south western aspect	507200	6511300	canopy roost, tree not identified, approx. 1.25km distant from last roost site
5.9.'09	forest on ridge at Clear Place, northern aspect	507492	6511741	crevice roost in mature 300+cm dbh Banyan, approx. 450m distant from last roost site
6.9.'09	forest in head of gully high on ridge on western side of Intermediate Hill, western aspect	508007	6509669	canopy roost, tree not identified, approx. 2.2km distant from last roost site
7.9.'09	forest in head of gully high on south western side of Intermediate Hill, southern aspect	507918	6509289	hollow roost in 149cm dbh senescent Scalybark, flushed to two canopy perches nearby, approx. 400m distant from last roost site
8.9.'09	forest on high ridge on western side of Intermediate Hill, south western aspect	507800	6509500	tracked to general location only, tree not identified, approx. 250m distant from last roost site

cont. Appendix 5 Locations of roost sites of Masked Owl Female 1

date	roost site location	Easting MGA	Northing MGA	roost type, distance between roosts over 24hrs, comments
9.9.'09	forest on high bench on western side of Transit Hill, south western aspect	507256	6511329	canopy roost, tree not identified, approx. 1.9km distant from last roost site
10.9.'09	forest on high ridge on western side of Intermediate Hill, south western aspect	507800	6509500	tracked to general location only, tree not identified, approx. 1.9km distant from last roost site
11.9.'09	forest in head of gully high on south western side of Intermediate Hill, southern aspect	508100	6509200	tracked to general location only, tree not identified, approx. 400m distant from last roost site
12.9.'09	forest on high ridge on western side of Intermediate Hill, south western aspect	507800	6509500	tracked to general location only, tree not identified, approx. 400m distant from last roost site
13.9.'09	forest on high ridge on western side of Intermediate Hill, south western aspect	507800	6509500	tracked to general location only, tree not identified, same location as last roost site
18.9.'09	forest on high ridge on western side of Intermediate Hill, south western aspect	507800	6509700	tracked to general location only, tree not identified, in vicinity of previous roost sites
19.9.'09	forest in small mid-slope gully on north western side of Intermediate Hill	507800	6510100	tracked to general location only, tree not identified, same location as last roost site
23.9.'09	forest in small mid-slope gully on north western side of Intermediate Hill	507800	6510100	tracked to general location only, tree not identified, in vicinity of previous roost sites
21.10.'09	forest on high bench on western side of Transit Hill, south western aspect	507200	6511300	tracked to general location only, tree not identified, in vicinity of previous roost sites
22.10.'09	forest on high bench on western side of Transit Hill, south western aspect	507200	6511300	tracked to general location only, tree not identified, same location as last roost site
23.10.'09	forest on high bench on western side of Transit Hill, south western aspect	507200	6511300	tracked to general location only, tree not identified, same location as last roost site
24.10.'09	forest on high bench on western side of Transit Hill, south western aspect	507200	6511300	tracked to general location only, tree not identified, same location as last roost site
25.10.'09	forest on high bench on western side of Transit Hill, south western aspect	507287	6511331	canopy roost, tree not identified, approx. 50m distant from last roost site

cont. Appendix 5 Locations of roost sites of Masked Owl Female 1

date	roost site location	Easting MGA	Northing MGA	roost type, distance between roosts over 24hrs, comments
26.10.'09	forest on high bench on western side of Transit Hill, south western aspect	507200	6511300	tracked to general location only, tree not identified, same location as last roost site
27.10.'09	forest on high bench on western side of Transit Hill, south western aspect	507200	6511300	tracked to general location only, tree not identified, same location as last roost site
28.10.'09	forest high on western side of Transit Hill, south western aspect	507276	6511414	canopy roost, tree not identified, approx. 100m distant from last roost site
29.10.'09	forest on high bench on western side of Transit Hill, south western aspect	507200	6511300	tracked to general location only, tree not identified, same location as last roost site
30.10.'09	forest on high bench on western side of Transit Hill, south western aspect	507200	6511300	tracked to general location only, tree not identified, same location as last roost site
31.10.'09	forest on high bench on western side of Transit Hill, south western aspect	507244	6511315	canopy roost in crown of 39cm dbh Greybark, flushed to canopy perch close to previous hollow roost in 100cm dbh Scalybark, same location as last roost site
1.11.'09	forest on high bench on western side of Transit Hill, south western aspect	507200	6511300	tracked to general location only, tree not identified, same location as last roost site
2.11.'09	forest on high bench on western side of Transit Hill, south western aspect	507200	6511300	tracked to general location only, tree not identified, same location as last roost site
3.11.'09	forest on high bench on western side of Transit Hill, south western aspect	507200	6511300	tracked to general location only, tree not identified, same location as last roost site
4.11.'09	forest high in head of gully on western side of Intermediate Hill, south western aspect	507900	6509400	tracked to general location only, tree not identified, approx. 2.0km distant from last roost site
5.11.'09	forest on high bench on western side of Transit Hill, south western aspect	507200	6511300	tracked to general location only, tree not identified, approx. 2.0km distant from last roost site
6.11.'09	forest on high bench on western side of Transit Hill, south western aspect	507278	6511324	canopy roost in crown of 43cm dbh Greybark, flushed to two other canopy perches close by, same location as last roost site
7.11.'09	forest in small gully on lower slopes of south eastern side of Transit Hill, south western aspect	507652	6511013	canopy roost in crown of 57cm dbh Greybark, flushed to another canopy perch close by, approx. 550m distant from last roost site

cont. Appendix 5 Locations of roost sites of Masked Owl Female 1

date	roost site location	Easting MGA	Northing MGA	roost type, distance between roosts over 24hrs, comments
9.1.‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, south eastern aspect	507488	6511475	canopy roost in crown of stunted 35cm dbh Greybark, flushed to another canopy perch close by, in vicinity of previous roost sites
10.1.‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, south eastern aspect	507500	6511500	tracked to general location only, tree not identified, same location as last roost site
11.1.‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, south eastern aspect	507500	6511500	tracked to general location only, tree not identified, same location as last roost site
12.1.‟10	forest on high bench on western side of Transit Hill, south western aspect	507252	6511324	canopy roost in crown of 39cm dbh Greybark, previous roost site, flushed to canopy perch in Scalybark, approx. 450m distant from last roost site
14.1.‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, south eastern aspect	507500	6511500	tracked to general location only, tree not identified, in vicinity of previous roost sites
15.1.‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, south eastern aspect	507500	6511500	tracked to general location only, tree not identified, same location as last roost site
17.1.‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, south eastern aspect	507500	6511500	tracked to general location only, tree not identified, in vicinity of previous roost sites
7.3.‟10	forest on high bench on western side of Transit Hill, south western aspect	507200	6511300	tracked to general location only, tree not identified, in vicinity of previous roost sites
9.3.‟10	forest on high bench on western side of Transit Hill, south western aspect	507244	6511315	canopy roost in crown of 39cm dbh Greybark, previous roost site, flushed to perch in Scalybark where previously found roosting, in vicinity of previous roost sites
10.3.‟10	forest on lower north western slopes of Transit Hill, northern aspect	506821	6511324	canopy roost, tree not identified, flushed to hollow roost in hole in Elkhorn cluster in 39cm dbh Greybark, did not flush from hollow, approx. 500m distant from last roost site
11.3.‟10	forest on high bench on western side of Transit Hill, south western aspect	507200	6511300	tracked to general location only, tree not identified, approx. 450m distant from last roost site

cont. Appendix 5 Locations of roost sites of Masked Owl Female 1

date	roost site location	Easting MGA	Northing MGA	roost type, distance between roosts over 24hrs, comments
12.3.‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, south eastern aspect	507500	6511500	tracked to general location only, tree not identified, approx. 450m distant from last roost site
14.3.‟10	forest on lower north western slopes of Intermediate Hill, north western aspect	507600	6510000	tracked to general location only, tree not identified, approx. 1.6km distant from roost site two days previously, most southerly roost recorded to date
15.3.‟10	forest on ridge at Clear Place, northern aspect	507450	6511736	canopy roost in 300+m dbh Banyan, previous roost site, flushed to another canopy perch close by, approx. 1.8km distant from last roost site
16.3.‟10	forest on lower north western slopes of Transit Hill, northern aspect	506800	6511300	tracked to general location only, tree not identified, approx. 750m distant from last roost site
17.3.‟10	forest on lower north western slopes of Transit Hill, northern aspect	506788	6511321	hollow roost in hole in Elkhorn cluster in 23cm dbh Greybark, did not flush from hollow, in same location as last roost site
18.3.‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507500	6511600	tracked to general location only, tree not identified, approx. 800m distant from last roost site
19.3.‟10	forest on ridge at Clear Place, northern aspect	507400	6511700	tracked to general location only, tree not identified, approx. 150m distant from last roost site
20.3.‟10	forest on ridge at Clear Place, northern aspect	507400	6511700	tracked to general location only, tree not identified but in Banyan stand, in same location as last roost site
21.3.‟10	forest on ridge at Clear Place, northern aspect	507478	6511773	crevice roost in 300+m dbh Banyan, previous roost site, did not flush, in same location as last roost site
22.3.‟10	forest on lower northern slopes of Mt Lidgbird, northern aspect	507700	6508600	tracked to general location only, tree not identified, approx. 3.2km distant from last roost site
23.3.‟10	forest on lower northern slopes of Mt Lidgbird, northern aspect	507700	6508800	tracked to general location only, tree not identified, approx. 200m distant from last roost site
24.3.‟10	forest on lower western slopes of Mt Lidgbird, north western aspect	507380	6507270	tracked to general location only 150m upslope from MGA co-ordinates, tree not identified, approx. 1.5km distant from last roost site, most southerly roost recorded to date
25.3.‟10	forest on high bench on western side of Transit Hill, south western aspect	507244	6511315	tracked to general location only, tree not identified, approx. 150m south of MGA co-ordinates, approx. 3.9km distant from last roost site

cont. Appendix 5 Locations of roost sites of Masked Owl Female 1

date	roost site location	Easting MGA	Northing MGA	roost type, distance between roosts over 24hrs, comments
26.3.‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507500	6511600	tracked to general location only, tree not identified, approx. 400m distant from last roost site
27.3.‟10	forest in small gully on lower slopes of south eastern side of Transit Hill, south western aspect	507645	6511023	canopy roost, tree not identified, did not flush, close to previous roost site, approx. 600m distant from last roost site
28.3.‟10	forest on high bench on western side of Transit Hill, south western aspect	507244	6511315	tracked to general location only, tree not identified, approx. 150m south of MGA co-ordinates, approx. 450m distant from last roost site
29.3.‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507500	6511600	tracked to general location only, tree not identified, approx. 450m distant from last roost site
31.3.‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507500	6511600	tracked to general location only, tree not identified, close to previous roost sites
1.4.‟10	forest on lower northern slopes of Transit Hill south of Valley of the Shadows	507300	6511750	tracked to general location only, tree not identified but in Banyan stand, approx. 300m distant from last roost site
2.4.‟10	forest on ridge at Clear Place, northern aspect	507470	6511740	crevice roost in 300+m dbh Banyan, previous roost site, did not flush, approx. 200m distant from last roost site
3.4.‟10	forest on high bench on western side of Transit Hill, south western aspect	507250	6511300	tracked to general location only, tree not identified, approx. 450m distant from last roost site
4.4.‟10	forest on high bench on western side of Transit Hill, south western aspect	507244	6511315	canopy roost in 39cm dbh Greybark, previous roost site, did not flush initially, eventually flushed to canopy perch, same location as last roost site
5.4.‟10	forest on high bench on western side of Transit Hill, south western aspect	507250	6511300	tracked to general location only, tree not identified, same location as last roost site
6.4.‟10	forest on high bench on western side of Transit Hill, south western aspect	507244	6511315	tracked to general location only, tree not identified, approx. 50m south of MGA co-ordinates, same location as last roost site
10.5.‟10	forest on northern slope of western ridge of Transit Hill, north east aspect	506900	6511200	tracked to general location only, tree not identified, in vicinity of previous roost sites

cont. Appendix 5 Locations of roost sites of Masked Owl Female 1

date	roost site location	Easting MGA	Northing MGA	roost type, distance between roosts over 24hrs, comments
11.5.‵10	forest on high bench on western side of Transit Hill, south western aspect	507214	6511369	canopy roost in 79cm dbh Maulwood, did not flush initially, eventually flushed to another canopy perch, approx. 350m distant from last roost site
12.5.‵10	forest on high bench on western side of Transit Hill, south western aspect	507250	6511300	tracked to general location only, tree not identified, same location as last roost site
13.5.‵10	forest in Stevens Reserve in Settlement, south western aspect	506422	6512359	canopy roost in 71cm dbh Greybark, did not flush, approx. 1.4km distant from last roost site
14.5.‵10	forest in upper Settlement, south western aspect	506610	6512380	canopy roost in 300m dbh Banyan, did not flush, approx. 150m distant from last roost site
15.5.‵10	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507500	6511600	tracked to general location only, tree not identified, approx. 900m distant from last roost site
16.5.‵10	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507533	6511598	understorey roost in dead Greybark, flushed to canopy perch, same location as last roost site
17.5.‵10	forest on high bench on western side of Transit Hill, south western aspect	507244	6511315	tracked to general location only, tree not identified, approx. 50m south of MGA co-ordinates, approx. 400m distant from last roost site
20.5.‵10	forest on high bench on western side of Transit Hill, south western aspect	507214	6511369	canopy roost in 79cm dbh Maulwood, previous roost site, did not flush initially, eventually flushed to another canopy perch, in vicinity of previous roost sites
21.5.‵10	forest on high bench on western side of Transit Hill, south western aspect	507250	6511300	tracked to general location only, tree not identified, same location as last roost site
22.5.‵10	forest on high bench on western side of Transit Hill, south western aspect	507250	6511300	tracked to general location only, tree not identified, same location as last roost site
23.5.‵10	forest on western side of ridge running from Transit Hill to Clear Place, north western aspect	507347	6511528	hollow roost in 73cm dbh Scalybark, did not flush, approx. 250m distant from last roost site
24.5.‵10	forest on ridge at Clear Place, northern aspect	507408	6511756	crevice roost in 300+cm dbh Banyan, previous roost site, did not flush, approx. 250m distant from last roost site
26.5.‵10	forest on ridge at Clear Place, northern aspect	507400	6511700	canopy roost, tree not identified but in Banyan stand, in vicinity of previous roost sites

cont. Appendix 5 Locations of roost sites of Masked Owl Female 1

date	roost site location	Easting MGA	Northing MGA	roost type, distance between roosts over 24hrs, comments
17.7.‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507550	6511668	canopy roost in stunted 17cm dbh Greybark, flushed to another canopy roost, in vicinity of previous roost sites
18.7.‟10	forest on ridge at Clear Place, northern aspect	507469	6511744	canopy roost in 270cm dbh Banyan, did not flush, close to previous roost sites, approx. 150m distant from last roost site
20.7.‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507500	6511600	tracked to general location only, tree not identified, in vicinity of previous roost sites
22.7.‟10	forest on ridge at Clear Place, northern aspect	507425	6511760	crevice roost in 300+cm dbh Banyan, previous roost site, did not flush, in vicinity of previous roost sites
24.7.‟10	forest on ridge at Clear Place, northern aspect	507425	6511760	crevice roost in 300+cm dbh Banyan, previous roost site, did not flush, in vicinity of previous roost sites
25.7.‟10	forest on high bench on western side of Transit Hill, south western aspect	507250	6511300	tracked to general location only, tree not identified, approx. 500m distant from last roost site
26.7.‟10	forest on high bench on western side of Transit Hill, south western aspect	507214	6511369	canopy roost in 79cm dbh Maulwood, previous roost site, did not flush initially, eventually flushed to another canopy perch, same location as last roost site
27.7.‟10	forest on high bench on western side of Transit Hill, south western aspect	507350	6511100	canopy roost, tree not identified, approx. 350m distant from last roost site
28.7.‟10	forest on high bench on western side of Transit Hill, south western aspect	507200	6511300	tracked to general location only, tree not identified, approx. 250m distant from last roost site
29.7.‟10	forest on mid north western slopes of Intermediate Hill, western aspect	507700	6509800	tracked to general location only, tree not identified, approx. 1.6km distant from last roost site

Appendix 6 Movements of Masked Owl Female 1 between successive roost sites between August 2009 and July 2010

dates	first roost site	Easting/ Northing MGA	second roost site	Easting/ Northing MGA	distance km
28-29 Aug. '09	forest on high ridge on western side of Intermediate Hill, south western aspect	507835/ 6509503	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	1.9
29-30 Aug. '09	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest in high gully on western side of Intermediate Hill, south west aspect	507900/ 6509400	2.0
30-31 Aug. '09	forest in high gully on western side of Intermediate Hill, south west aspect	507900/ 6509400	forest on high bench on western side of Transit Hill, south western aspect	507256/ 6511198	1.9
31 Aug.- 1 Sep. '09	forest on high bench on western side of Transit Hill, south western aspect	507256/ 6511198	forest in small mid-slope gully on northern side of Intermediate Hill	507886/ 6510069	1.3
1-2 Sep. '09	forest in small mid-slope gully on northern side of Intermediate Hill	507886/ 6510069	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	1.4
2-3 Sep. '09	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest on high ridge on western side of Intermediate Hill, south western aspect	507842/ 6509724	1.7
3-4 Sep. '09	forest on high ridge on western side of Intermediate Hill, south western aspect	507842/ 6509724	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	1.7
4-5 Sep. '09	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest on ridge at Clear Place, northern aspect	507492/ 6511741	0.5
5-6 Sep. '09	forest on ridge at Clear Place, northern aspect	507492/ 6511741	forest in head of gully high on ridge on western side of Intermediate Hill, western aspect	508007/ 6509669	2.1
6-7 Sep. '09	forest in head of gully high on ridge on western side of Intermediate Hill, western aspect	508007/ 6509669	forest in head of gully high on south western side of Intermediate Hill, southern aspect	507918/ 6509289	0.4
7-8 Sep. '09	forest in head of gully high on south western side of Intermediate Hill, southern aspect	507918/ 6509289	forest on high ridge on western side of Intermediate Hill, south western aspect	507800/ 6509500	0.3
8-9 Sep. '09	forest on high ridge on western side of Intermediate Hill, south western aspect	507800/ 6509500	forest on high bench on western side of Transit Hill, south western aspect	507256/ 6511329	1.9

cont. Appendix 6 Movements of Masked Owl Female 1 between successive roost sites

dates	first roost site	Easting/ Northing MGA	second roost site	Easting/ Northing MGA	distance km
9-10 Sep. '09	forest on high bench on western side of Transit Hill, south western aspect	507256/ 6511329	forest on high ridge on western side of Intermediate Hill, south western aspect	507800/ 6509500	1.9
10-11 Sep. '09	forest on high ridge on western side of Intermediate Hill, south western aspect	507800/ 6509500	forest in head of gully high on south western side of Intermediate Hill, southern aspect	508100/ 6509200	0.4
11-12 Sep. '09	forest in head of gully high on south western side of Intermediate Hill, southern aspect	508100/ 6509200	forest on high ridge on western side of Intermediate Hill, south western aspect	507800/ 6509500	0.4
12-13 Sep. '09	forest on high ridge on western side of Intermediate Hill, south western aspect	507800/ 6509500	forest on high ridge on western side of Intermediate Hill, south western aspect	507800/ 6509500	0
18-19 Sep. '09	forest on high ridge on western side of Intermediate Hill, south western aspect	507800/ 6509700	forest in small mid-slope gully on north western side of Intermediate Hill	507800/ 6510100	0.4
21-22 Oct. '09	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	0
22-23 Oct. '09	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	0
23-24 Oct. '09	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	0
24-25 Oct. '09	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest on high bench on western side of Transit Hill, south western aspect	507287/ 6511331	0.1
25-26 Oct. '09	forest on high bench on western side of Transit Hill, south western aspect	507287/ 6511331	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	0
26-27 Oct. '09	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	0

cont. Appendix 6 Movements of Masked Owl Female 1 between successive roost sites

dates	first roost site	Easting/ Northing MGA	second roost site	Easting/ Northing MGA	distance km
27-28 Oct. "09	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest high on western side of Transit Hill, south western aspect	507276/ 6511414	0.1
28-29 Oct. "09	forest high on western side of Transit Hill, south western aspect	507276/ 6511414	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	0.1
29-30 Oct. "09	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	0
30-31 Oct. "09	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest on high bench on western side of Transit Hill, south western aspect	507244/ 6511315	0
31 Oct.- 1 Nov. "09	forest on high bench on western side of Transit Hill, south western aspect	507244/ 6511315	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	0
1-2 Nov. "09	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	0
2-3 Nov. "09	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	0
3-4 Nov. "09	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest high in head of gully on western side of Intermediate Hill, south western aspect	507900/ 6509400	2.0
4-5 Nov. "09	forest high in head of gully on western side of Intermediate Hill, south western aspect	507900/ 6509400	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	2.0
5-6 Nov. "09	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest on high bench on western side of Transit Hill, south western aspect	507278/ 6511324	0
6-7 Nov. "09	forest on high bench on western side of Transit Hill, south western aspect	507278/ 6511324	forest in small gully on lower slopes of south eastern side of Transit Hill, south western aspect	507652/ 6511013	0.6
9-10 Jan. "10	forest on eastern side of ridge running from Transit Hill to Clear Place, south eastern aspect	507488/ 6511475	forest on eastern side of ridge running from Transit Hill to Clear Place, south eastern aspect	507500/ 6511500	0

cont. Appendix 6 Movements of Masked Owl Female 1 between successive roost sites

dates	first roost site	Easting/ Northing MGA	second roost site	Easting/ Northing MGA	distance km
10-11 Jan. "10	forest on eastern side of ridge running from Transit Hill to Clear Place, south eastern aspect	507500/ 6511500	forest on eastern side of ridge running from Transit Hill to Clear Place, south eastern aspect	507500/ 6511500	0
11-12 Jan. "10	forest on eastern side of ridge running from Transit Hill to Clear Place, south eastern aspect	507500/ 6511500	forest on high bench on western side of Transit Hill, south western aspect	507252/ 6511324	0.3
14-15 Jan. "10	forest on eastern side of ridge running from Transit Hill to Clear Place, south eastern aspect	507500/ 6511500	forest on eastern side of ridge running from Transit Hill to Clear Place, south eastern aspect	507500/ 6511500	0
9-10 Mar. "10	forest on high bench on western side of Transit Hill, south western aspect	507244/ 6511315	forest on lower north western slopes of Transit Hill, northern aspect	506821/ 6511324	0.4
10-11 Mar. "10	forest on lower north western slopes of Transit Hill, northern aspect	506821/ 6511324	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	0.4
11-12 Mar. "10	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest on eastern side of ridge running from Transit Hill to Clear Place, south eastern aspect	507500/ 6511500	0.3
14-15 Mar. "10	forest on lower north western slopes of Intermediate Hill, north western aspect	507600/ 6510000	forest on ridge at Clear Place, northern aspect	507450/ 6511736	1.8
15-16 Mar. "10	forest on ridge at Clear Place, northern aspect	507450/ 6511736	forest on lower north western slopes of Transit Hill, northern aspect	506800/ 6511300	0.8
16-17 Mar. "10	forest on lower north western slopes of Transit Hill, northern aspect	506800/ 6511300	forest on lower north western slopes of Transit Hill, northern aspect	506788/ 6511321	0
17-18 Mar. "10	forest on lower north western slopes of Transit Hill, northern aspect	506788/ 6511321	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507500/ 6511600	0.8
18-19 Mar. "10	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507500/ 6511600	forest on ridge at Clear Place, northern aspect	507400/ 6511700	0.2

cont. Appendix 6 Movements of Masked Owl Female 1 between successive roost sites

dates	first roost site	Easting/ Northing MGA	second roost site	Easting/ Northing MGA	distance km
19-20 Mar. ‟10	forest on ridge at Clear Place, northern aspect	507400/ 6511700	forest on ridge at Clear Place, northern aspect	507400/ 6511700	0
20-21 Mar. ‟10	forest on ridge at Clear Place, northern aspect	507400/ 6511700	forest on ridge at Clear Place, northern aspect	507478/ 6511773	0
21-22 Mar. ‟10	forest on ridge at Clear Place, northern aspect	507478/ 6511773	forest on lower northern slopes of Mt Lidgbird, northern aspect	507700/ 6508600	3.2
22-23 Mar. ‟10	forest on lower northern slopes of Mt Lidgbird, northern aspect	507700/ 6508600	forest on lower northern slopes of Mt Lidgbird, northern aspect	507700/ 6508800	0.2
23-24 Mar. ‟10	forest on lower northern slopes of Mt Lidgbird, northern aspect	507700/ 6508800	forest on lower western slopes of Mt Lidgbird, north western aspect	507332/ 6507382	1.6
24-25 Mar. ‟10	forest on lower western slopes of Mt Lidgbird, north western aspect	507332/ 6507382	forest on high bench on western side of Transit Hill, south western aspect	507244/ 6511315	4.1
25-26 Mar. ‟10	forest on high bench on western side of Transit Hill, south western aspect	507244/ 6511315	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507500/ 6511600	0.4
26-27 Mar. ‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507500/ 6511600	forest in small gully on lower slopes of south eastern side of Transit Hill, south western aspect	507645/ 6511023	0.6
27-28 Mar. ‟10	forest in small gully on lower slopes of south eastern side of Transit Hill, south western aspect	507645/ 6511023	forest on high bench on western side of Transit Hill, south western aspect	507244/ 6511315	0.5
28-29 Mar. ‟10	forest on high bench on western side of Transit Hill, south western aspect	507244/ 6511315	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507500/ 6511600	0.4
31 Mar.- 1 Apr. ‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507500/ 6511600	forest on lower northern slopes of Transit Hill south of Valley of Shadows	507200/ 6511600	0.3
1-2 Apr. ‟10	forest on lower northern slopes of Transit Hill south of Valley of Shadows	507200/ 6511600	forest on ridge at Clear Place, northern aspect	507470/ 6511740	0.2

cont. Appendix 6 Movements of Masked Owl Female 1 between successive roost sites

dates	first roost site	Easting/ Northing MGA	second roost site	Easting/ Northing MGA	distance km
2-3 Apr. ‟10	forest on ridge at Clear Place, northern aspect	507470/ 6511740	forest on high bench on western side of Transit Hill, south western aspect	507250/ 6511300	0.5
3-4 Apr. ‟09	forest on high bench on western side of Transit Hill, south western aspect	507250/ 6511300	forest on high bench on western side of Transit Hill, south western aspect	507244/ 6511315	0
4-5 Apr. ‟10	forest on high bench on western side of Transit Hill, south western aspect	507244/ 6511315	forest on high bench on western side of Transit Hill, south western aspect	507250/ 6511300	0
5-6 Apr. ‟10	forest on high bench on western side of Transit Hill, south western aspect	507250/ 6511300	forest on high bench on western side of Transit Hill, south western aspect	507244/ 6511315	0
10-11 May ‟10	forest on northern slope of western ridge of Transit Hill, north east aspect	506900/ 6511200	forest on high bench on western side of Transit Hill, south western aspect	507214/ 6511369	0.4
11-12 May ‟10	forest on high bench on western side of Transit Hill, south western aspect	507214/ 6511369	forest on high bench on western side of Transit Hill, south western aspect	507250/ 6511300	0
12-13 May ‟10	forest on high bench on western side of Transit Hill, south western aspect	507250/ 6511300	forest in Stevens Reserve in Settlement, south western aspect	506422/ 6512359	1.4
13-14 May ‟10	forest in Stevens Reserve in Settlement, south western aspect	506422/ 6512359	forest in upper Settlement, south western aspect	506610/ 6512880	0.2
14-15 May ‟10	forest in upper Settlement, south western aspect	506610/ 6512380	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507500/ 6511600	1.2
15-16 May ‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507500/ 6511600	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507533/ 6511598	0
16-17 May ‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507533/ 6511598	forest on high bench on western side of Transit Hill, south western aspect	507244/ 6511315	0.4
20-21 May ‟10	forest on high bench on western side of Transit Hill, south western aspect	507214/ 6511369	forest on high bench on western side of Transit Hill, south western aspect	507250/ 6511300	0

cont. Appendix 6 Movements of Masked Owl Female 1 between successive roost sites

dates	first roost site	Easting/ Northing MGA	second roost site	Easting/ Northing MGA	distance km
21-22 May "10	forest on high bench on western side of Transit Hill, south western aspect	507250/ 6511300	forest on high bench on western side of Transit Hill, south western aspect	507250/ 6511300	0
22-23 May "10	forest on high bench on western side of Transit Hill, south western aspect	507250/ 6511300	forest on western side of ridge running from Transit Hill to Clear Place, north western aspect	507347/ 6511528	0.3
23-24 May "10	forest on western side of ridge running from Transit Hill to Clear Place, north western aspect	507347/ 6511528	forest on ridge at Clear Place, northern aspect	507408/ 6511528	0.3
17-18 Jul. "10	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507550/ 6511668	forest on ridge at Clear Place, northern aspect	507469/ 6511744	0.2
24-25 Jul. "10	forest on ridge at Clear Place, northern aspect	507425/ 6511760	forest on high bench on western side of Transit Hill, south western aspect	507250/ 6511300	0.5
25-26 Jul. "10	forest on high bench on western side of Transit Hill, south western aspect	507250/ 6511300	forest on high bench on western side of Transit Hill, south western aspect	507214/ 6511369	0
26-27 Jul. "10	forest on high bench on western side of Transit Hill, south western aspect	507214/ 6511369	forest on high bench on western side of Transit Hill, south western aspect	507350/ 6511100	0.4
27-28 Jul. "10	forest on high bench on western side of Transit Hill, south western aspect	507350/ 6511100	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	0.3
28-29 Jul. "10	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest on mid north western slopes of Intermediate Hill, western aspect	507700/ 6509800	1.6

data from Appendix 5

Appendix 7 Distances between successive roosts sites of Masked Owl Female 1 between August 2009 and July 2010

date	first roost site location	second roost site location	distance between locations, km
28-29.8.‟09	Intermediate Hill	Transit Hill	1.9
29-30.8.‟09	Transit Hill	Intermediate Hill	2.0
30-31.8.‟09	Intermediate Hill	Transit Hill	1.9
31.8-1.9.‟09	Transit Hill	Intermediate Hill	1.3
1-2.9.‟09	Intermediate Hill	Transit Hill	1.4
2-3.9.‟09	Transit Hill	Intermediate Hill	1.7
3-4.9.‟09	Intermediate Hill	Transit Hill	1.7
4-5.9.‟09	Transit Hill	Valley of the Shadows	0.5
5-6.9.‟09	Valley of the Shadows	Intermediate Hill	2.1
6-7.9.‟09	Intermediate Hill	Intermediate Hill	0.4
7-8.9.‟09	Intermediate Hill	Intermediate Hill	0.3
8-9.9.‟09	Intermediate Hill	Transit Hill	1.9
9-10.9.‟09	Transit Hill	Intermediate Hill	1.9
10-11.9.‟09	Intermediate Hill	Intermediate Hill	0.4
11-12.9.‟09	Intermediate Hill	Intermediate Hill	0.4
12-13.9.‟09	Intermediate Hill	Intermediate Hill	0
18-19.9.‟09	Intermediate Hill	Intermediate Hill	0.4
21-22.10. ‟09	Transit Hill	Transit Hill	0
22-23.10. ‟09	Transit Hill	Transit Hill	0
23-24.10. ‟09	Transit Hill	Transit Hill	0
24-25.10. ‟09	Transit Hill	Transit Hill	0.1
25-26.10. ‟09	Transit Hill	Transit Hill	0
26-27.10.‟09	Transit Hill	Transit Hill	0
27-28.10.‟09	Transit Hill	Transit Hill	0.1
28-29.10.‟09	Transit Hill	Transit Hill	0.1
29-30.10.‟09	Transit Hill	Transit Hill	0
30-31.10.‟09	Transit Hill	Transit Hill	0
31.10-1.11.‟09	Transit Hill	Transit Hill	0
1-2.11.‟09	Transit Hill	Transit Hill	0
2-3.11.‟09	Transit Hill	Transit Hill	0
3-4.11.‟09	Transit Hill	Intermediate Hill	2.0
4-5.11.‟09	Intermediate Hill	Transit Hill	2.0
5-6.11.‟09	Transit Hill	Transit Hill	0
6-7.11.‟09	Transit Hill	Transit Hill	0.6
9-10.1.‟10	Transit Hill	Transit Hill	0
10-11.1.‟10	Transit Hill	Transit Hill	0
11-12.1.‟10	Transit Hill	Transit Hill	0.3
14-15.1.‟10	Transit Hill	Transit Hill	0
9-10.3.‟10	Transit Hill	Transit Hill	0.4
10-11.3.‟10	Transit Hill	Transit Hill	0.4
11-12.3.‟10	Transit Hill	Transit Hill	0.3
14-15.3.‟10	Intermediate Hill	Valley of the Shadows	1.8
15-16.3.‟10	Valley of the Shadows	Transit Hill	0.8

cont. Appendix 7 Distances between successive roosts sites of Masked Owl Female 1

date	first roost site location	second roost site location	distance between locations, km
16-17.3.‟10	Transit Hill	Transit Hill	0
17-18.3.‟10	Transit Hill	Transit Hill	0.8
18-19.3.‟10	Transit Hill	Valley of the Shadows	0.2
19-20.3.‟10	Valley of the Shadows	Valley of the Shadows	0
20-21.3.‟10	Valley of the Shadows	Valley of the Shadows	0
21-22.3.‟10	Valley of the Shadows	Mt Lidgbird	3.2
22-23.3.‟10	Mt Lidgbird	Mt Lidgbird	0.2
23-24.3.‟10	Mt Lidgbird	Mt Lidgbird	1.6
24-25.3.‟10	Mt Lidgbird	Transit Hill	4.1
25-26.3.‟10	Transit Hill	Transit Hill	0.4
26-27.3.‟10	Transit Hill	Transit Hill	0.6
27-28.3.‟10	Transit Hill	Transit Hill	0.5
28-29.3.‟10	Transit Hill	Transit Hill	0.4
31.3-1.4.‟10	Transit Hill	Transit Hill	0.3
1-2.4.‟10	Transit Hill	Valley of the Shadows	0.2
2-3.4.‟10	Valley of the Shadows	Transit Hill	0.5
3-4.4.‟09	Transit Hill	Transit Hill	0
4-5.4.‟10	Transit Hill	Transit Hill	0
5-6.4.‟10	Transit Hill	Transit Hill	0
10-11.5.‟10	Transit Hill	Transit Hill	0.4
11-12.5.‟10	Transit Hill	Transit Hill	0
12-13.5.‟10	Transit Hill	Settlement	1.4
13-14.5.‟10	Settlement	Settlement	0.2
14-15.5.‟10	Settlement	Transit Hill	1.2
15-16.5.‟10	Transit Hill	Transit Hill	0
16-17.5.‟10	Transit Hill	Transit Hill	0.4
20-21.5.‟10	Transit Hill	Transit Hill	0
21-22.5.‟10	Transit Hill	Transit Hill	0
22-23.5.‟10	Transit Hill	Transit Hill	0.3
23-24.5.‟10	Transit Hill	Valley of the Shadows	0.3
17-18.7.‟10	Transit Hill	Valley of the Shadows	0.2
24-25.7.‟10	Valley of the Shadows	Transit Hill	0.5
25-26.7.‟10	Transit Hill	Transit Hill	0
26-27.7.‟10	Transit Hill	Transit Hill	0.4
27-28.7.‟10	Transit Hill	Transit Hill	0.3
28-29.7.‟10	Transit Hill	Intermediate Hill	1.6

data from Appendix 6

Appendix 8 Locations of roost sites of Masked Owl Female 2 between September 2009 and July 2010

date	roost site location	Easting MGA	Northing MGA	roost type, distance between roosts over 24hrs, comments
11.9.‵09	forest in gully on lower western slopes of Intermediate Hill, southern aspect	507554	6509681	hollow roost in 124cm dbh Scalybark, flushed to canopy perch nearby, approx. 150m distant from capture site on previous night
12.9.‵09	forest in gully on lower western slopes of Intermediate Hill, southern aspect	507600	6509650	tracked to general location only, tree not identified, approx. 150m distant from last roost site
13.9.‵09	forest in gully on lower western slopes of Intermediate Hill, southern aspect	507600	6509700	tracked to general location only, tree not identified, approx. 100m distant from last roost site
18.9.‵09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507540	6509670	tracked to general location only, tree not identified, in vicinity of previous roost sites
19.9.‵09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507500	6509600	tracked to general location only, tree not identified, approx. 150m distant from last roost site
23.9.‵09	forest on mid western slopes of Intermediate Hill, north western aspect	507624	6509589	hollow roost in 115cm dbh Scalybark, in vicinity of previous roost sites
21.10.‵09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507509	6509577	canopy roost, tree not identified, flushed to hollow perch in 108cm dbh Scalybark nearby, in vicinity of previous roost sites
22.10.‵09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507600	6509700	tracked to general location only, tree not identified, approx. 150m distant from last roost site
23.10.‵09	forest in gully on mid western slopes of Intermediate Hill, western aspect	507607	6509720	canopy roost, tree not identified, did not flush, approx. 50m distant from last roost site
24.10.‵09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507600	6509700	tracked to general location only, tree not identified, approx. 200m distant from last roost site
25.10.‵09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507600	6509700	tracked to general location only, tree not identified, same location as last roost site
26.10.‵09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507600	6509700	tracked to general location only, tree not identified, same location as last roost site

cont. Appendix 8 Locations of roost sites of Masked Owl Female 2

date	roost site location	Easting MGA	Northing MGA	roost type, distance between roosts over 24hrs, comments
27.10.'09	forest on mid-high western slopes of Intermediate Hill, western aspect	507629	6509768	canopy roost, tree not identified, flushed to another canopy perch, approx. 250m distant from last roost site
29.10.'09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507600	6509700	tracked to general location only, tree not identified, in vicinity of previous roost sites
30.10.'09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507624	6509668	canopy roost, tree not identified, flushed to another canopy perch, approx. 150m distant from last roost site
1.11.'09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507600	6509700	tracked to general location only, tree not identified, in vicinity of previous roost sites
2.11.'09	forest on mid north western slopes of Intermediate Hill, north western aspect	507600	6510100	tracked to general location only, tree not identified, approx. 600m distant from last roost site
3.11.'09	forest on high western slopes of Intermediate Hill, south western aspect, aspect	507733	6509574	canopy roost in 60cm dbh Greybark, flushed to another canopy perch, approx. 600m distant from last roost site
4.11.'09	forest on mid northern slopes of Intermediate Hill, northern aspect	507926	6510009	canopy roost in 58cm dbh Greybark, flushed to another canopy perch, approx. 500m distant from last roost site
5.11.'09	forest in gully on lower western slopes of Intermediate Hill, southern aspect	507600	6509700	tracked to general location only, tree not identified, approx. 650m distant from last roost site
6.11.'09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507600	6509700	tracked to general location only, tree not identified, same location as last roost site
7.11.'09	forest on northern slopes of Intermediate Hill, north western aspect	508000	6509700	tracked to general location only, tree not identified, approx. 550m distant from last roost site
10.1.'10	forest in gully on lower western slopes of Intermediate Hill, western aspect	507600	6509700	tracked to general location only, tree not identified, in vicinity of previous roost sites
11.1.'10	forest in head of gully on upper mid south west slopes of Intermediate Hill, south western aspect	507759	6509536	hollow roost in trunk of 108cm dbh Scalybark, did not flush, emerged at dusk, approx. 500m distant from last roost site
12.1.'10	forest in gully on lower north western slopes of Intermediate Hill, western aspect	507607	6509739	canopy roost in 32cm Greybark, did not flush, previous roost site, approx. 250m distant from last roost site

cont. Appendix 8 Locations of roost sites of Masked Owl Female 2

date	roost site location	Easting MGA	Northing MGA	roost type, distance between roosts over 24hrs, comments
14.1.‟10	forest on lower western slopes of Intermediate Hill, western aspect	507525	6509614	canopy roost, tree not identified, flushed to other canopy perches, in vicinity of previous roost sites
15.1.‟10	forest on western slopes of Intermediate Hill, south western aspect	507710	6509555	canopy roost in 25cm dbh Greybark, flushed to another canopy perch, approx. 200m distant m from last roost site
17.1.‟10	forest on western slopes of Intermediate Hill, southern aspect	507700	6509500	tracked to general location only, tree not identified, in vicinity of previous roost sites
7.3.‟10	forest on north western ridge of Intermediate Hill, south western aspect	507965	6509797	canopy roost, tree not identified, flushed to other canopy perches, in vicinity of previous roost sites
8.3.‟10	forest on north western slopes of Intermediate Hill, north western aspect	507914	6509631	canopy roost, tree not identified, flushed to another canopy perch, approx. 150m distant from last roost site
11.3.‟10	forest in gully on lower north western slopes of Intermediate Hill, western aspect	507629	6509753	canopy roost in 32cm dbh Greybark, previous roost site, did not flush, in vicinity of previous roost sites
13.3.‟10	forest on mid western slopes of Intermediate Hill, north western aspect	507603	6509587	hollow roost in 115cm dbh Scalybark, previous roost site, did not flush, in vicinity of previous roost sites
14.3.‟10	forest on lower north western slopes of Intermediate Hill, western aspect	507476	6509578	hollow roost in 148cm dbh Scalybark, did not flush, previous roost site, approx. 100m distant from last roost site
15.3.‟10	forest on mid north western slopes of Intermediate Hill, north western aspect	507700	6509700	tracked to general location only, tree not identified, approx. 300m distant from last roost site
16.3.‟10	forest on mid north western slopes of Intermediate Hill, south western aspect	507764	6509551	canopy roost, tree not identified but in Scalybark stand, flushed to other canopy perches, approx. 150m distant from last roost site
18.3.‟10	forest in gully on lower north western slopes of Intermediate Hill, western aspect	507600	6509700	tracked to general location only, tree not identified, in vicinity of previous roost sites
19.3.‟10	forest on north western ridge of Intermediate Hill, south western aspect	507900	6509700	tracked to general location only, tree not identified but in Scalybark stand, approx. 300m distant from last roost site
20.3.‟10	forest on mid western slopes of Intermediate Hill, south western aspect	507600	6509500	tracked to general location only, tree not identified, same location as last roost site

cont. Appendix 8 Locations of roost sites of Masked Owl Female 2

date	roost site location	Easting MGA	Northing MGA	roost type, distance between roosts over 24hrs, comments
21.3.‟10	forest on mid western slopes of Intermediate Hill, south western aspect	507600	6509500	tracked to general location only, tree not identified, same location as last roost site
22.3.‟10	forest on mid western slopes of Intermediate Hill, south western aspect	507600	6509500	tracked to general location only, tree not identified, same location as last roost site
23.3.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	507848	6509766	canopy roost in 35cm dbh Scalybark, flushed to another canopy perch, approx. 350m distant from last roost site
24.3.‟10	forest on mid western slopes of Intermediate Hill, western aspect	507700	6509500	tracked to general location only, tree not identified, approx. 300m from last roost site
25.3.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	507700	6509700	tracked to general location only, tree not identified, approx. 200m distant from last roost site
26.3.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	507800	6509800	tracked to general location only, tree not identified, approx. 100m distant from last roost site
27.3.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	507800	6509800	tracked to general location only, tree not identified, same location as last roost site
28.3.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	507900	6509600	tracked to general location only, tree not identified, approx. 300m distant from last roost site
29.3.‟10	forest on upper north western slopes of Intermediate Hill, western aspect	508018	6509702	canopy roost in 31cm dbh Scalybark, in vicinity of other roost sites, did not flush initially, eventually flushed to another canopy perch, approx. 200m distant from last roost site
31.3.‟10	forest in gully on lower north western slopes of Intermediate Hill, western aspect	507600	6509700	tracked to general location only, tree not identified, in vicinity of previous roost sites
1.4.‟10	forest on mid western slopes of Intermediate Hill, north western aspect	507602	6509590	hollow roost in 115cm dbh Scalybark, previous roost site, did not flush, approx 100m distant from last roost site
2.4.‟10	forest on upper north western slopes of Intermediate Hill, western aspect	507900	6509600	tracked to general location only, tree not identified, approx. 350m distant from last roost site
3.4.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	508100	6509500	tracked to general location only, tree not identified, approx. 200m distant from last roost site

cont. Appendix 8 Locations of roost sites of Masked Owl Female 2

date	roost site location	Easting MGA	Northing MGA	roost type, distance between roosts over 24hrs, comments
4.4.‟10	forest on upper north western slopes of Intermediate Hill, western aspect	507700	6509700	tracked to general location only, tree not identified, approx. 400m distant from last roost site
5.4.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	508100	6509500	tracked to general location only, tree not identified, approx. 400m distant from last roost site
6.4.‟10	forest on mid north western slopes of Intermediate Hill, south western aspect	507600	6509500	tracked to general location only, tree not identified, approx. 450m distant from last roost site
10.5.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	507700	6509450	canopy roost, tree not identified but in Scalybark stand, flushed to other canopy perches, in vicinity of previous roost sites
11.5.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	507750	6509750	canopy roost, tree not identified but in Scalypark stand, flushed to another canopy perch, approx. 300m distant from last roost site
12.5.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	508047	6509719	canopy roost in 41cm dbh Greybark, did not flush, approx. 250m distant from last roost site
13.5.‟10	forest on upper north western slopes of Intermediate Hill, western aspect	507700	6509700	tracked to general location only, tree not identified, approx. 300m distant from last roost site
14.5.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	507800	6509700	tracked to general location only, tree not identified, approx. 200m distant from last roost site
15.5.‟10	forest on mid north western slopes of Intermediate Hill, western aspect	507716	6509631	canopy roost in 74cm dbh Scalybark, flushed to another canopy perch, approx. 200m distant from last roost site
16.5.‟10	forest on ridge on lower western slopes of Intermediate Hill, south western aspect	507691	6509400	canopy roost in 40cm dbh Greybark, did not flush, approx. 250m distant from last roost site
17.5.‟10	forest on mid north western slopes of Intermediate Hill, south western aspect	507800	6509800	tracked to general location only, tree not identified, approx. 200m distant from last roost site
20.5.‟10	forest on upper north western slopes of Intermediate Hill, western aspect	507900	6509600	tracked to general location only, tree not identified, in vicinity of previous roost sites
21.5.‟10	forest on upper north western slopes of Intermediate Hill, western aspect	507900	6509600	tracked to general location only, tree not identified, same location as last roost site

cont. Appendix 8 Locations of roost sites of Masked Owl Female 2

date	roost site location	Easting MGA	Northing MGA	roost type, distance between roosts over 24hrs, comments
22.5.‟10	forest on lower western slopes of Intermediate Hill, southern aspect	507508	6509350	canopy roost in 44cm dbh Scalybark, did not flush initially, eventually flushed to another canopy perch, approx. 500m distant from last roost site
23.5.‟10	forest on upper north western slopes of Intermediate Hill, western aspect	508000	6509600	tracked to general location only, tree not identified, approx. 600m distant from last roost site
24.5.‟10	forest on upper north western slopes of Intermediate Hill, western aspect	508000	6509600	tracked to general location only, tree not identified, same location as last roost site
25.5.‟10	forest on upper north western slopes of Intermediate Hill, western aspect	507905	6509534	canopy roost in 31cm dbh Greybark, did not flush, approx. 100m distant from last roost site
26.5.‟10	forest on upper north western slopes of Intermediate Hill, western aspect	507700	6509950	tracked to general location only, tree not identified, approx. 400m distant from last roost site
16.7.‟10	forest on upper north western slopes of Intermediate Hill, western aspect	507887	6509625	canopy roost in 35cm dbh Blackbutt, flushed to other canopy perches including large Scalybark, in vicinity of previous roost sites
17.7.‟10	forest on mid western slopes of Intermediate Hill, north western aspect	507602	6509589	hollow roost in 115cm dbh Scalybark, did not flush, previous roost site, approx. 300m from last roost site
18.7.‟10	forest on ridge on lower western slopes of Intermediate Hill, south western aspect	507690	6509399	canopy roost in 40cm dbh Greybark, did not flush, approx. 200m distant from last roost site
20.7.‟10	forest on lower western slopes of Intermediate Hill, south western aspect	507700	6509400	tracked to general location only, tree not identified, in vicinity of previous roost sites
21.7.‟10	forest on mid western slopes of Intermediate Hill, south western aspect	507904	6509543	canopy roost in 39cm dbh Scalybark, flushed to another canopy perch, approx. 300m distant from last roost site
22.7.‟10	forest on mid western slopes of Intermediate Hill, western aspect	507700	6509600	tracked to general location only, tree not identified, approx. 150m distant from last roost site
24.7.‟10	forest on mid western slopes of Intermediate Hill, south western aspect	507700	6509500	tracked to general location only, tree not identified, in vicinity of previous roost sites
25.7.‟10	forest on mid western slopes of Intermediate Hill, south western aspect	507759	6509531	hollow roost in 103cm dbh Scalybark, did not flush, previous roost site, approx. 50m from last roost site

cont. Appendix 8 Locations of roost sites of Masked Owl Female 2

date	roost site location	Easting MGA	Northing MGA	roost type, distance between roosts over 24hrs, comments
27.7.‟10	forest on mid western slopes of Intermediate Hill, south western aspect	507500	6509600	tracked to general location only, tree not identified, in vicinity of previous roost sites
28.7.‟10	forest on mid western slopes of Intermediate Hill, south western aspect	507637	6509986	hollow in 58cm dbh Greybark, did not flush, approx. 400m from last roost site
29.7.‟10	forest on ridge on lower western slopes of Intermediate Hill, south western aspect	507700	6509400	tracked to general location only, tree not identified, approx. 500m from last roost site

Appendix 9 Movements of Masked Owl Female 2 between successive roost sites between September 2009 and July 2010

date	first roost site	Easting/ Northing MGA	second roost site	Easting/ Northing MGA	distance km
11-12 Sep. „09	forest in gully on lower western slopes of Intermediate Hill, southern aspect	507554/ 6509681	forest in gully on lower western slopes of Intermediate Hill, southern aspect	507550/ 6509900	0.2
12-13 Sep. „09	forest in gully on lower western slopes of Intermediate Hill, southern aspect	507550/ 6509900	forest in gully on lower western slopes of Intermediate Hill, southern aspect	507500/ 6509400	0.1
18-19 Sep. „09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507350/ 6509500	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507500/ 6509600	0.2
21-22 Oct. „09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507509/ 6509577	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507500/ 6509500	0.2
22-23 Oct. „09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507500/ 6509500	forest in gully on mid western slopes of Intermediate Hill, western aspect	507607/ 6509720	0.1
23-24 Oct. „09	forest in gully on mid western slopes of Intermediate Hill, western aspect	507607/ 6509720	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507500/ 6509500	0.2
24-25 Oct. „09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507500/ 6509500	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507500/ 6509500	0
25-26 Oct. „09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507500/ 6509500	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507500/ 6509500	0
26-27 Oct. „09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507500/ 6509500	forest on mid-high western slopes of Intermediate Hill, western aspect	507629/ 6509768	0.3
29-30 Oct. „09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507500/ 6509500	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507624/ 6509668	0.2
1-2 Nov. „09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507500/ 6509500	forest on mid north western slopes of Intermediate Hill, north western aspect	507600/ 6510100	0.4
2-3 Nov. „09	forest on mid north western slopes of Intermediate Hill, north western aspect	507600/ 6510100	forest on high western slopes of Intermediate Hill, south western aspect, aspect	507733/ 6509574	0.5

cont. Appendix 9 Movements of Masked Owl Female 2 between successive roost sites

date	first roost site	Easting/ Northing MGA	second roost site	Easting/ Northing MGA	distance km
3-4 Nov. „09	forest on high western slopes of Intermediate Hill, south western aspect, aspect	507733/ 6509574	forest on mid northern slopes of Intermediate Hill, northern aspect	507926/ 6510009	0.5
4-5 Nov. „09	forest on mid northern slopes of Intermediate Hill, aspect	507926/ 6510009	forest in gully on lower western slopes of Intermediate Hill, southern aspect	507500/ 6509400	0.5
5-6 Nov. „09	forest in gully on lower western slopes of Intermediate Hill, southern aspect	507500/ 6509400	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507500/ 6509500	0
6-7 Nov. „09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507500/ 6509500	forest on northern slopes of Intermediate Hill, north western aspect	508000/ 6509700	0.4
10-11 Jan. „10	forest in gully on lower western slopes of Intermediate Hill, western aspect	507600/ 6509900	forest in head of gully on upper mid south west slopes of Intermediate Hill, south western aspect	507759/ 6509536	0.2
11-12 Jan. „10	forest in head of gully on upper mid south west slopes of Intermediate Hill, south western aspect	507759/ 6509536	forest in gully on lower north western slopes of Intermediate Hill, western aspect	507607/ 6509739	0.3
14-15 Jan. „10	forest on lower western slopes of Intermediate Hill, western aspect	507525/ 6509614	forest on western slopes of Intermediate Hill, south western aspect	507710/ 6509555	0.2
7-8 Mar. „10	forest on north western ridge of Intermediate Hill, south western aspect	507965/ 6509797	forest on north western slopes of Intermediate Hill, north western aspect	507914/ 6509631	0.2
13-14 Mar. „10	forest on mid western slopes of Intermediate Hill, north western aspect	507603/ 6509587	forest on lower north western slopes of Intermediate Hill, western aspect	507476/ 6509578	0.1
14-15 Mar. „10	forest on lower north western slopes of Intermediate Hill, western aspect	507476/ 6509578	forest on mid north western slopes of Intermediate Hill, north western aspect	507700/ 6509700	0.3
15-16 Mar. „10	forest on mid north western slopes of Intermediate Hill, north western aspect	507700/ 6509700	forest on mid north western slopes of Intermediate Hill, south western aspect	507764/ 6509551	0.2

cont. Appendix 9 Movements of Masked Owl Female 2 between successive roost sites

date	first roost site	Easting/ Northing MGA	second roost site	Easting/ Northing MGA	distance km
18-19 Mar. „10	forest in gully on lower north western slopes of Intermediate Hill, western aspect	507600/ 6509700	forest on north western ridge of Intermediate Hill, south western aspect	507900/ 6509700	0.3
19-20 Mar. „10	forest on north western ridge of Intermediate Hill, south western aspect	507900/ 6509700	forest on mid western slopes of Intermediate Hill, south western aspect	507600/ 6509500	0
20-21 Mar. „10	forest on mid western slopes of Intermediate Hill, south western aspect	507600/ 6509500	forest on mid western slopes of Intermediate Hill, south western aspect	507600/ 6509500	0
21-22 Mar. „10	forest on mid western slopes of Intermediate Hill, south western aspect	507600/ 6509500	forest on mid western slopes of Intermediate Hill, south western aspect	507600/ 6509500	0
22-23 Mar. „10	forest on mid western slopes of Intermediate Hill, south western aspect	507600/ 6509500	forest on upper north western slopes of Intermediate Hill, south western aspect	507848/ 6509766	0.4
23-24 Mar. „10	forest on upper north western slopes of Intermediate Hill, south western aspect	507848/ 6509766	forest on mid western slopes of Intermediate Hill, western aspect	507700/ 6509500	0.3
24-25 Mar. „10	forest on mid western slopes of Intermediate Hill, western aspect	507700/ 6509500	forest on upper north western slopes of Intermediate Hill, south western aspect	507700/ 6509700	0.2
25-26 Mar. „10	forest on upper north western slopes of Intermediate Hill, south western aspect	507700/ 6509700	forest on upper north western slopes of Intermediate Hill, south western aspect	507800/ 6509800	0.1
26-27 Mar. „10	forest on upper north western slopes of Intermediate Hill, south western aspect	507800/ 6509800	forest on upper north western slopes of Intermediate Hill, south western aspect	507800/ 6509800	0
27-28 Mar. „10	forest on upper north western slopes of Intermediate Hill, south western aspect	507800/ 6509800	forest on upper north western slopes of Intermediate Hill, south western aspect	507900/ 6509600	0.3
28-29 Mar. „10	forest on upper north western slopes of Intermediate Hill, south western aspect	507900/ 6509600	forest on upper north western slopes of Intermediate Hill, western aspect	508018/ 6509702	0.2
31 Mar.- 1 Apr. „10	forest in gully on lower north western slopes of Intermediate Hill, western aspect	507600/ 6509700	forest on mid western slopes of Intermediate Hill, north western aspect	507602/ 6509590	0.1

cont. Appendix 9 Movements of Masked Owl Female 2 between successive roost sites

date	first roost site	Easting/ Northing MGA	second roost site	Easting/ Northing MGA	distance km
1-2 Apr. „10	forest on mid western slopes of Intermediate Hill, north western aspect	507602/ 6509590	forest on upper north western slopes of Intermediate Hill, western aspect	507900/ 6509600	0.4
2-3 Apr. „10	forest on upper north western slopes of Intermediate Hill, western aspect	507900/ 6509600	forest on upper north western slopes of Intermediate Hill, south western aspect	508100/ 6509500	0.2
3-4 Apr. „10	forest on upper north western slopes of Intermediate Hill, south western aspect	508100/ 6509500	forest on upper north western slopes of Intermediate Hill, western aspect	507700/ 6509700	0.5
4-5 Apr. „10	forest on upper north western slopes of Intermediate Hill, western aspect	507700/ 6509700	forest on upper north western slopes of Intermediate Hill, south western aspect	508100/ 6509500	0.5
5-6 May „10	forest on upper north western slopes of Intermediate Hill, south western aspect	508100/ 6509500	forest on mid north western slopes of Intermediate Hill, south western aspect	507600/ 6509500	0.5
10-11 May „10	forest on upper north western slopes of Intermediate Hill, south western aspect	507700/ 6509450	forest on upper north western slopes of Intermediate Hill, south western aspect	507750/ 6509750	0.3
11-12 May „10	forest on upper north western slopes of Intermediate Hill, south western aspect	507750/ 6509750	forest on upper north western slopes of Intermediate Hill, south western aspect	508047/ 6509719	0.3
12-13 May „10	forest on upper north western slopes of Intermediate Hill, south western aspect	508047/ 6509719	forest on upper north western slopes of Intermediate Hill, western aspect	507700/ 6509700	0.3
13-14 May „10	forest on upper north western slopes of Intermediate Hill, western aspect	507700/ 6509700	forest on upper north western slopes of Intermediate Hill, south western aspect	507800/ 6509700	0.2
14-15 May „10	forest on upper north western slopes of Intermediate Hill, south western aspect	507800/ 6509700	forest on mid north western slopes of Intermediate Hill, western aspect	507716/ 6509631	0.2
15-16 May „10	forest on mid north western slopes of Intermediate Hill, western aspect	507716/ 6509631	forest on ridge on lower western slopes of Intermediate Hill, south western aspect	507691/ 6509400	0.3
16-17 May „10	forest on ridge on lower western slopes of Intermediate Hill, south western aspect	507691/ 6509400	forest on mid north western slopes of Intermediate Hill, south western aspect	507800/ 6509800	0.2

cont. Appendix 9 Movements of Masked Owl Female 2 between successive roost sites

date	first roost site	Easting/ Northing MGA	second roost site	Easting/ Northing MGA	distance km
20-21 May „10	forest on upper north western slopes of Intermediate Hill, western aspect	507900/ 6509600	forest on upper north western slopes of Intermediate Hill, western aspect	507900/ 6509600	0
21-22 May „10	forest on upper north western slopes of Intermediate Hill, western aspect	507900/ 6509600	forest on lower western slopes of Intermediate Hill, southern aspect	507508/ 6509350	0.5
22-23 May „10	forest on lower western slopes of Intermediate Hill, southern aspect	507508/ 6509350	forest on upper north western slopes of Intermediate Hill, western aspect	508000/ 6509600	0.6
23-24 May „10	forest on upper north western slopes of Intermediate Hill, western aspect	508000/ 6509600	forest on upper north western slopes of Intermediate Hill, western aspect	508000/ 6509600	0
24-25 May „10	forest on upper north western slopes of Intermediate Hill, western aspect	508000/ 6509600	forest on upper north western slopes of Intermediate Hill, western aspect	507905/ 6509534	0.1
25-26 May „10	forest on upper north western slopes of Intermediate Hill, western aspect	507905/ 6509534	forest on upper north western slopes of Intermediate Hill, western aspect	507700/ 6509950	0.5
16-17 Jul. „10	forest on upper north western slopes of Intermediate Hill, western aspect	507887/ 6509625	forest on mid western slopes of Intermediate Hill, north western aspect	507602/ 6509589	0.3
17-18 Jul. „10	forest on mid western slopes of Intermediate Hill, north western aspect	507602/ 6509589	forest on ridge on lower western slopes of Intermediate Hill, south western aspect	507690/ 6509399	0.2
20-21 Jul. „10	forest on lower western slopes of Intermediate Hill, south western aspect	507700/ 6509400	forest on mid western slopes of Intermediate Hill, south western aspect	507904/ 6509543	0.3
21-22 Jul. „10	forest on mid western slopes of Intermediate Hill, south western aspect	507904/ 6509543	forest on mid western slopes of Intermediate Hill, western aspect	507700/ 6509600	0.2
24-25 Jul. „10	forest on mid western slopes of Intermediate Hill, south western aspect	507700/ 6509500	forest on mid western slopes of Intermediate Hill, south western aspect	507759/ 6509531	0.1
27-28 Jul. „10	forest on mid western slopes of Intermediate Hill, south western aspect	507500/ 6509600	forest on mid western slopes of Intermediate Hill, south western aspect	507637/ 6509986	0.4

cont. Appendix 9 Movements of Masked Owl Female 2 between successive roost sites

date	first roost site	Easting/ Northing MGA	second roost site	Easting/ Northing MGA	distance km
28-29 Jul. „10	forest on mid western slopes of Intermediate Hill, south western aspect	507637/ 6509986	forest on ridge on lower western slopes of Intermediate Hill, south western aspect	507700/ 6509400	0.6

data from Appendix 8

Appendix 10 Distances between successive roosts sites of Masked Owl Female 2 between September 2009 and July 2010

date	first roost site location	second roost site location	distance between locations, km
11-12.9.„09	Intermediate Hill	Intermediate Hill	0.2
12-13.9.„09	Intermediate Hill	Intermediate Hill	0.1
18-19.9.„09	Intermediate Hill	Intermediate Hill	0.2
21-22.10.‟09	Intermediate Hill	Intermediate Hill	0.2
22-23.10.„09	Intermediate Hill	Intermediate Hill	0.1
23-24.10.„09	Intermediate Hill	Intermediate Hill	0.2
24-25.10.„09	Intermediate Hill	Intermediate Hill	0
25-26.10.„09	Intermediate Hill	Intermediate Hill	0
26-27.10.„09	Intermediate Hill	Intermediate Hill	0.3
29-30.10.„09	Intermediate Hill	Intermediate Hill	0.2
1-2.11.„09	Intermediate Hill	Intermediate Hill	0.4
2-3.11.„09	Intermediate Hill	Intermediate Hill	0.5
3-4.11.„09	Intermediate Hill	Intermediate Hill	0.5
4-5.11.„09	Intermediate Hill	Intermediate Hill	0.5
5-6.11.„09	Intermediate Hill	Intermediate Hill	0
6-7.11.„09	Intermediate Hill	Intermediate Hill	0.4
10-11.1.„10	Intermediate Hill	Intermediate Hill	0.2
11-12.1.„10	Intermediate Hill	Intermediate Hill	0.3
14-15.1.„10	Intermediate Hill	Intermediate Hill	0.2
7-8.3.„10	Intermediate Hill	Intermediate Hill	0.2
13-14.3.„10	Intermediate Hill	Intermediate Hill	0.1
14-15.3.„10	Intermediate Hill	Intermediate Hill	0.3
15-16.3.„10	Intermediate Hill	Intermediate Hill	0.2
18-19.3.„10	Intermediate Hill	Intermediate Hill	0.3
19-20.3.„10	Intermediate Hill	Intermediate Hill	0
20-21.3.„10	Intermediate Hill	Intermediate Hill	0
21-22.3.‟10	Intermediate Hill	Intermediate Hill	0
22-23.3.„10	Intermediate Hill	Intermediate Hill	0.4
23-24.3.„10	Intermediate Hill	Intermediate Hill	0.3
24-25.3.„10	Intermediate Hill	Intermediate Hill	0.2
25-26.3.„10	Intermediate Hill	Intermediate Hill	0.1
26-27.3.„10	Intermediate Hill	Intermediate Hill	0
27-28.3.‟10	Intermediate Hill	Intermediate Hill	0.3
28-29.3.„10	Intermediate Hill	Intermediate Hill	0.2
31.3-1.4.„10	Intermediate Hill	Intermediate Hill	0.1
1-2.4.„10	Intermediate Hill	Intermediate Hill	0.4
2-3.4.„10	Intermediate Hill	Intermediate Hill	0.2
3-4.4.„10	Intermediate Hill	Intermediate Hill	0.5
4-5.4.„10	Intermediate Hill	Intermediate Hill	0.5
5-6.5.„10	Intermediate Hill	Intermediate Hill	0.5
10-11.5.„10	Intermediate Hill	Intermediate Hill	0.3
11-12.5.„10	Intermediate Hill	Intermediate Hill	0.3
12-13.5.‟10	Intermediate Hill	Intermediate Hill	0.3
13-14.5.„10	Intermediate Hill	Intermediate Hill	0.2
14-15.5.„10	Intermediate Hill	Intermediate Hill	0.2
15-16.5.„10	Intermediate Hill	Intermediate Hill	0.3
16-17.5.„10	Intermediate Hill	Intermediate Hill	0.2

cont. Appendix 10 Distances between successive roosts sites of Masked Owl Female 2

date	first roost site location	second roost site location	distance between locations, km
20-21.5.„10	Intermediate Hill	Intermediate Hill	0
21-22.5.„10	Intermediate Hill	Intermediate Hill	0.5
22-23.5.„10	Intermediate Hill	Intermediate Hill	0.6
23-24.5.„10	Intermediate Hill	Intermediate Hill	0
24-25.5.„10	Intermediate Hill	Intermediate Hill	0.1
25-26.5.„10	Intermediate Hill	Intermediate Hill	0.5
16-17.7.„10	Intermediate Hill	Intermediate Hill	0.3
17-18.7.„10	Intermediate Hill	Intermediate Hill	0.2
20-21.7.„10	Intermediate Hill	Intermediate Hill	0.3
21-22.7.„10	Intermediate Hill	Intermediate Hill	0.2
24-25.7.„10	Intermediate Hill	Intermediate Hill	0.1
27-28.7.„10	Intermediate Hill	Intermediate Hill	0.4
28-29.7.„10	Intermediate Hill	Intermediate Hill	0.6

data from Appendix 9

Appendix 11 Nocturnal movements of Masked Owl Female 1 between September 2009 and July 2010

date	first location	actual/ approx. Easting/ Northing MGA	second location	approx. Easting/ Northing MGA	approx. distance km
8.9.'09	south western gully, Intermediate Hill	507800/ 6509500	forest on north western slope of Transit Hill	507100/ 6511600	2.2
10.9.'09	upper Soldiers Creek, Intermediate Hill	507800/ 6509500	edge of forest on western edge of southern end of Golf Course	507400/ 6509700	0.5
11.9.'09	upper Soldiers Creek, Intermediate Hill	508100/ 6509200	forest behind Pine Trees Resort, lower north western slopes of Transit Hill	506800/ 6511300	2.5
18.9.'09	forest on high ridge on western side of Intermediate Hill, south western aspect	507800/ 6509700	forest behind LHIB Depot, lower north western slopes of Transit Hill	506600/ 6511700	2.4
19.9.'09	forest on high ridge on north western side of Intermediate Hill, north eastern aspect	507800/ 6510100	forest edge along southern slopes of Transit Hill	507400/ 6510900	0.9
23.9.'09	forest in small mid-slope gully on northern side of Intermediate Hill	507800/ 6510100	forest edge along southern slopes of Transit Hill	507400/ 6510900	0.9
21.10.'09	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest high on northern slopes of Intermediate Hill, to ridge crest	507900/ 6509800	1.7
23.10.'09	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest behind Pine Trees Resort, lower north western slopes of Transit Hill	506800/ 6511300	0.4
24.10.'09	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest south of Clear Place on north eastern side of Transit Hill	507500/ 6511500	0.4
25.10.'09	forest on high bench on western side of Transit Hill, south western aspect	507287/ 6511331	forest on north western slope of Transit Hill	507100/ 6511600	0.3
28.10.'09	forest high on western side of Transit Hill, south western aspect	507276/ 6511414	forest on high bench on western side of Transit Hill	507200/ 6511300	0.1
29.10.'09	forest high on western side of Transit Hill, south western aspect	507200/ 6511300	forest on high bench on western side of Transit Hill	507200/ 6511300	0.1

cont. Appendix 11 Nocturnal movements of Masked Owl Female 1

date	first location	actual/ approx. Easting/ Northing MGA	second location	approx. Easting/ Northing MGA	approx. distance km
30.10.‟09	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest on northern slopes of Transit Hill, south of Middle Beach Common	507100/ 6511750	0.5
31.10.‟09	forest on high bench on western side of Transit Hill, south western aspect	507244/ 6511315	forest on northern slopes of Transit Hill, towards Clear Place	507300/ 6511600	0.3
4.11.‟09	forest high in head of gully on western side of Intermediate Hill, south western aspect	507900/ 6509400	forest low on northern slopes of Intermediate Hill	507800/ 6510000	0.6
5.11.‟09	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest on lower north western slopes of Intermediate Hill, then across to forest adjacent to Waste Management Facility	507600/ 6510100 to 507200/ 6510550	1.9 (1.3 + 0.6)
6.11.‟09	forest on high bench on western side of Transit Hill, south western aspect	507278/ 6511324	forest high on southern slopes of Transit Hill	507300/ 6511100	0.3
14.1.‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507500/ 6511500	forest on eastern side of ridge running from Transit Hill to Clear Place	507500/ 6511600	0.2
17.1.‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, northern south eastern aspect	507500/ 6511500	forest on upper western slopes of Transit Hill	507200/ 6511200	0.4
7.3.‟10	forest on high bench on western side of Transit Hill, south western aspect	507200/ 6511300	forest on lower western slopes of Transit Hill	506800/ 6511200	0.4
10.3.‟10	forest on lower north western slopes of Transit Hill, northern aspect	506821/ 6511324	forest on mid western slopes of Transit Hill	507000/ 6511200	0.2
14.3.‟10	forest on lower north western slopes of Intermediate Hill, north western aspect	507600/ 6510000	mid northern slopes of Transit Hill	507300/ 6511600	1.6
21.3.‟10	forest on ridge at Clear Place, northern aspect	507478/ 6511773	forest on mid western slopes of Transit Hill	507000/ 6511200	0.8
22.3.‟10	forest on lower northern slopes of Mt Lidgbird, northern aspect	507700/ 6508600	forest on lower northern slopes of Mt Lidgbird	507700/ 6508800	0.3

cont. Appendix 11 Nocturnal movements of Masked Owl Female 1

date	first location	actual/ approx. Easting/ Northing MGA	second location	approx. Easting/ Northing MGA	approx. distance km
23.3.‟10	forest on lower northern slopes of Mt Lidgbird, northern aspect	507700/ 6508800	forest on lower western slopes of Mt Lidgbird, under cliffs above Far Flats	507200/ 6507300	1.6
24.3.‟10	forest on lower western slopes of Mt Lidgbird, north western aspect	507332/ 6507382	forest on lower western slopes of Mt Lidgbird, under cliffs above Far Flats	507200/ 6507300	0.1
25.3.‟10	forest on high bench on western side of Transit Hill, south western aspect	507244/ 6511315	forest on lower northern slopes of Transit Hill	507300/ 6511700	0.3
26.3.‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507500/ 6511600	forest on eastern side of ridge running from Transit Hill to Clear Place	507500/ 6511600	0.1
27.3.‟10	forest in small gully on lower slopes of south eastern side of Transit Hill, south western aspect	507645/ 6511023	forest on lower northern slopes of Transit Hill	507200/ 6511700	0.8
28.3.‟10	forest on high bench on western side of Transit Hill, south western aspect	507244/ 6511315	forest on upper eastern slopes of Settlement	506650/ 6512200	1.1
29.3.‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507500/ 6511600	forest on lower north western slopes of Transit Hill	506900/ 6511650	0.6
1.4.‟10	forest on lower northern slopes of Transit Hill south of Valley of the Shadows	507200/ 6511600	forest on lower northern slopes of Transit Hill	507200/ 6511700	0.1
2.4.‟10	forest on ridge at Clear Place, northern aspect	507470/ 6511740	forest on upper eastern slopes of Settlement	506550/ 6512350	1.1
3.4.‟10	forest on high bench on western side of Transit Hill, south western aspect	507250/ 6511300	forest on lower north western slopes of Transit Hill near capture site	507200/ 6511800	0.5
4.4.‟10	forest on high bench on western side of Transit Hill, south western aspect	507244/ 6511315	forest on lower western slopes of Transit Hill	506800/ 6511200	0.5
5.4.‟10	forest on high bench on western side of Transit Hill, south western aspect	507250/ 6511300	forest on lower western slopes of Transit Hill	506800/ 6511200	0.5

cont. Appendix 11 Nocturnal movements of Masked Owl Female 1

date	first location	approx. Easting/ Northing MGA	second location	approx. Easting/ Northing MGA	approx. distance km
6.4.‟10	forest on high bench on western side of Transit Hill, south western aspect	507244/ 6511315	forest on lower north western slopes of Transit Hill near capture site	507200/ 6511800	0.5
11.5.‟10	forest on high bench on western side of Transit Hill, south western aspect	507214/ 6511369	forest on lower southern slopes of Transit Hill	507300/ 6510900	0.5
13.5.‟10	forest in Stevens Reserve in Settlement, south western aspect	506422/ 6512359	forest on upper eastern slopes of Settlement	506450/ 6512450	0.1
14.5.‟10	forest in upper Settlement, south western aspect	506610/ 6512380	forest on upper eastern slopes of Settlement	506400/ 6512400	0.2
15.5.‟10	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507500/ 6511600	forest on eastern side of ridge running from Transit Hill to Clear Place, eastern aspect	507500/ 6511500	0.1
17.5.‟10	forest on high bench on western side of Transit Hill, south western aspect	507244/ 6511315	forest on lower southern slopes of Transit Hill	507100/ 6511100	0.2
20.5.‟10	forest on high bench on western side of Transit Hill, south western aspect	507214/ 6511369	forest on mid northern slopes of Transit Hill	507400/ 6511600	0.3
21.5.‟10	forest on high bench on western side of Transit Hill, south western aspect	507250/ 6511300	forest on mid northern slopes of Transit Hill	507400/ 6511600	0.3
22.5.‟10	forest on high bench on western side of Transit Hill, south western aspect	507250/ 6511300	forest on high bench on western side of Transit Hill	507300/ 6511350	0.1
23.5.‟10	forest on western side of ridge running from Transit Hill to Clear Place, north western aspect	507347/ 6511528	forest on ridge at Clear Place	507400/ 6511700	0.3
26.5.‟10	forest on ridge at Clear Place, northern aspect	507400/ 6511700	forest on high bench on western side of Transit Hill	507250/ 6511300	0.4
24.7.‟10	forest on ridge at Clear Place, northern aspect	507425/ 6511760	forest on ridge at Clear Place	507500/ 6511700	0.1
27.7.‟10	forest on high bench on western side of Transit Hill, south western aspect	507350/ 6511100	forest on lower southern slopes of Transit Hill	507450/ 6810900	0.3

Appendix 12 Distances travelled by Masked Owl Female 1 in nocturnal movements between September 2009 and July 2010

date	first location	second location	distance between locations, km
8.9.‟09	Intermediate Hill	Transit Hill	2.2
10.9.‟09	Intermediate Hill	Intermediate Hill	0.5
11.9.‟09	Intermediate Hill	Transit Hill	2.5
18.9.‟09	Intermediate Hill	Transit Hill	2.4
19.9.‟09	Intermediate Hill	Transit Hill	0.9
23.9.‟09	Intermediate Hill	Transit Hill	0.9
21.10.‟09	Transit Hill	Intermediate Hill	1.7
23.10.‟09	Intermediate Hill	Transit Hill	0.4
24.10.‟09	Transit Hill	Transit Hill	0.4
25.10.‟09	Transit Hill	Transit Hill	0.3
28.10.‟09	Transit Hill	Transit Hill	0.1
29.10.‟09	Transit Hill	Transit Hill	0.1
30.10.‟09	Transit Hill	Transit Hill	0.5
31.10.‟09	Transit Hill	Transit Hill	0.3
4.11.‟09	Intermediate Hill	Intermediate Hill	0.6
5.11.‟09	Transit Hill	Intermediate Hill	1.9 (1.3 + 0.6)
6.11.‟09	Transit Hill	Transit Hill	0.3
14.1.‟10	Transit Hill	Transit Hill	0.2
17.1.‟10	Transit Hill	Transit Hill	0.4
7.3.‟10	Transit Hill	Transit Hill	0.4
10.3.‟10	Transit Hill	Transit Hill	0.2
14.3.‟10	Intermediate Hill	Transit Hill	1.6
21.3.‟10	Valley of the Shadows	Transit Hill	0.8
22.3.‟10	Mt Lidgbird	Mt Lidgbird	0.3
23.3.‟10	Mt Lidgbird	Mt Lidgbird	1.6
24.3.‟10	Mt Lidgbird	Mt Lidgbird	0.1
25.3.‟10	Transit Hill	Transit Hill	0.3
26.3.‟10	Transit Hill	Transit Hill	0.1
27.3.‟10	Transit Hill	Transit Hill	0.8
28.3.‟10	Transit Hill	Settlement	1.1
29.3.‟10	Transit Hill	Transit Hill	0.6
1.4.‟10	Transit Hill	Transit Hill	0.1
2.4.‟10	Valley of the Shadows	Settlement	1.1
3.4.‟10	Transit Hill	Transit Hill	0.5
4.4.‟10	Transit Hill	Transit Hill	0.5
5.4.‟10	Transit Hill	Transit Hill	0.5
6.4.‟10	Transit Hill	Transit Hill	0.5
11.5.‟10	Transit Hill	Transit Hill	0.5
13.5.‟10	Settlement	Settlement	0.1
14.5.‟10	Settlement	Settlement	0.2
15.5.‟10	Transit Hill	Transit Hill	0.1
17.5.‟10	Transit Hill	Transit Hill	0.2
20.5.‟10	Transit Hill	Transit Hill	0.3
21.5.‟10	Transit Hill	Transit Hill	0.3
22.5.‟10	Transit Hill	Transit Hill	0.1
23.5.‟10	Transit Hill	Valley of the Shadows	0.3
26.5.‟10	Valley of the Shadows	Transit Hill	0.4

cont. Appendix 12 Distances travelled by Masked Owl Female 1 in nocturnal movements

date	first location	second location	distance between locations, km
24.7.‟10	Valley of the Shadows	Valley of the Shadows	0.1
27.7.‟10	Transit Hill	Transit Hill	0.3

data from Appendices 5 and 11

Appendix 13 Nocturnal movements of Masked Owl Female 2 between September 2009 and July 2010

date	first location	approx. Easting/ Northing MGA	second location	approx. Easting/ Northing MGA	approx. distance
11.9.‟09	forest in gully on lower western slopes of Intermediate Hill, southern aspect	507554/ 6509681	western boundary of Golf Course	507600/ 6509900	0.2
18.9.‟09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507350/ 6509500	western boundary of Golf Course	507600/ 6509900	0.2
19.9.‟09	forest in gully on lower western slopes of Intermediate Hill, southern aspect	507500/ 6509600	western boundary of Golf Course	507600/ 6509900	0.3
23.9.‟09	forest on mid western slopes of Intermediate Hill, north western aspect	507624/ 6509589	western boundary of Golf Course	507600/ 6509900	0.3
21.10.‟09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507509/ 6509577	Cobby‟s Corner to mid northern slopes of Intermediate Hill above Blinky‟s Beach	507400/ 6510100- 508000/ 6510100	1.1 (0.5 + 0.6)
23.10.‟09	forest in gully on mid western slopes of Intermediate Hill, western aspect	507607/ 6509720	north-north western slopes of Intermediate Hill	507650/ 6510100	0.3
24.10.‟09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507500/ 6509500	mid to lower slopes of Intermediate Hill along Golf Course boundary	507650/ 6509950	0.3
25.10.‟09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507500/ 6509500	mid to lower slopes of Intermediate Hill along Golf Course boundary	507650/ 6509950	0.3
29.10.‟09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507500/ 6509500	mid to lower slopes of Intermediate Hill along Golf Course southern boundary	507450/ 6509750	0.2
30.10.‟09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507624/ 6509668	mid to lower northern and north eastern slopes of Intermediate Hill	507750/ 6510100- 507950/ 6510100	0.5
4.11.‟09	forest on mid northern slopes of Intermediate Hill	507926/ 6510009	lower slopes of Intermediate Hill along Golf Course southern boundary	507500/ 6509800	0.5
5.11.‟09	forest in gully on lower western slopes of Intermediate Hill, southern aspect	507500/ 6509400	lower slopes of Intermediate Hill along Golf Course southern boundary	507500/ 6509800	0.3

cont. Appendix 13 Nocturnal movements of Masked Owl Female 2

date	first location	approx. Easting/ Northing MGA	second location	approx. Easting/ Northing MGA	approx. distance
6.11.‟09	forest in gully on lower western slopes of Intermediate Hill, north western aspect	507500/ 6509500	mid to lower slopes of Intermediate Hill along Golf Course southern boundary	507500/ 6509800	0.1
17.1.‟10	forest on western slopes of Intermediate Hill, southern aspect	507700/ 6509500	forest on western slopes of Intermediate Hill	507400/ 6509600	0.3
7.3.‟10	forest on north western ridge of Intermediate Hill, south western aspect	507965/ 6509797	forest on north western ridge of Intermediate Hill	507950/ 6509800	0.1
8.3.‟10	forest on north western slopes of Intermediate Hill, north western aspect	507914/ 6509631	forest on northern slopes of Intermediate Hill	507900/ 6509950	0.2
13.3.‟10	forest on mid western slopes of Intermediate Hill, north western aspect	507603/ 6509587	forest on lower north western slopes of Intermediate Hill	507600/ 6509850	0.2
14.3.‟10	forest on lower north western slopes of Intermediate Hill, western aspect	507476/ 6509578	forest on mid northern slopes of Intermediate Hill	508250/ 6509750	0.8
15.3.‟10	forest on mid north western slopes of Intermediate Hill, north western aspect	507700/ 6509700	forest on mid north western slopes of Intermediate Hill	507600/ 6509700	0.1
21.3.‟10	forest on mid western slopes of Intermediate Hill, south western aspect	507600/ 6509500	forest on lower western slopes of Intermediate Hill	507500/ 6509700	0.3
22.3.‟10	forest on mid western slopes of Intermediate Hill, south western aspect	507600/ 6509500	forest on lower north western slopes of Intermediate Hill	507500/ 6509800	0.3
23.3.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	507848/ 6509766	forest on lower south western slopes of Intermediate Hill	507500/ 6509500	0.4
24.3.‟10	forest on mid western slopes of Intermediate Hill, western aspect	507700/ 6509500	forest on upper northern slopes of Intermediate Hill	507950/ 6509900	0.3
25.3.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	507700/ 6509700	forest on upper north western slopes of Intermediate Hill	507800/ 6509850	0.1

cont. Appendix 13 Nocturnal movements of Masked Owl Female 2

date	first location	approx. Easting/ Northing MGA	second location	approx. Easting/ Northing MGA	approx. distance
26.3.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	507800/ 6509800	forest on upper northern slopes of Intermediate Hill near summit	508300/ 6509500	0.6
27.3.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	507800/ 6509800	forest on lower south western slopes of Intermediate Hill	507600/ 6509200	0.6
28.3.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	507900/ 6509600	forest on upper northern slopes of Intermediate Hill	508300/ 6509650	0.4
29.3.‟10	forest on upper north western slopes of Intermediate Hill, western aspect	508018/ 6509702	forest on lower south western slopes of Intermediate Hill	507600/ 6509300	0.6
1.4.‟10	forest on mid western slopes of Intermediate Hill, north western aspect	507602/ 6509590	forest on upper north western slopes of Intermediate Hill	507800/ 6509900	0.3
2.4.‟10	forest on upper north western slopes of Intermediate Hill, western aspect	507900/ 6509600	forest on upper northern slopes of Intermediate Hill	508300/ 6509700	0.4
3.4.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	508100/ 6509500	forest on upper north western slopes of Intermediate Hill near summit	508000/ 6509500	0.1
4.4.‟10	forest on upper north western slopes of Intermediate Hill, western aspect	507700/ 6509700	forest on upper western slopes of Intermediate Hill below summit	508100/ 6509400	0.5
5.4.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	508100/ 6509500	forest on upper northern slopes of Intermediate Hill	508400/ 6509600	0.3
6.4.‟10	forest on mid north western slopes of Intermediate Hill, south western aspect	507600/ 6509500	forest on upper north western slopes of Intermediate Hill	507900/ 6509600	0.3
10.5.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	507700/ 6509450	forest on lower north western slopes of Intermediate Hill	507500/ 6509700	0.3
11.5.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	507750/ 6509750	forest on upper north western slopes of Intermediate Hill	507800/ 6509850	0.1

cont. Appendix 13 Nocturnal movements of Masked Owl Female 2

date	first location	approx. Easting/ Northing MGA	second location	approx. Easting/ Northing MGA	approx. distance
13.5.‟10	forest on upper north western slopes of Intermediate Hill, western aspect	507700/ 6509700	forest on upper northern slopes of Intermediate Hill	508500/ 6509600	0.8
14.5.‟10	forest on upper north western slopes of Intermediate Hill, south western aspect	507800/ 6509700	forest on upper northern slopes of Intermediate Hill	508400/ 6509600	0.6
15.5.‟10	forest on mid north western slopes of Intermediate Hill, western aspect	507716/ 6509631	forest on lower northern slopes of Intermediate Hill	508400/ 6509700	0.7
17.5.‟10	forest on mid north western slopes of Intermediate Hill, south western aspect	507800/ 6509800	forest on lower north western slopes of Intermediate Hill	507500/ 6509700	0.3
20.5.‟10	forest on upper north western slopes of Intermediate Hill, western aspect	507900/ 6509600	forest on mid north western slopes of Intermediate Hill	507750/ 6509600	0.3
21.5.‟10	forest on upper north western slopes of Intermediate Hill, western aspect	507900/ 6509600	forest on lower south western slopes of Intermediate Hill	507700/ 6509200	0.5
22.5.‟10	forest on lower western slopes of Intermediate Hill, southern aspect	507508/ 6509350	forest on upper northern slopes of Intermediate Hill	508300/ 6509700	0.9
23.5.‟10	forest on upper north western slopes of Intermediate Hill, western aspect	508000/ 6509600	forest on upper north eastern slopes of Intermediate Hill	508500/ 6509600	0.5
26.5.‟10	forest on upper north western slopes of Intermediate Hill, western aspect	507700/ 6509950	forest on lower north western slopes of Intermediate Hill	507650/ 6509800	0.3
16.7.‟10	forest on upper north western slopes of Intermediate Hill, western aspect	507887/ 6509625	forest on lower southern slopes of Intermediate Hill	507750/ 6509150	0.5

Appendix 14 Distances travelled by Masked Owl Female 2 in nocturnal movements between September 2009 and July 2010

date	first location	second location	distance between locations, km
11.9.‟09	Intermediate Hill	Intermediate Hill	0.2
18.9.‟09	Intermediate Hill	Intermediate Hill	0.2
19.9.‟09	Intermediate Hill	Intermediate Hill	0.3
23.9.‟09	Intermediate Hill	Intermediate Hill	0.3
21.10.‟09	Intermediate Hill	Intermediate Hill	1.1 (0.5 + 0.6)
23.10.‟09	Intermediate Hill	Intermediate Hill	0.3
24.10.‟09	Intermediate Hill	Intermediate Hill	0.3
25.10.‟09	Intermediate Hill	Intermediate Hill	0.3
29.10.‟09	Intermediate Hill	Intermediate Hill	0.2
30.10.‟09	Intermediate Hill	Intermediate Hill	0.5
4.11.‟09	Intermediate Hill	Intermediate Hill	0.5
5.11.‟09	Intermediate Hill	Intermediate Hill	0.3
6.11.‟09	Intermediate Hill	Intermediate Hill	0.1
17.1.‟10	Intermediate Hill	Intermediate Hill	0.3
7.3.‟10	Intermediate Hill	Intermediate Hill	0.1
8.3.‟10	Intermediate Hill	Intermediate Hill	0.2
13.3.‟10	Intermediate Hill	Intermediate Hill	0.2
14.3.‟10	Intermediate Hill	Intermediate Hill	0.8
15.3.‟10	Intermediate Hill	Intermediate Hill	0.1
21.3.‟10	Intermediate Hill	Intermediate Hill	0.3
22.3.‟10	Intermediate Hill	Intermediate Hill	0.3
23.3.‟10	Intermediate Hill	Intermediate Hill	0.4
24.3.‟10	Intermediate Hill	Intermediate Hill	0.3
25.3.‟10	Intermediate Hill	Intermediate Hill	0.1
26.3.‟10	Intermediate Hill	Intermediate Hill	0.6
27.3.‟10	Intermediate Hill	Intermediate Hill	0.6
28.3.‟10	Intermediate Hill	Intermediate Hill	0.4
29.3.‟10	Intermediate Hill	Intermediate Hill	0.6
1.4.‟10	Intermediate Hill	Intermediate Hill	0.3
2.4.‟10	Intermediate Hill	Intermediate Hill	0.4
3.4.‟10	Intermediate Hill	Intermediate Hill	0.1
4.4.‟10	Intermediate Hill	Intermediate Hill	0.5
5.4.‟10	Intermediate Hill	Intermediate Hill	0.3
6.4.‟10	Intermediate Hill	Intermediate Hill	0.3
10.5.‟10	Intermediate Hill	Intermediate Hill	0.3
11.5.‟10	Intermediate Hill	Intermediate Hill	0.1
13.5.‟10	Intermediate Hill	Intermediate Hill	0.8
14.5.‟10	Intermediate Hill	Intermediate Hill	0.6
15.5.‟10	Intermediate Hill	Intermediate Hill	0.7
17.5.‟10	Intermediate Hill	Intermediate Hill	0.3
20.5.‟10	Intermediate Hill	Intermediate Hill	0.3
21.5.‟10	Intermediate Hill	Intermediate Hill	0.5
22.5.‟10	Intermediate Hill	Intermediate Hill	0.9
23.5.‟10	Intermediate Hill	Intermediate Hill	0.5
26.5.‟10	Intermediate Hill	Intermediate Hill	0.3
16.7.‟10	Intermediate Hill	Intermediate Hill	0.5

data from Appendices 8 and 13

Appendix 15 Characteristics of Masked Owl Female 1 roost sites located between August 2009 and July 2010

roost site	location	Easting MGA	Northing MGA	tree species	dbh cm	roost type/ height above ground m	date	pellets found	notes
1	Transit Hill, north west	507256	6511198	Scalybark	100	branch hollow/ 8	31.8.‟09	-	flushed into hollow from canopy roost, flushed to other canopy perches
		(507250)	(6511311)				(25.10.‟09	(LHMO 6)	(absent)
		507260	6511299			branch	9.3.‟10	-	initially flushed to branch from canopy perch, flushed to canopy perch
							(12.3.‟10)	(LHMO 17)	(absent)
2	Intermediate Hill, north west	507842	6509724	dead Scalybark	98	trunk hollow/ 12	3.9.‟09		did not flush
3	Valley of the Shadows	507492	6511741	Banyan	300+	crevice/ 15	5.9.‟09	- -	flushed to canopy perches
		507450	6511736				15.3.‟10	-	flushed to canopy perches
		507478	6511773				21.3.‟10	-	did not flush
							2.4.‟10	-	did not flush
		507408	6511756				24.5.‟10	-	did not flush
		507425	6511760				22.7.‟10	-	did not flush
		507425	6511760				24.7.‟10	LHMO 48	did not flush
4	Intermediate Hill, south west	507918	6509289	Scalybark	149	trunk hollow/ 14	7.9.‟09		flushed to canopy perches

cont. Appendix 15 Characteristics of Masked Owl Female 1 roost sites

roost site	location	Easting MGA	Northing MGA	tree species	dbh cm	roost type/ height above ground m	date	pellets found	notes
5	Transit Hill, north west	507244 507252	6511315 6511324	Greybark	39	canopy/ 12	31.10.‟09 12.1.‟10 9.3.‟10 (12.3.‟10) 4.4.‟10	LHMO 7A-7F - - (LHMO 16) - 	flushed to canopy perch flushed to canopy perch flushed to canopy perch (absent) flushed to canopy perch
6	Transit Hill, north west	(507278)	(6511324)	Greybark	43	canopy/ 5	(4.11.‟09) 6.11.‟09 [15.11.‟09] (12.3.‟10)	(LHMO 10) - (LHMO 18, 19)	(absent) flushed to canopy perches [flushed to canopy perch – per J. Rowland] (absent)
7	Transit Hill, south east	507652 507645	6511013 6511023	Greybark	57	canopy/ 10	7.11.‟09 (15.3.‟10) 27.3.‟10	- (LHMO 22) -	flushed to canopy perch (absent) not flushed
8	Transit Hill, north	507488	6511475	Greybark	35	canopy/ 3	9.1.‟10	-	flushed to canopy perches
9	Transit Hill, west	506821	6511324	Elkhorn cluster in Greybark	39	epi-phyte hollow/ 14	10.3.‟10		did not flush

cont. Appendix 15 Characteristics of Masked Owl Female 1 roost sites

roost site	location	Easting MGA	Northing MGA	tree species	dbh cm	roost type/ height above ground m	date	pellets found	notes
10	Transit Hill, west	506788	6511321	Elkhorn cluster in Greybark	23	epi-phyte hollow/ 15	17.3.‟10	-	did not flush
11	Transit Hill, north west	507214	6511369	Maulwood	79	canopy/ 13	11.5.‟10	LHMO 25-32	flushed to canopy perch
							20.5.‟10	LHMO 36	flushed to canopy perch
		507214	6511369				26.7.‟10	LHMO 49 LHMO 50 LHMO 51	flushed to canopy perch
12	Stevens Reserve, Settlement area	508422	6512359	Greybark	71	canopy/ 16	13.5.‟10	-	did not flush
13	Andersons Road, Settlement area	506610	6512380	Banyan	300+	canopy/ 14	14.5.‟10	-	did not flush
14	Transit Hill, north	507533	6511598	dead fallen Greybark	-	mid-storey/ 5	16.5.‟10	-	flushed to canopy perch
15	Transit Hill, north	507347	6511528	Scalybark	73	trunk hollow/ 8	23.5.‟10	-	did not flush
16	Clear Place area	507550	6511668	Greybark	17	canopy/ 2	17.7.‟10	LHMO 37	flushed to canopy perch
17	Valley of the Shadows	507469	6511744	Banyan	270	canopy/ 20	18.7.‟10	-	did not flush

tree and epiphyte species:

Greybark *Drypetes deplanchei*
Banyan *Ficus macrophylla columnaris*
Maulwood *Olea paniculata*
Elkhorn *Platycerium bifurcatum*
Scalybark *Syzygium fullagari*

Appendix 16 Characteristics of Masked Owl Female 2 roost sites located between September 2009 and July 2010

roost site	location	Easting, MGA	Northing MGA	tree species	dbh, cm	roost type/ height above ground m	date	pellets found	notes
1	Intermediate Hill, north west	507554	6509681	Scalybark	124	trunk hollow/ 8	11.9.'09	-	flushed to canopy perch
2	Intermediate Hill, west	507624 507603 507602 (507605) 507602	6509589 6509587 6509590 (6509589) 6509589	senescent Scalybark	115	trunk hollow/ 10	23.9.'09 13.3.'10 1.4.'10 (30.10.'09) 17.7.'10	- - - -	did not flush did not flush did not flush (absent) did not flush
3	Intermediate Hill, west	507523	6509605	Scalybark	108	trunk hollow/ 9	21.10.'09	-	flushed into hollow from canopy roost
4	Intermediate Hill, west	507733	6509574	Greybark	60	canopy/ 16	3.11.'09 [21.11.'09]	- [LHMO 14]	flushed to canopy perch [absent – per J. Rowland]
5	Intermediate Hill, north west	507926 (507929)	6510009 (6509999)	Greybark	58	canopy/ 12	4.11.'09 (5.11.'09)	- (LHMO 11)	flushed to canopy perch (absent)
6	Intermediate Hill, west	507759 507759	6509536 6509531	Scalybark	108	trunk hollow/ 12	11.1.'10 25.7.'10	- -	did not flush did not flush
7	Intermediate Hill, north west	[507618] [507574] 507607 507629	[6509738] [6509738] 6509739 6509753	Greybark	32	canopy/ 15	[10.11.'09] [15.11.'09] 12.1.'10 11.3.'10 (13.3.'10)	+ [LHMO 13] LHMO 12 - (LHMO 21)	[did not flush – per J. Rowland] [roosting in vicinity – per J. Rowland] did not flush did not flush (absent)

cont. Appendix 16 Characteristics of Masked Owl Female 2 roost sites

roost site	location	Easting, MGA	Northing MGA	tree species	dbh, cm	roost type/ height above ground m	date	pellets found	notes
8	Intermediate Hill, west	507710	6509555	Greybark	25	canopy/ 10	15.1.‟10	-	flushed to canopy perch
9	Intermediate Hill, west	[507502] (507519)	[6509630] (6509584)	Scalybark	99	branch hollow/ 8	[3.3.‟10] (7.3.‟10)	- -	[flushed to canopy perch – per H. Bower] (absent)
10	Intermediate Hill, west	507476	6509578	Scalybark	148	trunk hollow/ 10	14.3.‟10	-	did not flush
11	Intermediate Hill, north west	507848	6509766	Scalybark	35	canopy/ 14	23.3.‟10	LHMO 24	flushed to canopy perch
12	Intermediate Hill, north west	508018	6509702	Scalybark	31	canopy/ 11	29.3.‟10	-	flushed to canopy perch
13	Intermediate Hill, north west	508047	6509719	Greybark	41	canopy/ 16	12.5.‟10	LHMO 33	did not flush
14	Intermediate Hill, west	507716	6509631	Scalybark	74	canopy/ 18	15.5.‟10	-	flushed to canopy perch
15	Intermediate Hill, west	507691 507690	6509400 6509399	Greybark	40	canopy/ 18	16.5.‟10 18.7.‟10	-	did not flush did not flush
16	Intermediate Hill, west	507508	6509350	Scalybark	44	canopy/ 15	22.5.‟10	-	flushed to canopy perch
17	Intermediate Hill, west	507905	6509533	Greybark	31	canopy/ 15	25.5.‟10	-	did not flush
18	Intermediate Hill, west	507887	6509625	Blackbutt	35	canopy/ 17	16.7.‟10	-	flushed to canopy perch
19	Intermediate Hill, west	507904	6509543	Scalybark	39	canopy/ 14	21.7.‟10	-	flushed to canopy perch

cont. Appendix 16 Characteristics of Masked Owl Female 2 roost sites

roost site	location	Easting, MGA	Northing MGA	tree species	dbh, cm	roost type/ height above ground m	date	pellets found	notes
20	Intermediate Hill, north west	507637	6509986	Greybark	58	branch hollow/ 12	28.7.‟10	-	did not flush

tree and epiphyte species:

Blackbutt *Cryptocarya triplinervis*
Greybark *Drypetes deplanchei*
Scalybark *Syzygium fullagari*

Appendix 17 Details of Masked Owl prey items from pellets and kills collected and located during searches between July 2009 and July 2010

no.	pellet code	date	kill re-mains/ pellets	location	Easting MGA	Northing MGA	prey items
1	LHMO 1 LHMO 2	10.7.'09	2 fresh pellets	adjacent Boat Harbour Track	508856	6508741	Black Rat *Rattus rattus*, hair, leg and other bones
2	LHMO 3 LHMO 4	9.7.'09	2 fresh pellets	adjacent Boat Harbour Track	508856	6508741	Black Rat *Rattus rattus*, hair, leg and other bones
3		26.8.'09	kill re-mains	adjacent to Wharf, Settlement area	505525	6512525	2+ White Tern *Gygis alba* heads, wings and body feathers
4	LHMO 5A	4.9.'09	1 fresh pellet	adjacent Boat Harbour Track	508856	6508741	Black Rat *Rattus rattus*, hair, skull, dentary, leg and other bones
5	LHMO 5B	4.9.'09	1 fresh pellet	adjacent Boat Harbour Track	508856	6508741	Black Rat *Rattus rattus*, hair, dentary, leg and other bones
6	LHMO 5C	12.9.'09	1 fresh pellet	adjacent Boat Harbour Track	508856	6508741	Black Rat *Rattus rattus*, hair, dentary, leg and other bones
7	LHMO 6	25.10.'09	4 old pellet re-mains	Transit Hill, north west	507287	6511331	Black Rat *Rattus rattus*, skulls, dentary, leg and other bones
8	LHMO 7A	31.10.'09 4.11.'09	26+ old pellet re-mains	Transit Hill, north west	507244	6511315	Black Rat *Rattus rattus*, 26 skulls, dentary, leg and other bones; unidentified mammal bones
9	LHMO 7B	31.10.'09	1 fresh pellet	Transit Hill, north west	507244	6511315	Black Rat *Rattus rattus*, hair, 1 skull, dentary, leg and other bones
10	LHMO 7C	31.10.'09	1 fresh pellet	Transit Hill, north west	507244	6511315	White Tern *Gygis alba* feathers, bones
11	LHMO 7D	31.10.'09	1 fresh pellet	Transit Hill, north west	507244	6511315	Black Rat *Rattus rattus*, hair, 1 skull, dentary, leg and other bones; House Mouse *Mus musculus* hair, dentary, leg and other bones
12	LHMO 7E	31.10.'09	1 fresh pellet	Transit Hill, north west	507244	6511315	immature Black Rat *Rattus rattus*, hair, 2 skulls, dentary, leg and other bones

cont. Appendix 17 Details of Masked Owl prey items

no.	pellet code	date	kill re-mains/ pellets	location	Easting MGA	Northing MGA	prey items
13	LHMO 7F	31.10.‟09	1 fresh pellet	Transit Hill, north west	507244	6511315	House Mouse *Mus musculus* hair, 1 skull, dentary, leg and other bones
14	LHMO 8	3.11.‟09	1 fresh pellet	Leanda Lei Resort, Settlement area	506574	6512123	Black Rat *Rattus rattus*, hair, dentary, leg and other bones
15	LHMO 9	3.11.‟09	1 old pellet re-mains	Leanda Lei Resort, Settlement area	506574	6512123	Black-winged Petrel *Pteradroma nigripennis* bones
16	LHMO 10	4.11.‟09	1 fresh pellet	Transit Hill, north west	507278	6511324	Black Rat *Rattus rattus*, hair, 1 skull, dentary, leg and other bones
17	LHMO 11	5.11.‟09	several old pellet re-mains	Intermediate Hill, north west	507929	6509999	Black Rat *Rattus rattus*, leg bone; House Mouse *Mus musculus* hair, dentary, leg and other bones; Black-winged Petrel *Pteradroma nigripennis* skull
18		7.11.‟10	kill re-mains	adjacent to Aquatic Club, Settlement area	506200	6511900	20+ White Tern *Gygis alba* wings, heads and body feathers
19	LHMO 12	12.1.‟10	1 fresh pellet	Intermediate Hill, north west	507607	6509739	House Mouse *Mus musculus* hair, 1 skull, dentary, leg and other bones; Sooty Tern *Sterna fuscata* bones
20	LHMO 13	15.11.‟09	7+ old pellet re-mains	Intermediate Hill, north west	507618	6509738	Black Rat *Rattus rattus*, 5 skulls, dentary, leg and other bones; House Mouse *Mus musculus* 1 skull, dentary, leg and other bones; large wader bones
21	LHMO 14	21.11.‟09	1 old pellet re-mains	Intermediate Hill, west	507733	6509574	Black Rat *Rattus rattus*, hair, 1 skull, dentary, leg and other bones
22	LHMO 15	18.11.‟09	2 fresh pellets	Transit Hill, south	507463	6510869	House Mouse *Mus musculus* hair, 3 skulls, dentary, leg and other bones

cont. Appendix 17 Details of Masked Owl prey items

no.	pellet code	date	kill remains/ pellets	location	Easting MGA	Northing MGA	prey items
23		15.1.‟10	kill remains	Settlement area	506800	6512300	wings and body feathers of Buff-banded Rail *Gallirallus philippensis*, White Tern *Gygis alba* and Sooty Tern *Onychoprion fuscata*
24	LHMO 16	12.3.‟10	4 old pellet remains	Transit Hill, north west	507244	6511315	Black Rat *Rattus rattus*, 4 skulls, dentary, leg and other bones
25	LHMO 17	12.3.‟10	2 old pellet remains	Transit Hill, north west	507256	6511198	Black Rat *Rattus rattus*, 2 skulls
26	LHMO 18	12.3.‟10	2 old pellet remains	Transit Hill, north west	507278	6511324	Black Rat *Rattus rattus*, 2 skulls
27	LHMO 19	12.3.‟10	1 fresh pellet	Transit Hill, north west	507278	6511324	Sooty Tern *Sterna fuscata* feathers, bones
28	LHMO 20	13.3.‟10	1 old pellet remains	Malabar Hill	505882	6513411	Black Rat *Rattus rattus*, 1 skull, dentary, other bones
29	LHMO 21	13.3.‟10	1 fresh pellet	Intermediate Hill, north west	507618	6509738	Black Rat *Rattus rattus*, hair, dentary and other bones; House Mouse *Mus musculus* hair and other bones; Lord Howe Woodhen *Gallirallus sylvestris* leg and other bones
30	LHMO 22	15.3.‟10	1 old pellet remains	Transit Hill, south east	507652	6511013	Black Rat *Rattus rattus*, 1 skull
31	LHMO 23	18.3.‟10	8+ old pellet remains	adjacent Boat Harbour Track	508860	6508738	Black Rat *Rattus rattus*, 8 skulls, dentary, leg and other bones
32	LHMO 24	23.3.‟10	1 fresh pellet	Intermediate Hill, north west	507848	6509766	Black Rat *Rattus rattus*, dentary, leg and other bones; House Mouse *Mus musculus* hair, 1 skull, dentary, leg and other bones

cont. Appendix 17 Details of Masked Owl prey items

no.	pellet code	date	kill re-mains/ pellets	location	Easting MGA	Northing MGA	prey items
33	LHMO 25	11.5.‟10	1 old pellet re-mains	Transit Hill, north west	507214	6511369	Black Rat *Rattus rattus*, 1 skull, dentary, leg and other bones
34	LHMO 26	11.5.‟10	1 old pellet re-mains	Transit Hill, north west	507214	6511369	Black Rat *Rattus rattus*, 1 skull, dentary, leg and other bones; House Mouse *Mus musculus* hair, dentary, leg and other bones
35	LHMO 27	11.5.‟10	1 fresh pellet	Transit Hill, north west	507214	6511369	Black Rat *Rattus rattus*, hair, 1 skull, dentary, leg and other bones
36	LHMO 28	11.5.‟10	1 fresh pellet	Transit Hill, north west	507214	6511369	Black-winged Petrel *Pteradroma nigripennis* feathers, feet, leg bones
37	LHMO 29	11.5.‟10	1 fresh pellet	Transit Hill, north west	507214	6511369	Black Rat *Rattus rattus*, hair, 1 skull, dentary, leg and other bones
38	LHMO 30	11.5.‟10	1 fresh pellet	Transit Hill, north west	507214	6511369	Little Shearwater *Puffinus assimilis* feathers, feet, leg bones
39	LHMO 31	11.5.‟10	1 fresh pellet	Transit Hill, north west	507214	6511369	House Mouse *Mus musculus* hair, 1 skull, dentary, leg and other bones
40	LHMO 32	11.5.‟10	1 fresh pellet	Transit Hill, north west	507214	6511369	Black-winged Petrel *Pteradroma nigripennis* feathers, bird feet, leg bones, possible
41	LHMO 33	12.5.‟10	1-2 old pellet re-mains	Intermediate Hill, north west	508047	6509719	Black Rat *Rattus rattus*, 2 skulls, dentary, leg and other bones
42	LHMO 34	14.5.‟10	1 fresh pellet	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair, 1 skull, leg and other bones
43	LHMO 35	14.5.‟10	1 fresh pellet	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair, 1 skull, leg and other bones
44	LHMO 36	20.5.‟10	1 fresh pellet	Transit Hill, north west	507214	6511369	Black Rat *Rattus rattus*, hair, 1 skull, dentary, leg and other bones; unidentified feathers

cont. Appendix 17 Details of Masked Owl prey items

no.	pellet code	date	kill re-mains/ pellets	location	Easting MGA	Northing MGA	prey items
45	LHMO 37	17.7."10	1 old pellet	Clear Place area	507550	6511668	Black Rat *Rattus rattus*, 1 skull, dentary, other bones; Black-winged Petrel *Pteradroma nigripennis* and Flesh-footed Shearwater *Ardenna carneipes* bones
46	LHMO 38	18.7."10	1 old pellet	adjacent Boat Harbour Track	508860	6508738	Black Rat *Rattus rattus*, 1 skull, dentary, leg and other bones
47	LHMO 39	18.7."10	1 fresh pellet	adjacent Boat Harbour Track	508860	6508738	Black Rat *Rattus rattus*, hair, 1 skull, dentary, leg and other bones
48	LHMO 40	18.7."10	1 fresh pellet	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair, 1 skull, dentary, leg and other bones
49	LHMO 41	18.7."10	1 fresh pellet	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair and other bones; House Mouse *Mus musculus* hair and other bones
50	LHMO 42	18.7."10	1 fresh pellet	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair, 1 skull, dentary and leg bones
51	LHMO 43	7.8."10	1 fresh pellet	west of Kim"s Lookout	504680	6513480	Black Rat *Rattus rattus*, hair, leg and other bones
53	LHMO 44	22.7."10	1 fresh pellet	adjacent Boat Harbour Track	508860	6508738	Black Rat *Rattus rattus*, hair, leg and other bones
54	LHMO 45	22.7."10	1 fresh pellet	adjacent Boat Harbour Track	508860	6508738	House Mouse *Mus musculus* hair, 1 skull, dentary, leg and other bones
55	LHMO 46	24.7."10	1 fresh pellet	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair, leg and other bones
56	LHMO 47	24.7."10	1 fresh pellet	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair and other bones
57	LHMO 48	24.7."10	1 fresh pellet	Valley of the Shadows	507423	6511780	Black-winged Petrel *Pteradroma nigripennis* feathers, bones

cont. Appendix 17 Details of Masked Owl prey items

no.	**pellet code**	**date**	**kill re-mains/ pellets**	**location**	**Easting MGA**	**Northing MGA**	**prey items**
58	LHMO 49	26.7.‟10	1 fresh pellet	Transit Hill, north west	507214	6511369	House Mouse *Mus musculus* hair, 1 skull, dentary, leg and other bones
59	LHMO 50	26.7.‟10	1 fresh pellet	Transit Hill, north west	507214	6511369	Black Rat *Rattus rattus*, 1 skull, dentary and other bones House Mouse *Mus musculus* hair, 1 skull, leg and other bones
60	LHMO 51	26.7.‟10	1 fresh pellet	Transit Hill, north west	507214	6511369	Little Shearwater *Puffinus assimilis* feathers, bones
61	LHMO 52	29.7.‟10	1 fresh pellet	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair, leg and other bones
62	LHMO 53	26.7.‟10	1 fresh pellet	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair, and other bones
63	LHMO 54	26.7.‟10	1 fresh pellet	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair, leg and other bones (2 individuals); House Mouse *Mus musculus* hair, leg and other bones
64	LHMO 55	26.7.‟10	1 fresh pellet	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair and other bones
65	LHMO 56	26.7.‟10	1 fresh pellet	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair and other bones; House Mouse *Mus musculus* hair, leg and other bones

Appendix 18 Details of Masked Owl Female 1 prey items from pellets collected between October 2009 and July 2010

pellet code	roost tree no./species	date	location	Easting MGA	Northing MGA	prey items	notes
LHMO 6	1 Scalybark	25.10.‟09	Transit Hill, north west	507250	6511311	Black Rat *Rattus rattus*, skulls, dentary, leg and other bones	4 old pellet remains
LHMO 7A	4 Greybark	31.10.‟09	Transit Hill, north west	507244	6511315	Black Rat *Rattus rattus*, 26 skulls, dentary, leg and other bones; unidentified mammal bones	26+ old pellet remains
LHMO 7B	4 Greybark	31.10.‟09	Transit Hill, north west	507244	6511315	Black Rat *Rattus rattus*, hair, 1 skull, dentary, leg and other bones	1 fresh pellet
LHMO 7C	4 Greybark	31.10.‟09	Transit Hill, north west	507244	6511315	White Tern *Gygis alba* feathers, bones	1 fresh pellet
LHMO 7D	4 Greybark	31.10.‟09	Transit Hill, north west	507244	6511315	Black Rat *Rattus rattus*, hair, 1 skull, dentary, leg and other bones; House Mouse *Mus musculus* hair, dentary, leg and other bones	1 fresh pellet
LHMO 7E	4 Greybark	31.10.‟09	Transit Hill, north west	507244	6511315	immature Black Rat *Rattus rattus*, hair, 2 skulls, dentary, leg and other bones	1 fresh pellet
LHMO 7F	4 Greybark	31.10.‟09	Transit Hill, north west	507244	6511315	House Mouse *Mus musculus* hair, 1 skull, dentary, leg and other bones	1 fresh pellet
LHMO 10	5 Greybark	4.11.‟09	Transit Hill, north west	507278	6511324	Black Rat *Rattus rattus*, hair, 1 skull, dentary, leg and other bones	1 fresh pellet
LHMO 16	4 Greybark	12.3.‟10	Transit Hill, north west	507244	6511315	Black Rat *Rattus rattus*, 4 skulls, dentary, leg and other bones	4 old pellet re-mains
LHMO 17	1 Scalybark	12.3.‟10	Transit Hill, north west	507250	6511311	Black Rat *Rattus rattus*, 2 skulls	2 old pellet re-mains
LHMO 18	5 Greybark	12.3.‟10	Transit Hill, north west	507278	6511324	Black Rat *Rattus rattus*, 2 skulls	2 old pellet re-mains

cont. Appendix 18 Details of Masked Owl Female 1 prey items

pellet code	roost tree no./species	date	location	Easting MGA	Northing MGA	prey items	notes
LHMO 19	5 Greybark	12.3."10	Transit Hill, north west	507278	6511324	Sooty Tern *Sterna fuscata* feathers, bones	1 fresh pellet
LHMO 22	6 Greybark	15.3."10	Transit Hill, south east	507652	6511013	Black Rat *Rattus rattus*, 1 skull	1 old pellet re-mains
LHMO 25	11 Maulwood	11.5."10	Transit Hill, north west	507214	6511369	Black Rat *Rattus rattus*, 1 skull, dentary, leg and other bones	1 old pellet re-mains
LHMO 26	11 Maulwood	11.5."10	Transit Hill, north west	507214	6511369	Black Rat *Rattus rattus*, 1 skull, dentary, leg and other bones; House Mouse *Mus musculus* hair, dentary, leg and other bones	1 old pellet re-mains
LHMO 27	11 Maulwood	11.5."10	Transit Hill, north west	507214	6511369	Black Rat *Rattus rattus*, hair, 1 skull, dentary, leg and other bones	1 fresh pellet
LHMO 28	11 Maulwood	11.5."10	Transit Hill, north west	507214	6511369	Black-winged Petrel *Pteradroma nigripennis* feathers, feet, leg bones	1 fresh pellet
LHMO 29	11 Maulwood	11.5."10	Transit Hill, north west	507214	6511369	Black Rat *Rattus rattus*, hair, 1 skull, dentary, leg and other bones	1 fresh pellet
LHMO 30	11 Maulwood	11.5."10	Transit Hill, north west	507214	6511369	Little Shearwater *Puffinus assimilis* feathers, feet, leg bones	1 fresh pellet
LHMO 31	11 Maulwood	11.5."10	Transit Hill, north west	507214	6511369	House Mouse *Mus musculus* hair, 1 skull, dentary, leg and other bones	1 fresh pellet
LHMO 32	11 Maulwood	11.5."10	Transit Hill, north west	507214	6511369	Black-winged Petrel *Pteradroma nigripennis* feathers, bird feet, leg bones, possible	1 fresh pellet

cont. Appendix 18 Details of Masked Owl Female 1 prey items

pellet code	roost tree no./species	date	location	Easting MGA	Northing MGA	prey items	notes
LHMO 36	11 Maulwood	20.5.‟10	Transit Hill, north west	507214	6511369	Black Rat *Rattus rattus*, hair, 1 skull, dentary, leg and other bones; unidentified feathers	1 fresh pellet
LHMO 37	Greybark	17.7.‟10	Clear Place area	507550	6511668	Black Rat *Rattus rattus*, 1 skull, dentary, other bones; Black-winged Petrel *Pteradroma nigripennis* and Flesh-footed Shearwater *Ardenna carneipes* bones	1 old pellet
LHMO 48	Banyan	24.7.‟10	Valley of the Shadows	507423	6511780	Black-winged Petrel *Pteradroma nigripennis* feathers, bones	1 fresh pellet
LHMO 49	11 Maulwood	26.7.‟10	Transit Hill, north west	507214	6511369	House Mouse *Mus musculus* hair, 1 skull, dentary, leg and other bones	1 fresh pellet
LHMO 50	11 Maulwood	26.7.‟10	Transit Hill, north west	507214	6511369	Black Rat *Rattus rattus*, 1 skull, dentary and other bones House Mouse *Mus musculus* hair, 1 skull, leg and other bones	1 fresh pellet
LHMO 51	11 Maulwood	26.7.‟10	Transit Hill, north west	507214	6511369	Little Shearwater *Puffinus assimilis* feathers, bones	1 fresh pellet

Appendix 19 Details of Masked Owl Female 2 prey items from pellets collected between November 2009 and May 2010

pellet code	roost tree no./species	date	location	Easting MGA	Northing MGA	prey items	notes
LHMO 11	5 Greybark	5.11.‟09	Intermediate Hill, north west	507926	6510009	Black Rat *Rattus rattus*, leg bone; House Mouse *Mus musculus* hair, dentary, leg and other bones; Black-winged Petrel *Pteradroma nigripennis* skull	several old pellet remains
LHMO 12	7 Greybark	12.1.‟10	Intermediate Hill, north west	507607	6509739	House Mouse *Mus musculus* hair, 1 skull, dentary, leg and other bones; Sooty Tern *Sterna fuscata* bones	I fresh pellet
LHMO 13	7 Greybark	15.11.‟09	Intermediate Hill, north west	507618	6509738	Black Rat *Rattus rattus*, 5 skulls, dentary, leg and other bones; House Mouse *Mus musculus* 1 skull, dentary, leg and other bones; large wader bones	7+ old pellet remains
LHMO 14	4 Greybark	21.11.‟09	Intermediate Hill, west	507733	6509574	Black Rat *Rattus rattus*, hair, 1 skull, tooth, leg and other bones	1 old pellet remains
LHMO 21	7 Greybark	13.3.‟10	Intermediate Hill, north west	507618	6509738	Black Rat *Rattus rattus*, hair, dentary and other bones; House Mouse *Mus musculus* hair and other bones; Lord Howe Woodhen *Gallirallus sylvestris* leg and other bones	1 fresh pellet

cont. Appendix 19 Details of Masked Owl Female 2 prey items

pellet code	roost tree no./species	date	location	Easting MGA	Northing MGA	prey items	notes
LHMO 24	10 Scalybark	23.3.‟10	Intermediate Hill, north west	507848	6509766	Black Rat *Rattus rattus*, dentary, leg and other bones; House Mouse *Mus musculus* hair, 1 skull, tooth, leg and other bones	1 fresh pellet
LHMO 33	12 Greybark	12.5.‟10	Intermediate Hill, north west	508047	6509719	Black Rat *Rattus rattus*, 2 skulls, dentary, leg and other bones	1-2 old pellet re-mains

Appendix 20 Details of Masked Owl prey items from pellets collected at the Boat Harbour Track regurgitation site between July 2009 and July 2010

pellet code	regurgitation tree/species	date	location	Easting MGA	Northing MGA	prey items	notes
LHMO 1 LHMO 2	1 Scalybark	10.7.‟09	adjacent Boat Harbour Track	508856	6508741	Black Rat *Rattus rattus*, hair, leg and other bones	2 fresh pellets
LHMO 3 LHMO 4	1 Scalybark	9.7.‟09	adjacent Boat Harbour Track	508856	6508741	Black Rat *Rattus rattus*, hair, leg and other bones	2 fresh pellets
LHMO 5A	1 Scalybark	4.9.‟09	adjacent Boat Harbour Track	508856	6508741	Black Rat *Rattus rattus*, hair, skull, dentary, leg and other bones	1 fresh pellet
LHMO 5B	1 Scalybark	4.9.‟09	adjacent Boat Harbour Track	508856	6508741	Black Rat *Rattus rattus*, hair, dentary, leg and other bones	1 fresh pellet
LHMO 5C	1 Scalybark	12.9.‟09	adjacent Boat Harbour Track	508856	6508741	Black Rat *Rattus rattus*, hair, dentary, leg and other bones	1 fresh pellet
LHMO 23	2 Scalybark	23.3.‟10	adjacent Boat Harbour Track	508860	6508738	Black Rat *Rattus rattus*, 8 skulls, dentary, leg and other bones	8+ old pellet remains
LHMO 34	2 Scalybark	14.5.‟10	adjacent Boat Harbour Track	508860	6508738	Black Rat *Rattus rattus*, hair, 1 skull, leg and other bones	1 fresh pellet
LHMO 35	2 Scalybark	14.5.‟10	adjacent Boat Harbour Track	508860	6508738	Black Rat *Rattus rattus*, hair, 1 skull, leg and other bones	1 fresh pellet
LHMO 38	1 Scalybark	18.7.‟10	adjacent Boat Harbour Track	508860	6508738	Black Rat *Rattus rattus*, 1 skull, dentary, leg and other bones	1 old pellet
LHMO 39	1 Scalybark	18.7.‟10	adjacent Boat Harbour Track	508860	6508738	Black Rat *Rattus rattus*, hair, 1 skull, dentary, leg and other bones	1 fresh pellet

cont. Appendix 20 Details of Masked Owl Boat Harbour Track regurgitation site prey items

pellet code	regurgitation tree/species	date	location	Easting MGA	Northing MGA	prey items	notes
LHMO 40	2 Scalybark	18.7.‟10	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair, 1 skull, dentary, leg and other bones	1 fresh pellet
LHMO 41	2 Scalybark	18.7.‟10	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair and other bones; House Mouse *Mus musculus* hair and other bones	1 fresh pellet
LHMO 42	2 Scalybark	18.7.‟10	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair, 1 skull, dentary and leg bones	1 fresh pellet
LHMO 44	1 Scalybark	22.7.‟10	adjacent Boat Harbour Track	508860	6508738	Black Rat *Rattus rattus*, hair, leg and other bones	1 fresh pellet
LHMO 45	1 Scalybark	22.7.‟10	adjacent Boat Harbour Track	508860	6508738	House Mouse *Mus musculus* hair, 1 skull, dentary, leg and other bones	1 fresh pellet
LHMO 46	2 Scalybark	24.7.‟10	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair, leg and other bones	1 fresh pellet
LHMO 47	2 Scalybark	24.7.‟10	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair and other bones	1 fresh pellet
LHMO 52	2 Scalybark	29.7.‟10	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair, leg and other bones	1 fresh pellet
LHMO 53	2 Scalybark	26.7.‟10	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair, and other bones	1 fresh pellet
LHMO 54	2 Scalybark	26.7.‟10	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair, leg and other bones (2 individuals); House Mouse *Mus musculus* hair, leg and other bones	1 fresh pellet

cont. Appendix 20 Details of Masked Owl Boat Harbour Track regurgitation site prey items

pellet code	regurgitation tree/species	date	location	Easting MGA	Northing MGA	prey items	notes
LHMO 55	2 Scalybark	26.7.'10	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair and other bones	1 fresh pellet
LHMO 56	2 Scalybark	26.7.'10	adjacent Boat Harbour Track	508858	6508737	Black Rat *Rattus rattus*, hair and other bones; House Mouse *Mus musculus* hair, leg and other bones	1 fresh pellet

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Molecular data contradicts historical records and cautions translocation of the Lord Howe Island masked owl

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ABSTRACT

Masked owls, reputedly all of the Tasmanian race (*Tyto novaehollandiae castanops*) were introduced onto Lord Howe Island (LHI) in the 1920s in an attempt to control the black rat (*Rattus rattus*). This attempt, however, has been unsuccessful and a co-eradication of the rats and masked owls has been planned to reduce the threat to endemic species and breeding seabirds on the island. As the Tasmanian masked owl is considered endangered, translocation of LHI masked owls to Tasmania has been suggested. Before translocation is considered the ancestry of the LHI masked owl needs to be confirmed, as LHI masked owls are typically smaller and paler than individuals occurring in Tasmania. Here we sequenced three sections of mitochondrial gene regions: cytochrome *b*, ATP6 and ND3 to assess the provenance of the LHI masked owl and screened a suite of microsatellite loci isolated from the barn owl (*Tyto alba*) to assess contemporary divergence. Phylogenetic analysis revealed two clades, one exhibited by individuals from LHI and south-eastern mainland Australia and the second by those from Tasmania. Cross species amplification of microsatellite loci was successful, with 18 loci polymorphic. Genotypic data revealed significant sub-structuring between LHI, south-eastern mainland Australia and Tasmania. Data presented here indicate that the south-eastern mainland masked owl was introduced to LHI and subsequently reproduced. The genetic integrity of the LHI masked owl population is therefore questionable and as such LHI individuals may not be suitable for translocation to Tasmania.

1. Introduction

Introduced species are one of the most destructive threatening processes within ecosystems worldwide (Courchamp et al., 2003). These species have been both unintentionally and deliberately introduced to many ecosystems, where they have established populations and facilitated the extinction of numerous native and endemic species (Donlan et al., 2003). One global ecosystem that has been severely affected by such species is islands. Island ecosystems are highly susceptible to introduced species due to the high level of endemism resulting from their isolation (Fordham and Brook, 2010). Management of introduced species on islands, however, can be complex due to interactions that have developed between both introduced and native species and between introduced species themselves. Consequently total removal of introduced species on islands must be approached with caution, but can be highly successful if achieved, due to the remoteness of the area involved (Courchamp et al., 2003). All issues associated with removal require consideration, for example, what happens when the introduced species' ancestral population is listed as threatened? In this situation eradication of the introduced species can be controversial and other management options should be considered to ensure the best outcome for the affected ecosystem and the species in question. An alternative option to eradication could be translocation, where individuals are removed from an island and relocated amongst their ancestral population or used for *ex situ* conservation from which the ancestral population could be re-stocked in the future. An example of where such a strategy has been successful is in the case of the New Zealand brush-tailed rock-wallaby (*Petrogale penicillata*) which was introduced from Australia to New Zealand in the early 1870s (Eldridge et al., 2001). The brush-tailed rock wallaby became well established in New Zealand, which had a significant impact on indigenous flora and fauna. Eradication of the wallaby is being undertaken, and as part of the eradication process wallabies have been translocated back to Australia to aid conservation of dwindling ancestral populations.

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Successful translocation depends on many factors, including the number of individuals released, pre and post translocation environments, demography, logistics of the program (Griffith et al., 1989; Sigg, 2006), whether the original threat has been removed (Fischer and Lindenmayer, 2000) and the genetic makeup of the population involved (Moritz, 1999). Obtaining genotypic information from individuals to be translocated is crucial to the success of the translocation (Larson et al., 2002). This is especially true when translocated individuals are to be integrated with an existing population as the introduction of new alleles can break up co-adapted gene complexes and break down local adaptation resulting in a reduction in the fitness of the recipient population.

The Lord Howe Island (LHI) masked owl (*Tyto novaehollandiae castanops*) represents an example of a native species introduced to an island that is currently considered a pest. The reputed ancestral population of the LHI masked owl, the Tasmanian masked owl (*T. n. castanops*) (Hindwood, 1940; Hutton, 1991), however, is listed as endangered under the Tasmanian Threatened Species Protection Act 1995. LHI was listed as a World Heritage Property in 1982 for its natural values as an example of outstanding natural beauty, containing habitats of considerable importance for *in situ* conservation of its biodiversity (Department of Environment and Climate Change, 2007). The island supports a diverse biota with a high level of endemic species, including the threatened Lord Howe woodhen (*Gallirallus sylvestris*), Lord Howe Island gecko (*Christinus guentheri*) and Lord Howe Island skink (*Cyclodina lichenigera*). There are important breeding colonies of threatened seabirds including most of the world's population of the providence petrel (*Pteradroma solandri*) (Department of Environment and Climate Change, 2007).

Masked owls, reputedly of the Tasmanian race (*T. n. castanops*) were introduced to LHI between 1922 and 1930, along with a number of other Australian and North American owl species to help control the introduced black rat (*Rattus rattus*). The masked owl was the only species to become established and is suggested to have contributed to the extinction of the LHI race of the southern boobook (*Ninox novaeseelandiae albaria*) in the 1950s through competition for resources (Hutton, 1991). The current density of masked owls on LHI is uncertain, although Milledge et al. (2010) estimated the population at between 20 and 30 pairs, and later (2011) at 20 pairs with a small number of non-breeding individuals. These estimates are unusually high for large forest owls which are territorial and generally require large home-ranges (Cooke et al., 2006). By comparison, in Tasmania, an area the size of LHI (1455 ha) would be unlikely to support more than three pairs of masked owls (Milledge et al., 2010). Despite this high density, the masked owl population on LHI has not significantly reduced the black rat population and a large scale poisoning programme to completely remove all rodents (rat and house mouse (*Mus musculus*)) from LHI is planned (Lord Howe Island Board, 2009). The removal of rodents from LHI should greatly benefit biodiversity conservation; however, their removal without the coincident removal of owls could actually have a negative effect, as the owls would be forced to find alternative prey to fill their main dietary requirement. Species likely to suffer from such a prey base shift include endemic species such as the Lord Howe Woodhen and the Lord Howe Currawong (*Strepera graculina crissalis*), as well as breeding seabirds. A co-eradication program which simultaneously removes the masked owl and rodents from the island will therefore deliver the greatest biodiversity benefits.

The most appropriate eradication method for the removal of masked owls from LHI has yet to be determined. One of the major issues in the decision is that its assumed ancestral population, the Tasmanian masked owl, is listed as endangered due to small population size (approximately 615 pairs) and habitat loss (Garnett et al., 2011). LHI masked owls are also suggested to have differentiated from the ancestral population over their 90 years of isolation, as LHI individuals measured are smaller than their Tasmanian counterparts (Milledge, 2011). The observed size difference could be due to the smaller size of the main prey item (black rats) on LHI compared to the range of prey in Tasmania e.g. bandicoots, possums and the European rabbit (*Oryctolagus cuniculus*) (Mooney, 1993). Smaller size could assist manoeuvrability in the densely vegetated forest and shrubland habitats of LHI, enabling more efficient capture of the agile, scansorial black rat. An alternative or concomitant explanation could be related to Bergmann's Rule which predicts that individuals of the same species are smaller in the lower latitudes of their range (Milledge et al., 2010). Milledge (2011) found that the mean morphometric data for a small sample of LHI masked owls measured (both males and females) fell in between the means for Tasmanian and mainland birds, which could suggest either interbreeding between the two or divergence of the Tasmanian birds. The paler colour, however, of many LHI owls is more consistent with the south-eastern mainland masked owl population than the Tasmanian (although the pale morph occurs in Tasmania); and therefore further questions the origin of the LHI population.

The mechanism for removing the masked owl from LHI needs careful consideration. Options include shooting, capture and euthanasia, or capture and translocation. The first two options may not be appropriate if the LHI population can serve as an "insurance population" for the endangered ancestral population. Before management decisions regarding the eradication of the masked owl from LHI are made, there is a clear need to establish the genetic affinities (as the introduction of deleterious genes could be a concern) and potential importance of its population which would include resolving the taxonomic classification of the masked owl in Australia.

Due to advancements in molecular and information technology, DNA can now be readily used to address ecological and taxonomic questions. A combination of mitochondrial and microsatellite markers can be used to assess sub-specific taxonomy, and the levels and nature of genetic variation (Roberts et al., 2011). Mitochondrial DNA is relatively conservative and can provide information for taxonomy, for example, Norman et al. (1998) used mitochondrial sequencing to confirm the taxonomic affinity of the endangered Norfolk Island boobook owl (*Ninox novaeseelandiae undulata*) in an attempt to conserve the genetic integrity of the species. Microsatellites are short tandem repeat sequences (located in the nuclear genome) which are hyper-variable and can provide information on contemporary divergence, population size, mating systems, inbreeding and can be used to equivocally identify an individual.

Here we first investigated whether the LHI masked owl originated from the island of Tasmania and/or from the south-eastern Australian mainland by sequencing partial sections of cytochrome *b*, ATP-6 and ND3 in the mitochondrial genome. Secondarily we screened a suite of barn owl (*Tyto alba*) microsatellite markers for their application in the masked owl and then used the genotypic data to assess contemporary divergence.

2. Methods

2.1. Sample collection

Previously collected individual masked owl samples were obtained from LHI ($n = 6$). Samples included tissue and/or plucked feathers from frozen deceased birds. For comparison, tissue was obtained from three races of masked owl, south-eastern mainland *T. n. novaehollandiae* (Victoria $n = 6$ and New South Wales $n = 4$), Tasmania *T. n. castanops* ($n = 19$) and Melville Island *T. n. melvillensis* ($n = 1$) (Fig. 1). A sample from a single barn owl (*Tyto abla*) was

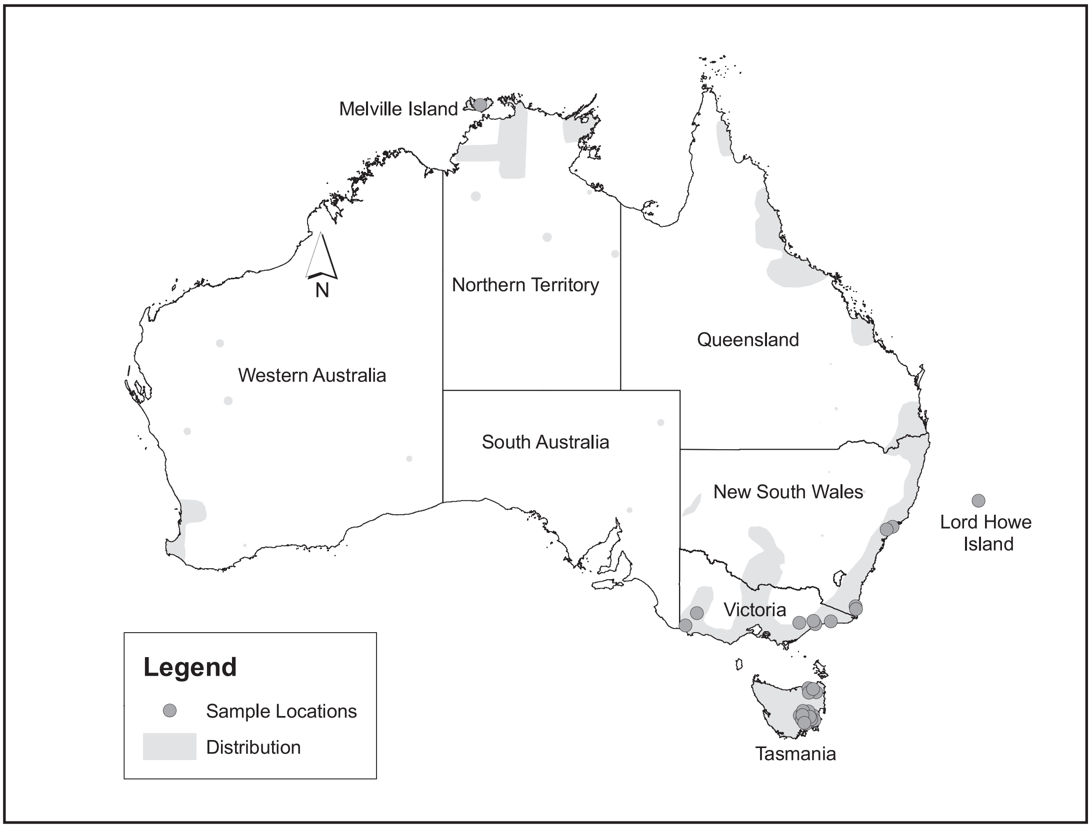

Fig. 1. Masked owl distribution adapted from HANZAB (Higgins, 1999) with sample locations overlayed.

used as an out group for phylogenetic analysis. Genomic DNA was extracted from samples using the QIAGEN DNeasy® Blood and Tissue Kit following the manufacturer's protocols.

2.2. Mitochondrial sequencing and phylogenetic analysis

Three mitochondrial DNA (mtDNA) fragments that included regions of the ND3, ATP6 and cytochrome *b* genes were amplified and sequenced using primer pairs L10755/H11151 (Chesser, 1999), L9245/H9947 (Eberhard and Bermingham, 2004) and L1481/H15149 (Kocher et al., 1989), respectively. Sequencing reactions were performed by the Australian Genome Research Facility (AGRF) using Big Dye Terminator (BDT) chemistry version 3.1 (Applied Biosystems) and were resolved by capillary electrophoresis on an Applied Biosystems AB3730 capillary sequencer.

Chromatograms were edited, aligned and checked by eye in Geneious Pro 5.6.5 (Drummond et al., 2010). Sites with missing data were removed from analysis. The number of haplotypes, number of variable sites, haplotype diversity (h), nucleotide diversity (π) and the number of synonymous and non-synonymous mutations in coding regions were calculated in DNASP 5.0 (Rozas et al., 2003). Coding and non-coding sections of the three regions were identified by aligning sequences to the annotated chicken genome (GENBANK accession number: NC_001323) (Desjardins and Morais, 1990). MEGA 5.0 (Tamura et al., 2011) was used to calculate transition to transversion bias (R).

The most appropriate nucleotide substitution model for our data was selected using the maximum likelihood method implemented in MEGA 5.0 (Tamura et al., 2011). The selected model was subsequently used in all relevant analyses. Evolutionary history was inferred using the maximum likelihood (ML) tree based on concatenated cytochrome *b*, ND3 and ATP6 regions with 2000 bootstraps in MEGA 5.0 (Tamura et al., 2011). Pairwise distances between populations, based on the average number of base substitutions per site were calculated, in MEGA 5.0 (Tamura et al., 2011). Phylogenetic relationships among haplotypes were visualised using a median-joining network calculated using maximum parsimony post-processing in Network 4.6.1.0 (Fluxus-Technology, www.fluxus-engineering.com) (Bandelt et al., 1999).

2.3. Microsatellite loci screening and analysis

The forward primer for 20 microsatellite loci described by Burri et al. (2008), together with the P2/P8 marker (to infer gender) described by Griffiths et al. (1998) were labelled with FAM, VIC, NED or PET fluorophores (Applied Biosystems), loci were arranged into three panels (Table 1). Products were separated on an AB3730 capillary sequencer and analysed using GENEMAPPER 3.7 software (Applied Biosystems) by AGRF.

Locus-based estimates of observed heterozygosity (H_o) and expected heterozygosity (H_e) were calculated using GENALEX 6 (Peakall and Smouse, 2006). GENEPOP 4.0 (Rousset, 2008) was used to test for deviations from HWE and linkage equilibrium at each locus in three populations, i.e. LHI, south-eastern mainland and Tasmania. Presence of nulls was checked by looking for consistent deviations from HWE in the direction of homozygous excess. Private alleles and expected heterozygosity within a population were calculated in GENALEX 6.

2.4. Genetic differentiation and population structure

The extent of pairwise genetic differences in allele-frequencies (F_{ST}) between populations of masked owls was calculated using GENEPOP 4.0 (Rousset, 2008). Because F_{ST} is allele-frequency-based, it reflects patterns of gene flow on longer time-scales than individual genotype-based analyses e.g. STRUCTURE.

Table 1
Characterisation of 20 barn owl microsatellite loci in the masked owl.

Locus	N	N_A	Size-range (bp)	Dye	Panel	H_o	H_e
Ta-202[a]	34	4	266–274	NED	3	0.618	0.543
Ta-204[a]	33	3	126–143	FAM	1	0.273	0.415
Ta-206[a]	29	8	276–292	FAM	3	0.655	0.692
Ta-207[a]	35	5	257–273	FAM	2	0.743	0.739
Ta-210	35	1	171	FAM	2	Mono	Mono
Ta-212[a]	33	4	254–261	VIC	3	0.242	0.271
Ta-214[a]	34	6	226–240	NED	1	0.765	0.770
Ta-215[a]	33	7	287–313	NED	2	0.758	0.733
Ta-216[a]	36	12	187–211	PET	3	0.722	0.816
Ta-218[a]	36	2	128–132	NED	1	0.083	0.080
Ta-219[a]	35	2	195–197	NED	3	0.371	0.485
Ta-220[a]	34	5	215–225	VIC	1	0.676	0.526
Ta-304	33	24	199–278	FAM	3	0.727	0.943
Ta-305	32	6	174–192	VIC	2	0.406	0.518
Ta-306[a]	35	2	168–171	VIC	1	0.257	0.224
Ta-308	33	7	220–277	FAM	1	0.212	0.586
Ta-310[a]	34	3	268–274	VIC	2	0.452	0.540
Ta-402[a]	34	8	186–216	PET	2	0.706	0.800
Ta-408	35	1	200	NED	2	Mono	Mono
Ta-413[a]	35	9	159–195	VIC	3	0.571	0.827

N, sample size; N_A, number of alleles; NED, yellow; FAM, blue; VIC, green; PET, red; H_o, observed heterozygosity; H_e, expected heterozygosity; mono, monomorphic.
[a] Loci retained for genetic analysis.

Fig. 2. Median-joining network indicating the relationship among 12 masked owl haplotypes for concatenated Cyt *b*, ND3 and ATP6 regions. Colours correspond to sampling location: Lord Howe Island (○, $N = 5$), Victoria (○, $N = 6$), NSW (○, $N = 4$), Melville Island (○, $N = 1$) and Tasmania (●, $N = 19$). Area of circles corresponds to frequency of haplotype and slices of circles correspond to proportion of individuals from each location with that haplotype. Dashes indicate a single nucleotide difference.

Population structure was inferred by implementing the Bayesian model-based clustering method within the program STRUCTURE (Pritchard et al., 2000). STRUCTURE uses genotypic data to identify the most likely number of genetic clusters (K) in a population sample and proportionally assigns individuals to each cluster. Because STRUCTURE is genotype-based (rather than allele-frequency-based) it provides a snapshot of contemporary population genetic structure. STRUCTURE was run using the admixture model with correlated allele frequencies. Values of K were set from 1 to 10. Twenty replicate runs (of 3×10^6 Markov Chain Monte Carlo (MCMC) after a burnin period of 10^6 repetitions) were performed for each value of K. Results were summarised using STRUCTURE HARVESTER v0.6.6 (Earl and vonHoldt, 2012). The most likely number of clusters (K) was determined using the Evanno et al. (2005) ΔK method. The ΔK method looks for the sharpest break in the distribution of $\mathrm{Ln}\,P(D)$ distribution (visualised as a peak in a ΔK vs. K plot). Cluster probabilities were averaged over the 20 runs for the most likely value of K using the Greedy algorithm with 1000 random input orders in CLUMPP 1.1.2 (Jakobsson and Rosenberg, 2007). Results were visualised using DISTRUCT 1.1. (Rosenberg, 2004).

To determine if genetic substructure among populations represented divergence on evolutionary or more recent timescales, pairwise permutation tests (10,000 permutations) were performed in SPAGeDi 1.3 (Hardy and Vekemans, 2002).

3. Results

3.1. Provenance of Lord Howe Island masked owl

We concatenated the three mitochondrial gene regions to give 1392 bp total sequence for 35 masked owl individuals and one barn owl (lengths of sequenced regions included cytochrome *b*, ATP6 and ND3 genes were which 308, 687 and 387 bp, respectively). Following removal of missing data, 1389 bp sequence was analysed. Mitochondrial origin of the three regions was supported by an absence of double peaks, ambiguities, unexpected stop-codons, or insertions/deletions. The most appropriate nucleotide substitution model for our data was TN93 + G (Tamura and Nei, 1993), which distinguishes between two types of transitions. Across the three masked owl populations 12 haplotypes were detected (Fig. 2), with 27 variable sites. All variable sites were located in coding regions, with 25 associated with synonymous base changes and two associated with non-synonymous base changes. Both non-synonymous changes were located in the ATP6 gene region, with one non-synonymous change constituting a fixed difference between Tasmania and the mainland/LHI samples. Haplotype (h) and nucleotide (π) diversities were 0.72 ± 0.076 and 0.007 ± 0.0004, respectively. Transition to transversion bias (R) within the masked owl sample was 13.15.

Among masked owl populations, divergence in terms of number of base substitutions per site was greatest for comparisons involving Tasmania (~1.3% for all comparisons, Table 2). Divergence between LHI, south mainland and Melville Island samples was very low (0.1–0.3%, Table 2). High haplotype divergence (16 nucleotide substitutions) was observed between Tasmanian owls and all other masked owl individuals sequenced (Fig. 2). Tasmanian masked owls exhibited two haplotypes, separated by a single nucleotide difference, with the majority ($n = 18$) sharing the same haplotype. Higher haplotype diversity was found for mainland Australia, with nine haplotypes observed, most of which were exclusive to individuals. All individuals from LHI, however, exhibited the same haplotype along with one individual from Victoria. Maximum likelihood phylogenetic analysis based on the concatenated mitochondrial regions supported the presence of two mitochondrial clades (85% bootstrap support): one included individuals from Tasmania and the other included individuals from LHI, south mainland and Melville Island (Fig. 3).

3.2. Characterisation of microsatellite loci

Genotypic data was obtained for 20 microsatellite loci in 36 individuals. The mean number of alleles across all loci was 6.2 ± 5.1, with 18 of the 20 loci being polymorphic (Table 1). Mean expected heterozygosity was 0.533 ± 0.288 while mean observed heterozygosity was 0.468 ± 0.268.

Within each of the three populations (LHI, south mainland and Tasmania (the Melville island individual was excluded)) all loci conformed to HWE expectations, with the exception of Ta-308. For the locus Ta-308, homozygotes were found only in the heterogametic (female) sex, which is indicative of sex-linkage. There were no consistent patterns of linkage disequilibrium amongst the loci. Monomorphic loci Ta-210 and Ta-408, stuttering loci Ta-304 and Ta-305, and sex linked Ta-308 were all omitted from further analysis.

3.3. Patterns of genetic diversity

Private alleles within a population can provide a simplistic measure of genetic distinctiveness. LHI has three alleles present on the mainland (at frequencies 0.05–0.1) that are not observed in the Tasmanian population and three alleles present in Tasmania (at frequencies 0.03–0.09) that are not observed in the mainland population (Table 3). Three alleles were unique to LHI. The sharing of unique alleles between the LHI population and the two reference populations could suggest hybridization between Tasmanian and

Table 2
Sample sizes (*N*) and divergence estimates (lower diagonal) for comparisons involving Lord Howe Island (LHI), mainland Australia, Tasmania, Melville Island and the outgroup barn owl *Tyto alba*. Divergence is measured as the number of base substitutions per site averaged over all sequence pairs between population groups. Standard error estimate(s) are shown above the diagonal.

	N	LHI	Mainland	Tasmania	Melville Is.	*T. alba*
LHI	5		0.000	0.003	0.001	0.01
South-eastern mainland	10	0.001		0.003	0.001	0.01
Tasmania	19	0.013	0.013		0.003	0.01
Melville Is.	1	0.003	0.003	0.013		0.01
T. alba	1	0.12	0.12	0.12	0.12	

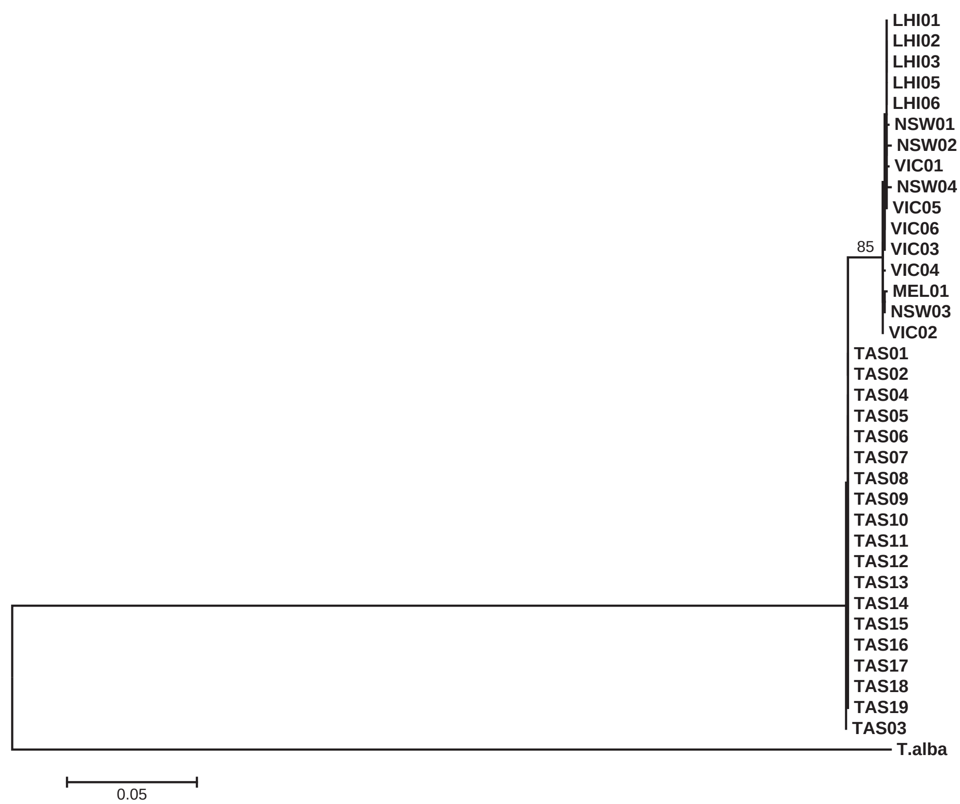

Fig. 3. Maximum likelihood tree based on concatenated Cyt *b*, ND3 and ATP6 regions showing inferred evolutionary relationships among masked owls from Tasmania (TAS), Lord Howe Island (LHI), Victoria (VIC), New South Wales (NSW) and Melville Island (MEL). The outgroup was the barn owl *Tyto alba* (*T. alba*). The tree is drawn to scale, with branch lengths measured in the number of substitutions per site. The percentage of replicate trees in which the associated taxa clustered together in the bootstrap test (2000 replicates) is shown above branches (for values >50%).

Table 3
Number of individuals (*N*), number of alleles unique to a population (#private alleles) and expected heterozygosity (H_e) for Lord Howe Island (LHI), mainland Australia, and Tasmania population samples.

Population	*N*	#Private alleles	H_e
LHI	6	3	0.39
South-eastern mainland	10	19	0.55
TAS	19	8	0.52

mainland individuals. Private allelic richness, however, is highly dependent on sample size (Kalinowski, 2004) and the proportion of private alleles here may well be disproportional to the real allele frequency (although our LHI sample could represent anywhere between 5% and 30% of the population depending upon census) .

3.4. Genetic differentiation and population structure

Analysis of microsatellite allele frequencies revealed the presence of substantial geographic substructure. Genetic differentiation between both LHI and south-eastern mainland ($F_{ST} = 0.115$, $p < 0.001$) and between LHI and Tasmania ($F_{ST} = 0.126$, $p < 0.001$), was greater than between south-eastern mainland and Tasmania ($F_{ST} = 0.052$, $p < 0.001$).

Based on ΔK method the most likely number of genetic clusters detected using STRUCTURE was three (Fig. 4). Strong contemporary genetic substructure was apparent in the admixture plot where individuals were clustered into three distinct groups (1) LHI, (2) mainland (including individuals from Victoria, New South Wales and Melville Island) and (3) Tasmania. There was some evidence of admixture between LHI and the mainland and between the mainland and Tasmania (Fig. 5).

There was no evidence that differences in allele size contribute to population structure, as R_{ST} values were not significantly greater than ρR_{ST} values (Table 4). Thus we would infer that populations have not accumulated evolutionary differences via a stepwise mutation process at these markers, and so differences are more likely the result of genetic drift (i.e. random changes in allele frequencies over generations).

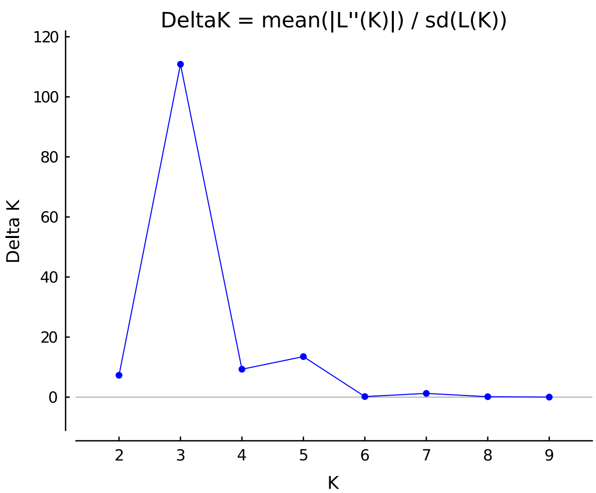

Fig. 4. Δ*K* for each value of *K*.

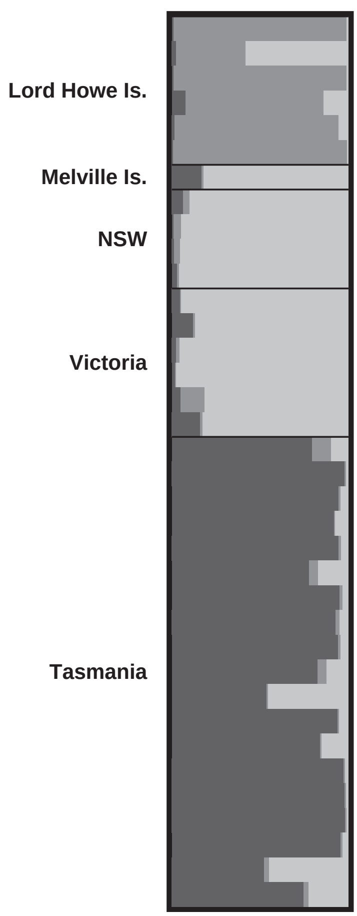

Fig. 5. Structure analysis ($K = 3$) for masked owls across Lord Howe Island ($N = 6$), mainland New South Wales ($N = 4$), mainland Victoria ($N = 6$), Tasmania ($N = 19$) and Melville Island ($N = 1$). Each column on the *x*-axis is a masked owl individual and the *y*-axis represents the proportional assignment (Q) of each individual to each of the three genetic clusters identified by STRUCTURE.

4. Discussion

4.1. Molecular data contradicts historic masked owl translocation data

Phylogenetic analysis from the concatenated mitochondrial gene regions, cytochrome *b*, ATP6 and ND3, shown here indicates that at least part of the LHI masked owl ancestry lies with the south-eastern Australian mainland masked owl (*T. n. novaehollandiae*) and not solely with the Tasmanian masked owl (*T. n. castanops*). This finding is contradictory to the origin claimed in previously published works e.g. Hindwood (1940), Higgins (1999) and Garnett et al. (2011), who consider the LHI masked owl to have originated from the race *T. n. castanops*. Hindwood (1940) describes owl translocation events to LHI which occurred between December 1922 and October 1930, where up to one hundred owls of various species were introduced in an effort to control the rats. Most of the birds introduced were believed to be Tasmanian masked owls, which were sourced by Taronga Zoo and then subsequently translocated to LHI. Such translocation events are documented in historical records held by Taronga Zoo (S. Brice pers. comm.). Hindwood (1940) also stated that there appeared to be no evidence that south-eastern mainland masked owls were included in the shipments from Taronga Zoo to LHI. Interbreeding of Tasmanian and mainland masked owls in captivity, pre-translocation, is also unlikely as large owls were not breed in captivity in Australia until the 1940s. Phylogenetic relationship data shown here therefore disputes this last statement by Hindwood (1940) as all five individuals sequenced from LHI shared the same haplotype as one individual from Victoria (Fig. 2). Maximum likelihood analysis also showed clear support (85% bootstrap) for two mitochondrial clades, one which included all individuals sampled from Tasmania ($n = 19$) and the other included individuals ($n = 16$) from LHI, south mainland (Victoria and New South Wales) and Melville Island. This data indicates that at least one female masked owl from the south-eastern mainland population was introduced to LHI and subsequently bred, as mitochondrial DNA is inherited maternally. The perceived provenance and current accepted taxonomy of the LHI masked owl, *T. n. castanops*, is therefore not supported by data presented here.

Table 4
SPAGEDI test – pairwise FST, R_{ST} and ρR_{ST} comparisons. *P* values from one-tailed tests based on 10,000 permutations.

Populations	F_{ST}	R_{ST}	ρR_{ST}	ρR_{ST} 95% CI	P ($R_{ST} > \rho R_{ST}$)
LHI vs. Sth. E. mainland	0.15	0.15	0.13	(−0.01 to 0.31)	0.38
LHI vs. TAS	0.20	0.31	0.19	(0.03–0.44)	0.15
Sth. E. mainland vs. TAS	0.07	0.03	0.08	(0.003–0.18)	0.85

Wink et al. (2008) examined the phylogeny of owls globally using cytochrome *b* and RAG-1 with small sample sizes of each species. They found a 0.52% divergence between the Australian masked owl (source of origin unknown) and the Tasmanian masked owl. Using genetic divergence and morphological characteristics they considered the two groups as separate species, *T. novaehollandiae* and *T. castanops*. Weick (2006) also supports the speciation of the masked owl due to size (*T. novaehollandiae* length: 330–470 mm, body mass 420–670 g; *T. castanops* length: 470–550 mm, body mass 600–1260 g) and geographical isolation. Norman et al. (1998), however, suggest that sister species divergence is higher e.g. 4.4% in the *Ninox rufa* - *N. strenua* complex and non-sister species divergences from 6.4% to 9.1%. Here we found a 1.3% divergence between *T. n. novaehollandiae* and *T. n. castanops* which supports the current separation of the mainland and Tasmanian races.

Interestingly data here also suggests that the individual from Melville Island is a descendent of the south mainland population. Both mitochondrial and nuclear DNA analysis grouped the Melville Island individual with the south-eastern mainland population. The Melville Island masked owl population is located on a remote island off the north coast of the Northern Territory (Fig. 1). The population is considered a separate race, *T. n. melvillensis*, and is classified as Endangered nationally under the EPBC Act 1999. Due to the geographical isolation of this population from the south-eastern mainland population, we would have expected to observe differentiation in both mitochondrial and nuclear analysis, as this was not the case it could indicate misidentification of the specimen (although the sample was deemed to be from a reliable source). In neither case, this unexpected result highlights the need for further molecular investigation into the taxonomy of Australian masked owls and perhaps Australian owls in general.

4.2. Issues with translocating island species

Islands have long been used as a refuge for dwindling populations of threatened species, and have been used to bolster threatened populations by translocation, as was the case of the New Zealand brush-tailed rock-wallaby being translocated back to Australia (Eldridge et al., 2001). The isolation and small size of island populations, however, can often render them to loss of genetic diversity and inbreeding (Miller et al., 2011), making them potentially unsuitable for translocation. LHI individuals assessed here had a lower genetic diversity ($H_e = 0.39$) than the south-eastern mainland ($H_e = 0.55$) and Tasmanian ($H_e = 0.52$) populations. Lack of diversity in the LHI population raises concerns about introducing these individuals to Tasmania and/or the mainland, as adaptive changes could compromise not only the source population, but the fitness of the individuals translocated into new habitats (Eldridge et al., 2001).

Unfortunately Bayesian model-based clustering did not pin point the source of the LHI population amongst the populations tested. Three populations were identified in the analysis and all individuals were assigned to their correct origin without spatial information. Private alleles were observed in all three populations (LHI, south mainland and Tasmania). LHI was found to contain three unique alleles, and shared three unique alleles with the Tasmanian population and three unique alleles with the mainland population. The sharing of alleles, population substructure and lack of evolutionary divergence could indicate breeding between the Tasmanian and mainland races, which has resulted in the 'hybrid' LHI population.

Between 1988 and 2007, 108 individual masked owls were shot on LHI, of which approximately 30% were juveniles (Milledge, 2011). Culling was concentrated around settled areas, with a number of pairs taken on occasion (Milledge, 2011). This contraction in population size could have caused rapid genetic drift to occur in the LHI population, the effects of such drift can be seen in Fig. 5 in the population structure plot. Morphometric data was obtained from only a few ($n = 4$) of the culled individuals, two males and two females. Weights and wing measurements for one male and one female, were closer to the average for the Tasmanian race, whereas those for the other male and female were closer to the average for the mainland race (Milledge, 2011), further supporting the possibility of hybridization between the Tasmanian and mainland races.

Genetic changes, such as those observed in the LHI population, could adversely affect the Tasmanian and/or mainland population, as the loss of alleles can be more significant than the loss of heterozygosity. Rapid genetic drift due to small captive bred populations has been shown to be the cause of differentiation between founder and translocated populations in the bridled nailtail wallaby (*Onychogalea fraenata*) (Sigg, 2006), where the more individuals released from a small founder population actually had a negative effect on the genetic diversity of the translocated and recipient population.

4.3. The role of DNA profiling in future management of the LHI masked owl

Cross species amplification of the microsatellite loci characterised for the barn owl by Burri et al. (2008) was successful with 18 loci being polymorphic in the masked owl. Interestingly, reverse ascertainment bias was observed here for Ta-304 which was monomorphic in the barn owl but had the highest heterozygosity in the masked owl. Hogan et al. (2009) also showed a similar scenario in *Ninox* spp. where monomorphic markers in the target species were highly polymorphic in other closely related species. The genotypic information from these markers indicates that they will be useful for future genetic studies of this species, with eight loci $H_e > 0.6$ which, according to Waits et al. (2001) will provide a probability of identity (P_{ID}) of one in 10,000. As the south-eastern mainland masked owl population is estimated to be approximately 7000 breeding birds (Garnett and Crowley, 2000) and the Tasmanian masked owl population is estimated to be approximately 1300 breeding birds (Garnett et al., 2011) these markers will be sufficient to distinguish between close relatives, such as siblings or parent–offspring.

Future sampling of additional masked owls on LHI is necessary to unravel the 'story' behind the LHI masked owl population. Masked owls, however, are cryptic, elusive, wary and difficult to catch (Milledge, 2011) to obtain DNA. Shed feathers have been found to be a reliable source of DNA for both mitochondrial sequencing and microsatellite genotyping (Hogan et al., 2008). Rudnick et al. (2005) and Hogan and Cooke (2010) demonstrated that DNA extracted from shed feathers, used in concert with microsatellite markers, can be used to genetically tag individuals, which can provide information on breeding behaviour, relatedness of individuals, population differentiation, habitat use, population size and allow for individual identification.

The collection of shed feathers, in conjunction with other DNA sources e.g. deceased and trapped individuals will increase the sampling effort of LHI masked owls. A larger sample will provide further information about the origin of the population through mitochondrial sequencing and increase the number of individual profiles obtained through microsatellite genotyping. Individual profiles obtained through the 14 microsatellite loci characterised here will also provide an accurate census of the LHI population and provide individual accountability during future management of the masked owl from LHI, whether that is through translocation or eradication.

4.4. Conclusion

Results of this study highlight the importance of molecular genetics in conservation biology, especially in relation to management of species involving translocation. Past *adhoc* translocation events are often poorly documented and assumptions on a species origin cannot be based on historical data and/or morphology alone. Without molecular data the translocation of masked owls from LHI could have preceded, which may have had had dire consequences for the already endangered Tasmanian masked owl.

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Lord Howe Island Rodent Eradication Project

NSW Species Impact Statement

February 2017

Appendix G - Biodiversity Benefits Monitoring Package

G.1 Biodiversity Benefits Project Report

G.2 LHI Land Birds Report 2014

G.3 LHI Land Birds Report 2013

Assessing impacts of introduced rats on Lord Howe Island plants including the Little Mountain Palms and its habitat on Mt Gower

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Summary

We used selective caging and cafeteria trials to determine removal and loss of fruits and seeds to Black Rats (*Rattus rattus*) on Lord Howe Island. Of the 16 species examined, losses to Black Rats were very high for six species (*Howea forsteriana, Olea paniculata, Baloghia inophylla, Jasminium simplicifolium, Smilax australis* and *Geitonoplesium cymosum*); potentially very high but variable for one species (*Ochrosia elliptica*); moderate for three species (*Syzygium fullagarii, Chionanthus quadristamineus, Dietes robinsoniana*) (the actual losses may be higher as the trials only ran for a short period) and low-moderate in the remaining 6 species. No species tested was entirely free of seed or fruit losses to Black Rats. This suggests Black Rats are likely to impact on many species across LHI and further testing of species is warranted to examine the number of species likely to be at risk due to impacts on seed production, seed survival and plant recruitment. In addition, further work on what impact the loss of seeds or fruits may have on the affected plant populations is also necessary.

The high impact of Black Rats on the Little Mountain Palm (*Lepidorrhachis mooreana*) on Mt Gower that had been identified by Auld *et al*. (2010) was confirmed by repeat sampling 8 years after the original sampling was done. While there is some successful recruitment in this species where rodent baiting occurs on Mt Gower, recruitment failure is evident at locations over 100 m or so from bait stations. This suggests that to successfully maintain this critically endangered palm on Mt Gower rat control or eradication will be required across the Mt Gower summit. The habitat of the Little Mountain Palm, the Gnarled Mossy Cloud Forest, was assessed as critically endangered using the IUCN Red List for Ecosystems criteria. Control of Black Rats on the summit of Mt Gower is the most practical means to reduce the threat to this ecological community in the short term.

Introduction

The flora of Lord Howe Island is recognised as globally significant due to the high level of endemism and unique vegetation communities. Auld and Hutton (2004) detail this as: "The flora of Lord Howe Island has a high level of endemism and many of the floristic assemblages are also unique to the island group (Pickard 1983, Green 1994). There are five plant genera endemic to Lord Howe Island — *Negria*, *Lordhowea* and three palms, *Howea*, *Hedyscepe* and *Lepidorrachis*. For the vascular plants, Green (1994) lists 459 species, 241 indigenous (53%), of which 105 are endemic (44%) and 218 naturalised (48%). Of the indigenous vascular plants, 58 species are ferns and 183 are flowering plants. Several more species of both indigenous and naturalised plants have been found since Green's (1994) work. The high level of endemism is typical of islands and comparable with megadiverse regional areas of continents (Lowry 1998)."

It is widely recognised that invasive species may have significant negative impacts on oceanic islands, particularly for many narrow range endemics and ecological communities. While Lord Howe Island was originally free of mammals (except for small insectivorous bats) when first encountered by humans in 1788 and first settled in 1834 (Hutton 1986), Black rats (*Rattus rattus*) were accidentally introduced when a steamship ran aground in 1918 (Billing and Harden 2000). A number of plant species and vegetation communities have been identified as being at risk from the impacts of Black Rats and house mice on LHI. These impacts include:

- Loss of fruits and seeds to rats, e.g. *Baloghia inophylla, Chionanthus quadristamineus, Drypetes deplanchei, Elaeodendron curtipendulum, Hedyscape canterburyana, Howea forsteriana, Howea belmoreana, Lepidorrhachis mooreana, Pandanus forsteri, Ochrosia elliptica* (Auld & Hutton 2004, Auld *et al*. 2010);
- loss of seedlings and stem damage (the four palm species, *Hedyscape canterburyana, Howea forsteriana, Howea belmoreana, Lepidorrhachis mooreana*, *Dietes robinsoniana* (Wedding Lily) and at least two fern species, *Asplenium milnei* and *Adiantum hispidulum*) (Auld & Hutton 2004);
- impacts on the critically endangered Gnarled Mossy Cloud Forest Ecological Community confined to the summits of the southern mountains (NSW Scientific Committee 2011);

As well, the extinctions of two Lord Howe Island plant species, *Sicyos australis* and *Solanum bauerianum*, were most likely influenced by consumption of seeds and fruits by introduced animals (Auld & Hutton 2004; NSW Scientific Committee 2010). *Solanum bauerianum* is now considered to be globally extinct.

In this work, we undertook to quantify the impact of introduced rats on 2 aspects of the vegetation of LHI. Firstly, we wanted to understand the breadth of plants species that may be impacted by rats. To do this, in the field we tested the magnitude of fruit and seed loss to rats across a range of species, with the species tested being dictated by fruit and seed availability. For some species we were able to replicate the trials in different locations or at different times of the year. Secondly, we re-examined the size distribution of plants of the little mountain palm (*Lepidorrhachis mooreana*) on Mt Gower. Previously, Auld *et al*. (2010) had shown that rats were preventing the establishment of new plants into the parts of the population that were not baited. We re-measured these sites to determine if the impact of rats was ongoing and to try and see if rat baiting was leading to sufficient protection for these palms.

Finally, through funding support from an Australian Research Council Grant to TA and others we assessed the extinction risk for the Gnarled Mossy Cloud Forest Ecological Community using the recently developed IUCN Red List for Ecosystems criteria (Keith *et al*. 2013).

Methods

Impact of Black Rats on fruits and seeds

At one or more sites (See Table 1) we established 5 plots beneath mature plants of several species (*Howea forsteriana* (Kentia Palm), *Ochrosia elliptica* (Berrywood), *Olea paniculata* (Maulwood), *Coprosma putida*) (Table 1). Each plot contained three treatments: uncaged; caged to exclude only birds (rodents could enter in gaps at each end (see Fig. 1); and caged to exclude both rodents and birds. At each plot, in each treatment we placed 5 mature fruits. The density of fruits so placed was not dissimilar to that found naturally below plants with mature fruits. We recorded the fate of seeds over 3-7 days. We also established an infared camera at one plot for each species to record what animal was responsible for seed removal or loss (these cameras were set up to activate and take 10 photos when a warm blooded animals comes into view of the camera (i.e. a rat , a mouse, a bird, a human).

We also established plots for multiple species in a ‘cafeteria’ trial within the habitat where they generally occur. We did this for 12 species at 5 sites (See Table 1). In this trial 5 fruits or seeds of 4-6 species were placed together in small clumps (see Fig. 2). At each plot all seeds were uncaged. Again, like above, the fate of the fruits/seeds was followed over 3-7 days if possible.

*Impact of Black Rats on the Little Mountain Palm (*Lepidorrhachis mooreana*) on Mt Gower*

We repeated the sampling of Auld *et al*. (2010) (see Appendix 1) and sampled the size structure of stands of Little Mountain Palms in cloud forest on the Mount Gower plateau. We stratified the sampling between areas that have been baited by the Lord Howe Island Board to control rat numbers and those that have never been baited. In each of the baited and unbaited areas we sampled three separate plots for the Little Mountain Palm (*Lepidorrhachis mooreana*) (6 plots). We also sampled an additional 4 plots in the gradient between baited and unbaited areas. We estimated the distance for each of our 10 sampled plots from an existing bait station to determine if there was any additional benefit of baiting into surrounding unbaited areas. At each plot, we established a 5 m wide transect across the site and sampled all individual palms within the transect. The transects were sampled until we had encountered a minimum of 30-50 *Lepidorrhachis* individuals with an emergent trunk. We measured the trunk height to the base of the leaves, the number of leaf scars for individuals with a trunk and the height of individuals for individuals without a trunk.

Extinction risk for the Gnarled Mossy Cloud Forest Ecological Community

To assess the Gnarled Mossy Cloud Forest against the IUCN Red List for Ecosystems criteria (Keith *et al*. 2013), we searched the available literature for evidence of any threats to the ecosystem that may result in ecosystem decline. We assessed the Gnarled Mossy Cloud Forest against four of the IUCN criteria (see Appendix 2, Auld and Leishman 2015 for more details):

- Decline was assessed using historical vegetation reports (Maiden 1898, 1914; Oliver 1916; Pickard 1983; Green 1994; Mueller-Dombois & Fosberg 1998; Harris *et al*. 2005). For more recent changes, we inspected satellite imagery (Google Earth and 2011 air photo imagery).
- For Restricted geographic distribution we used available Geographical Information System data layers for the distribution of Gnarled Mossy Cloud Forest (mapped from Pickard 1983) to estimate both the extent of occurrence and area of occupancy of the ecosystem.
- To assess changes in abiotic features that directly impact on Gnarled Mossy Cloud Forest, we used two metrics based on collated data from the Australian Bureau of Meteorology from mid 1940s onwards (Rainfall and cloud cover).
- For biotic degradation, we reviewed the impact of exotic rats on limiting recruitment of key species in the ecosystem and in changing the structure and composition of the ecosystem.

Results

Impact of Black Rats on fruits and seeds

In total, we were able to test the removal of fruits or seeds in 16 species, comprising a mixture of plant families, life forms (trees, shrubs, vines) and habitats. Most species examined had a fleshy fruit. In summary, seed or fruit losses were apparent in all study species, at least at some sites.

Virtually all seed losses occurred at night and there was little removal of fleshy fruits by birds from our ground based trials. It is likely that most bird removal of fruits occurs on the plants and not the ground. Occasionally a shearwater returning to its nest disturbed one of our plots and scattered fruits, but this was not recorded as fruit loss in our calculations. Evidence of seed or fruit losses to rats was indicated by:

- Camera images of rats removing or consuming fruits/seeds (see Figs 3-6)
- In situ seed or fruit remains indicating rats (eg, incisor marks etc) (see Figs 7-11)

We found no clear pattern of greater loss in areas without rat baiting stations present versus those with baiting stations.

<u>Trees</u>

Howea forsteriana

There was high levels of seed removal in this species in all trials (5 sites, 2 time periods, Table 1), with 5/6 trials with 100% fruit loss and 1/6 with 80% loss.

Olea paniculata

All four trails across 4 different sites showed 100% seed loss.

Syzygium fullagarii

Fruit loss was around 40-44% at 2 study sites. For both sites, the trials only ran for 2-3 days so further fruit losses could be expected.

Sarcomelicope simplicifolia

12% fruit loss at one site (insufficient fruits available for further study).

Psychotria carronis
20% fruit loss at one site (trial only ran for 2 nights so further losses may occur).

Chionanthus quadristamineus
32% fruit loss at one site (trial only ran for 2 nights so further losses may occur).

Dysoxylon pachyphyllum
4% fruit loss at one site (trial only ran for 2 nights so further losses may occur).

Drypetes deplanchei
Seed loss ranged from 8-32% across 2 sites. Only fruits with no flesh available for trials.

Sophora howinsula
Seed loss ranged from 0-36% across four sites. When eaten seed, seeds were consumed in situ (see Fig. 8).

Baloghia inophylla
100% seed loss in all trials across 4 sites.

<u>Shrubs</u>
Ochrosia elliptica
Fruit loss varied from 4-96% across sites (Table 1). One of the sites with low losses was in a location with no adult plants. The cameras showed clear evidence of rats removing fruits (Fig. 4). On other occasions fruits were eaten *in situ* and fruit remains where present.

Coprosma putida
Fruit loss varied from 0-16% across 2 study sites.

Dietes robinsoniana
36% fruit loss at one site (trial only ran for 2 nights so further losses may occur).

<u>Vines</u>
Jasminium simplicifolium
Total fruit loss (100%) at three sites and 64% at the fourth

Smilax australis
Fruit loss varied from 92-100% across four sites.

Geitonoplesium cymosum
68-100% fruit loss across 2 sites.

*Impact of Black Rats on the Little Mountain Palm (*Lepidorrhachis mooreana*) on Mt Gower*

Based on sampling in 2006, Auld *et al*. (2010) showed that not only were the fruits of *Lepidorrhachis mooreana* consumed by rats, but the recruitment and establishment of a juvenile seedling bank only occurred in the baited habitats on Mt Gower. Our re-sampling of these and other sites in 2014 found the pattern remains unchanged. Two of the 3 sites that were unbaited lacked new seedlings and small juveniles (eg. Fig. 12) and one of these showed a decline in larger juveniles over time, suggesting ongoing recruitment failure. The unbaited site nearest the baiting stations showed a small pulse of juveniles less than 50 cm in height, suggesting that that there may have been some decline in rat impacts for a period in this area. The three sites in the baited area, all showed evidence of some small juveniles being present, but the abundance of small juveniles was greatly reduced in 2014 compared to 2006 (eg see Fig. 13). For the 4 additional sites sampled, one had no juvenile plants at all, two had no seedlings (one of these sites had only 1 juvenile less than 50 cm high), while only one site had a few seedlings.

There was a pattern of greater recruitment of juvenile plants closer to bait stations (Fig. 14) with recruitment of small plants declining to zero at plots sampled around 250 m from bait stations.

Extinction risk for the Gnarled Mossy Cloud Forest Ecological Community

Overall the Gnarled Mossy Cloud Forest is considered to be Critically Endangered based on a restricted geographic distribution combined with continuing decline.

Historical Decline: There have been no observed changes in the extent of this ecosystem in the last 50 years (Pickard 1983). No changes are indicated since Pickard's 1983 vegetation classification based on inspection of recent satellite imagery (Google Earth and 2011 air photo imagery) and field traverses. The status of the ecosystem is therefore Least Concern under criterion A1.

Geographical Extent and Continuing Decline: The geographic distribution of the ecosystem is below the IUCN threshold for Critically Endangered (Auld and Leishman 2015). Decline was inferred from: a loss of moisture from declining rainfall and cloud cover due to climate change (affecting disturbance regimes, gap formation and species survival and recruitment); ongoing exotic rat predation on seeds and seedlings of several sensitive species that are structural components of the ecosystem (affecting survival and recruitment); and the fact that the ecosystem is considered to exist at only one location (Auld and Leishman 2015).

Decline in abiotic processes and features: There was a trend for decline in both rainfall and the frequency of cloud cover although there is still a great deal of variation in the degree of decline predicted (Auld and Leishman 2015, see Appendix 2).

Decline in biotic processes and interactions: Rats damage key functional plant species in the ecosystem via predation on seeds and seedlings (Auld & Hutton 2004; Auld *et al*. 2010). Most of the area (93%) of Gnarled Mossy Cloud Forest is subject to impact by rats (7% is baited to reduce impact). The extent and severity of seed predation by rats is high for two key species (mountain palms, but the severity of seed predation by rats on other taxa in the ecosystem is uncertain. More work on this aspect is required.

Discussion

Impact of Black Rats on fruits and seeds

There was evidence that rats were consuming fruits or seeds in all 16 species examined. In summary, seed or fruit losses were apparent in all study species, at least at some sites. Losses were very high for six study species (*Howea forsteriana, Olea paniculata, Baloghia inophylla, Jasminium simplicifolium, Smilax australis* and *Geitonoplesium cymosum*); potentially very high but variable for one species (*Ochrosia elliptica*); moderate for three species (*Syzygium fullagarii, Chionanthus quadristamineus, Dietes robinsoniana*) (the actual losses may be higher as the trials only ran for a short period); generally low in 4 species (*Sarcomelicope simplicifolia, Psychotria carronis, Dysoxylon pachyphyllum, Coprosma putida*) (but the actual losses may be higher where the trials only ran for a short period); and low-moderate in two species (*Sophora howinsula, Drypetes deplanchei*).

Further work on examining the impact of fruit losses on the ecology of the study species would assist interpretation of these data. Does the impact of these losses result in reduced potential for recruitment of new plants in the study species as has been previously demonstrated for the Little Mountain Palm (*Lepidorrhachis mooreana*) and Big Mountain Palm (*Hedyscepe canterburyana*) (Auld *et al*. 2010, Simmons *et al*. 2012)? Given that losses are occurring in all tested species, it would also be worthwhile to extend the sampling to additional species as many other species are also likely to be impacted by rats.

*Impact of Black Rats on the Little Mountain Palm (*Lepidorrhachis mooreana*) on Mt Gower*

Repeat sampling in 2014 confirmed the earlier findings of Auld *et al*. (2010) that Black Rats are significantly impacting on Little Mountain Palms on Mt Gower. Baiting appears to be effective in allowing the development of a juvenile bank of palms, although there was evidence that the size of this juvenile bank was greatly reduced in 2014 compared to 2006. Sites within about 100m of bait stations had some seedlings and small juveniles (indicating recent recruitment), but sites 250m or further away mostly had zero recent recruitment. This suggests that to successfully maintain this critically endangered palm on Mt Gower rat control or eradication across the Mt Gower summit will be required.

Extinction risk for the Gnarled Mossy Cloud Forest Ecological Community

Assessment of the Gnarled Mossy Cloud Forest against the IUCN Red List for Ecosystems criteria indicated that the ecosystem is critically endangered due to its very highly restricted geographic distribution (confined to summits of Mt Gower and Mt Lidgbird) combined with continuing decline due to a loss of moisture from declining rainfall and cloud cover as a result of climate change (affecting disturbance regimes, gap formation and species survival and recruitment); ongoing exotic rat predation on seeds and seedlings of several sensitive species that are structural components of the ecosystem (affecting survival and recruitment); and the fact that the ecosystem is considered to exist at only one location (see Auld and Leishman 2015, Appendix 2 for details. This supports the current listing of this ecological community as critically endangered under the NSW *Threatened Species Conservation Act* (NSW Scientific Committee 2011).

The recognition that the introduced Black Rat is a threat to the Gnarled Mossy Cloud Forest mirrors similar threats from exotic species and climate change to other Pacific island cloud forests (Meyer *et al*. 2010). Eradication of rats from Lord Howe Island will reduce the immediate risk to this ecosystem, however, only global mitigation of greenhouse gases could alleviate risk from declining cloud cover and moisture availability. If rat eradication does not occur or is unsuccessful, regular rodent baiting across much of the distribution of the ecosystem, particularly on Mt Gower would be needed to alleviate the threat. This may not be a long-term solution as the rodents may gain resistance to the poisons. A reduction in rat impact is needed to both allow successful seed production and recruitment of new plants in the Gnarled Mossy Cloud Forest.

Acknowledgements

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Table 1 Seed and fruit losses across species and sites.

Family	Scientific Name	Common Name	Life form	Experiment Type	Site	Date of trial	Seeds lost to rats (%)
Fleshy Fruit species							
Arecaceae	*Howea forsteriana*	Kentia Palm	Palm	Single	Neds Beach	Nov-13	100
	Howea forsteriana			Single	Research Station	Nov-13	100
	Howea forsteriana			Single	Windy Ridge W	Nov-13	100
	Howea forsteriana			Single	Windy Ridge	Nov-13	100
	Howea forsteriana			Single	Windy Ridge E	Nov-13	80
	Howea forsteriana			Single	Neds Beach	Jan-14	100
Oleaceae	*Olea paniculata*	Maulwood	Tree	Single	Research Station	Nov-13	100
	Olea paniculata			Single	Middle Beach	Nov-13	100
	Olea paniculata			Single	Windy Ridge W	Nov-13	100
	Olea paniculata			Single	Windy Ridge E	Nov-13	100
Apocynaceae	*Ochrosia elliptica*	Red Berrywood	Shrub	Single	Neds Beach	Nov-13	96
	Ochrosia elliptica			Single	Middle Beach	Nov-13	96
	Ochrosia elliptica			Single	Windy Ridge W	Nov-13	12
	Ochrosia elliptica			Single	Windy Ridge E	Nov-13	4
Myrtaceae	*Syzygium fullagarii*	Scalybark	Tree	Single	Research Station	Jun-14	44
	Syzygium fullagarii			Cafeteria	Erskine Valley	Jun-14	40
Rubiaceae	*Coprosma putida*	Stinkwood	Shrub	Single	Research Station	Jun-14	0
	Coprosma putida			Single	Erskine Valley	Jun-14	16
Oleaceae	*Jasminium simplicifolium*	Jasmine	Vine	Cafeteria	Research Station	Nov-13	64
	Jasminium simplicifolium			Cafeteria	Middle Beach	Nov-13	100
	Jasminium simplicifolium			Cafeteria	Windy Ridge E	Nov-13	100
	Jasminium simplicifolium			Cafeteria	Windy Ridge	Nov-13	100
Smilacaceae	*Smilax australis*		Vine	Cafeteria	Research Station	Nov-13	92
	Smilax australis			Cafeteria	Middle Beach	Nov-13	100
	Smilax australis			Cafeteria	Windy Ridge E	Nov-13	92
	Smilax australis			Cafeteria	Windy	Nov-	96

					Ridge	13	
Smilacaceae	*Geitonoplesium cymosum*		Vine	Cafeteria	Research Station	Nov-13	68
	Geitonoplesium cymosum			Cafeteria	Middle Beach	Nov-13	100
Rutaceae	*Sarcomelicope simplicifolia*	Yellow Wood	Tree	Cafeteria	Research Station	Nov-13	12
Rubiaceae	*Psychotria carronis*	Black Grape	Tree	Cafeteria	Erskine Valley	Jun-14	20
Iridaceae	*Dietes robinsoniana*	Wedding lily	Herb	Cafeteria	Erskine Valley	Jun-14	36
Oleaceae	*Chionanthus quadristamineus*	Blue Plum	Tree	Cafeteria	Erskine Valley	Jun-14	32
Meliacaea	*Dysoxylon pachyphyllum*	Island Apple	Tree	Cafeteria	Erskine Valley	Jun-04	4
Old Fruit with no pulp							
Euphorbiaceae	*Drypetes deplanchei*	Greybark	Tree	Cafeteria	Research Station	Nov-13	8
				Cafeteria	Middle Beach	Nov-13	32
Dry seeds							
Fabaceae	*Sophora howinsula*	Lignum Vitae	Tree	Cafeteria	Research Station	Nov-13	32
	Sophora howinsula			Cafeteria	Middle Beach	Nov-13	36
	Sophora howinsula			Cafeteria	Windy Ridge E	Nov-13	0
	Sophora howinsula			Cafeteria	Windy Ridge	Nov-13	0
Euphorbiaceae	*Baloghia inophylla*	Bloodwood	Tree	Cafeteria	Neds beach	Nov-13	100
	Baloghia inophylla			Cafeteria	Middle Beach	Nov-13	100
	Baloghia inophylla			Cafeteria	Windy Ridge E	Nov-13	100
	Baloghia inophylla			Cafeteria	Windy Ridge	Nov-13	100

Fig. 1 Layout of single treatment with fully enclosed cages, uncaged fruits and cage open at each end. *Ochrosia elliptica* fruits at Windy Pt west.

Fig. 2. Layout of cafeteria treatment. Species visible are (L to R): *Smilax, Sarcomelicope, Baloghia*.

Fig. 3. Black Rat removing mature fruit of *Howea forsteriana* near Ned's Beach (Photo Ian Hutton)

Fig. 4. Black Rat removing fruit of *Ochrosia elliptica* from open ended cage.

Fig. 5. Black Rat removing fruit of *Chionanthus quadristamineus* fruit in Erskine Valley.

Fig 6. Black Rat fruit damage on *Howea belmoreana* (photo Ian Hutton)

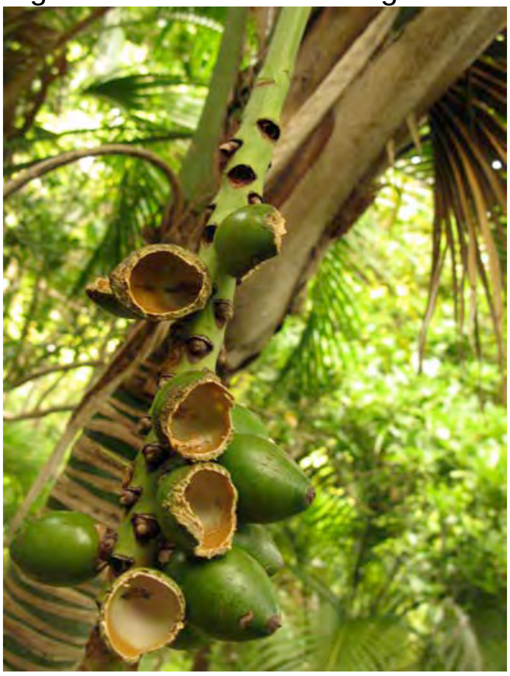


Fig.7 Black Rat damage on *Chionanthus quadristamineus* in Erskine Valley

Fig. 8. Black Rat damage to *Sophora howinsula* seeds

Fig. 9 Black Rat damage to *Olea paniculata* fruits.

Fig. 10. Black Rat damage to *Baloghia* seeds.

Fig. 11. Black Rat damage to *Smilax* fruits and seeds

Fig. 12. A comparison of juvenile plants sizes between 2006 and 2014 at an unbaited site of Little Mountain Palm on Mt Gower. Note the lack of small juveniles and seedlings.

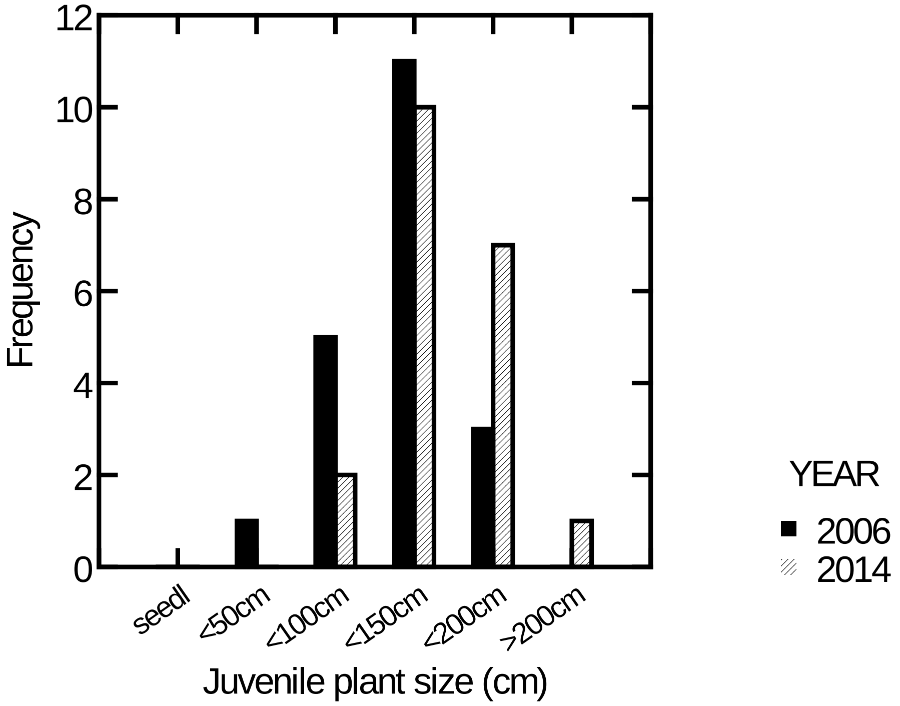


Fig. 13. A comparison of juvenile plants sizes between 2006 and 2014 at a baited site of Little Mountain Palm on Mt Gower. Note the presence of small juveniles and seedlings (particularly in 2006).

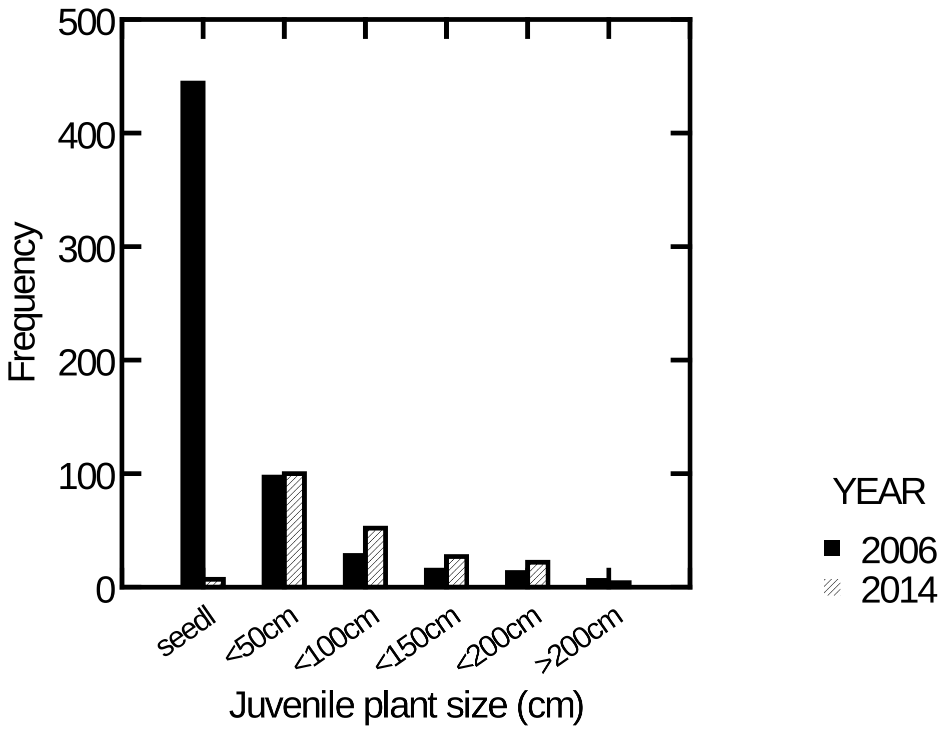
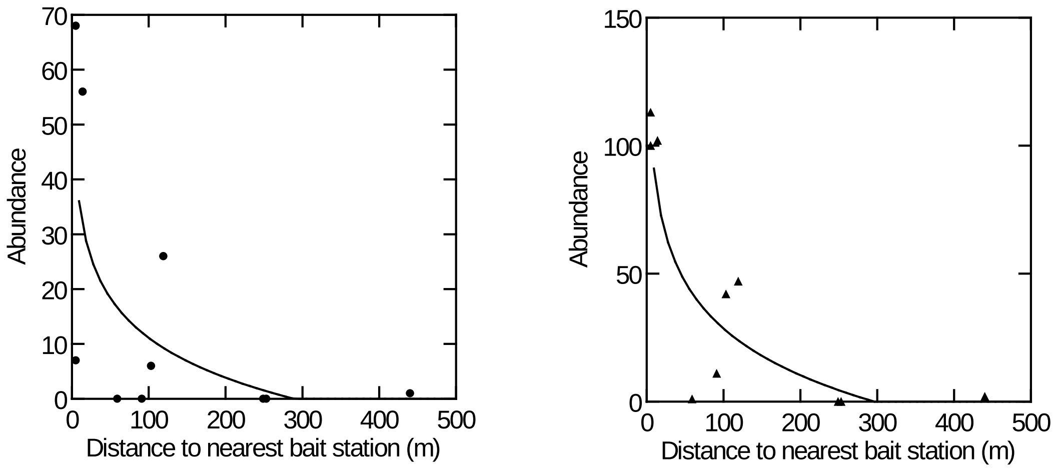


Fig. 14. Abundance of seedlings (black circles) and small juveniles (black triangles) of Little Mountain Palms in relation to distance from nearest bait station on Mt Gower.



Appendix 1

Auld TD, Hutton I, Ooi MKJ and Denham AJ (2010) Disruption of recruitment in two endemic palms on Lord Howe Island by invasive rats. *Biological Invasions* 12, 3351-61.

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ORIGINAL PAPER

Disruption of recruitment in two endemic palms on Lord Howe Island by invasive rats

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Abstract Invasive species may have negative impacts on many narrow range endemics and species restricted to oceanic islands. Predicting recent impacts of invasive species on long-lived trees is difficult because the presence of adult plants may mask population changes. We examined the impact of introduced black rats (*Rattus rattus*) on two palm species restricted to cloud forests and endemic to Lord Howe Island, a small oceanic island in the southern Pacific. We combined estimates of the standing size distribution of these palms with the proximal impacts of rats on fruit survival in areas baited to control rats and in unbaited areas. The size distribution of palms with trunks was comparable across baited and unbaited sites. Small juvenile palms lacking a trunk (<50 cm tall) were abundant in baited areas, but rare in unbaited sites for *Lepidorrhachis mooreana*, and rare or absent in 3 out of 4 unbaited *Hedyscepe canterburyana* sites. All ripe fruits were lost to rats in the small fruited *L. mooreana.* Fruit removal was widespread but less (20–54%) in *H. canterburyana.* Both palms showed evidence of a reduced capacity to maintain a juvenile bank of palms through regular recruitment as a consequence of over 90 years of rat impact. This will limit the ability of these species to take advantage of episodic canopy gaps. Baiting for rat control reduced fruit losses and resulted in the re-establishment of a juvenile palm bank. Conservation of both endemic palms necessitates control (or eradication) of rat populations on the unique cloud forest summits of the island.

Keywords Seed predation · Lord Howe Island · Australia · Palms · Black rat *Rattus rattus*

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Introduction

Invasive species disrupt a range of ecological habitats via direct impacts on individuals (either as adults or juveniles) or by altering habitats, ecological processes (Soule 1990; Lonsdale 1999) or disturbance regimes (Mack and D'Antonio 1998). Invasive species are generally competitors, predators, herbivores or pathogens. Endemic populations of plants and animals on oceanic islands often comprise few individuals, occupy highly restricted areas or specialised habitats and cannot recolonise from other areas. These populations are particularly sensitive to declines or extinction caused by invasive species (Sakai et al. 2002; Coote and Loeve 2003; Wiles et al. 2003; Blackburn et al. 2004; Towns et al. 2006; Trevino et al. 2007), often in combination with loss of habitat (Hunt 2007; Athens 2009).

In parts of the Pacific, much of the flora and fauna have evolved in the absence of mammalian predators and grazers. The subsequent introduction of such predators, including humans, has led to a number of serious declines or extinctions of species, including birds (Hindwood 1940; Holdaway 1989; Blackburn et al. 2004; Cheke 2006), invertebrates (Priddel et al. 2003; Coote and Loeve 2003; Towns et al. 2006) and plants (Duncan and Young 2000; Campbell and Atkinson 2002). For long-lived plants, extinctions caused by introduced species have rarely been recorded (Prebble and Dowe 2008), and in some cases the life span of individual plants may be longer than the period since the introduction of particular weeds, predators or pathogens. For such plants, continuing impacts may result in population declines, even if these declines are hard to detect. Janzen (1986) described such situations as blurry catastrophes and such species may be candidates for the "living dead" (sensu Janzen 1986) where a key part of the life history has been disrupted and successful reproduction has ceased. To identify recent impacts of invasive species on long-lived plants we need to determine if reproduction is sufficient to maintain a stable population.

Past changes to population dynamics in plant species have been inferred using paeleoenvironmental records (Hunt 2007; Athens 2009) or standing size distributions across a range of plant communities from arid shrublands (Crisp and Lange 1976; Walker et al. 1986) to rainforests (Ogden 1985), including palms (Enright 1985) and other species on oceanic islands (Allen et al. 1994). To successfully apply these techniques, an understanding of proximal population dynamics is also needed. Assumptions about growth rates or turnover in size or stage classes must be made or estimated from direct observation (Enright 1985; Ogden 1985). Proximate factors limiting fecundity and survival, and the life or size stages at which they act, need to be understood to permit effective conservation management.

In this paper, we assess the impact of introduced black rats (*Rattus rattus*) on two highly restricted endemic palm species (Arecaceae) from Lord Howe Island in the southern Pacific Ocean. Palms are a useful study group as they are readily counted and age classes may be inferred from leaf scars (Tomlinson 1979). We inferred past impacts on populations by examining standing size structures in combination with some limited data on leaf production. Concurrently, we estimated the proximal impact of seed predation by rats across habitats either baited (to reduce rat numbers) or unbaited. We applied selective caging experiments to exclude vertebrates from gaining access to seeds on the ground. Finally, we combined these two approaches to infer the conservation implication of the invasion of rats on the endemic palm populations and the likely response of these species to rat removal.

Methods

Study site

Lord Howe Island (31°30′S, 159°05′E) is a small oceanic island (0.3–2.8 km wide and 11 km long, 1,455 ha) formed from volcanic activity 6.3–7 million years ago (Hutton et al. 2007). It is situated ~570 km from the east coast of Australia, 1,350 km from New Zealand and 1,250 km from New Caledonia (Pickard 1983a). Almost 80% of the island is protected in a permanent park preserve (Davey 1986). It has been a UNESCO World Heritage Area since 1982 (Department of Environment and Climate Change NSW 2007). Topography on the island is dominated by its two southern mountains (Mt Lidgbird at 777 m and Mt Gower at 875 m). Both mountains are basaltic in origin and Mt Gower is considered to be an eroded caldera (McDougall et al. 1981).

The Lord Howe Island climate is humid-subtropical. It has a mean annual temperature of 19.2°C, ranging from 17 to 25°C in December–February to 14–18°C in June–August (Mueller-Dumbois and Fosberg 1998). Average annual rainfall in the lowlands is 1,645 mm (Australian Bureau of Meterology), although rainfall in the southern mountains is likely to be much higher (Department of Environment and Climate Change NSW 2007). Rainfall is unevenly distributed throughout the year, with the driest period in late summer (February, average of 100 mm) and the wettest in winter (June/July average of 200 mm).

The island was originally free of mammals (except for small insectivorous bats) when first encountered by humans in 1788 and first settled in 1834 (Hutton 1986). It now has a resident population of about 300 people (Hutton et al. 2007). There is no archaeological evidence of Polynesian occupation of the island prior to 1788 (Anderson 2003) and the Pacific rat (*Rattus exulans*) is not considered to have ever reached the island. Black rats (*Rattus rattus*) were accidentally introduced when a steamship ran aground in 1918 (Billing and Harden 2000). Rat control measures have been sporadic until 1986 when a number of baited areas were established and ongoing baiting was maintained (Billing and Harden 2000). Approximately 8% of the island is currently baited (Billing 2000). This rat control program is now part of an integrated management plan for biodiversity conservation on Lord Howe Island (Department of Environment and Climate Change NSW 2007). The primary aim of the baiting has been to reduce seed predation by rats upon the two species of the endemic lowland palm genus *Howea*, especially *H. forsteriana* which forms the basis of a commercial seedling export enterprise on the island for horticultural trade (Pickard 1980). The baiting program also benefits other species, including seabirds (McAllan et al. 2004), invertebrates (Department of Environment and Climate Change NSW 2007) and plants (Auld and Hutton 2004).

Study species and habitat

We sampled the two endemic mountain palm species from Lord Howe Island. *Lepidorrhachis mooreana* (F. Muell.) O.F. Cook (Arecoideae: Areceae; Dransfield et al. 2008) is a small palm (trunks generally up to 3 m) restricted to the cloud forest vegetation (Pickard 1983a; Harris et al. 2005; Baker and Hutton 2006) on the 27 Ha summit plateau of Mt Gower (about 700–875 m in elevation). It has also been reported from the very small summit of Mt Lidgbird, but this requires confirmation. The species is considered to be rare on Lord Howe Island (Pickard 1983b), with introduced rats and climate change considered to threaten the cloud forest habitat of the species (Baker and Hutton 2006). *Hedyscepe canterburyana* (C. Moore and F. Muell.) H Wend. & Drude has a trunk of up to 6 m and is generally confined to the higher elevations (600–875 m) of the southern mountains, although on sheltered slopes it can be found down to 300 m. It is listed as vulnerable under the IUCN red list of threatened trees. It co-occurs with *L. mooreana* on the summit of Mt Gower, but also occurs at lower elevations in forests on several extensive ledges below the summits of both Mt Gower and Mt Lidgbird (Pickard 1983a). Since the two palm species belong to monospecific genera we hereafter refer to them as *Hedyscepe* and *Lepidorrhachis*.

The size and dry weight (air dried at room temperature) of fruits of the species are very different. *Lepidorrhachis* fruits are globular drupes $\sim$1.3 cm in diameter, weighing an average of 1.4 $\pm$ 0.04 g ($n = 20$ fruits). Fruits of *Hedyscepe* are large and ovoid, $\sim$3 $\times$ 4.4 cm, weighing 24.8 $\pm$ 0.5 g ($n = 30$ fruits).

Standing size structure

We sampled the size structure of stands of the two species in cloud forest on the Mount Gower plateau. We stratified the sampling between areas that have been baited by the Lord Howe Island Board to control rat numbers and those that have never been baited. Baiting currently involves placement of poison every 3 months at fixed stations throughout the baited area. Baiting has been conducted on Mt Gower for the last 20 years (Billing 2000). Only a small proportion ($\sim$7%) of the eastern area of the summit has been baited (1.9 ha of a total 27 ha) and not all the baited or unbaited habitat is occupied by the study species. Although both mountain palms occur across the summit plateau and *Hedyscepe* and *Lepidorrhachis* co-occur in places, there is a tendency for *Hedyscepe* to occupy more sheltered sites and gully slopes while *Lepidorrhachis* is more common on small ridge tops. In each of the baited and unbaited areas we sampled three separate plots for each palm species (12 plots overall). At each plot, we established a 5 m wide transect across the site and sampled all individual palms within the transect. The transects were sampled until we had encountered a minimum of 30 *Hedyscepe* or 50 *Lepidorrhachis* individuals with an emergent trunk. Hence, the number of juvenile plants without a trunk that were sampled varied between plots. Transects ran for a minimum of 20 m up to 35 m, but occasionally to obtain sufficient numbers of plants with trunks we had to sample additional trunked plants beyond this length. These latter plants were not included in our estimates of plant densities. We measured canopy height (=leaf height in plants lacking a trunk) for all individuals. For plants with emergent trunks, we also scored flowering or fruiting and measured two additional plant size attributes:

1. trunk height to the base of the leaf sheaths; and
2. the number of leaf scars on the trunk.

Occasionally, trunks were covered in mosses and lichens and it was not possible to count the number of leaf scars on the entire trunk. Where this occurred, mainly in *Hedyscepe*, we counted a section of the trunk and extrapolated to the length of the trunk. This assumed even rates of growth between leaf scars. In *Hedyscepe* and *Lepidorrhachis*, there was a pattern of larger intervals between leaf scars at the base of trunks and smaller intervals at the top (after the plants had matured). Consequently, where we had to subsample a trunk, we chose a section that included the transition between smaller and larger intervals between leaf scars. We also calculated the average leaf scar interval per trunked plant from the stem length divided by number of leaf scars.

We additionally sampled one population of *Hedyscepe* at the summit of Mt Lidgbird. The summit of this mountain is very narrow and there is little available habitat. The habitat of *Hedyscepe* palms on this mountain top has not been subject to rat baiting. Sufficient habitat was available to sample one plot, where we ran a 5 m transect along the undulating summit and sampled as per above. It was not possible to sample *Lepidorrhachis* on Mt Lidgbird as no plants could be located.

Hedyscepe also occurs on large ledges below the summits of Mt Lidgbird and Mt Gower. However, to ensure that all our samples were confined to comparable habitat on the mountain summits in cloud forest vegetation, we did not sample in these areas.

Inferring plant age or growth rates

For *Lepidorrhachis*, we tagged leaf bases on 10 mature trunked plants to determine the rate of production of leaf scars over a 31 month period. The length of time a palm had a trunk was then inferred from the mean number of leaves produced per year times the number of leaf scars. All plants sampled were on ridges on the summit of Mt Gower across the gradient in elevation. Loss of tags from *Hedyscepe* plants prevented a similar estimation in that species.

Impact of rats on fruit survival

To examine the direct proximal impacts of rats on the palms we established seed predation exclusion experiments on Mt Gower. We ran the experiments on 2 occasions in 2006 (winter–July; and late spring–November). This replication allowed us to examine temporal variation in seed predation rates across the long period of fruit maturation. For both replicate trials, there were developing and ripe fruits available on mature plants of both species. For *Lepidorrhachis*, there were considerably more ripe fruits in July than November, while for *Hedyscepe*, slightly more ripe fruits were available in November. At each time, we sampled 4 sites per species, 2 in rat baited and 2 in unbaited areas. At each site, we established 10 randomised plots of treatments, with the location of each plot constrained by being under a palm with a fruiting infructescence, but such plants were chosen randomly from those available at the site. For *Hedyscepe*, at each chosen palm, we set up 2 batches of 10 mature fruits in a cache, one caged and one uncaged. The caged fruits were covered with a 1 cm^2 wire mesh cage that was held into place by wire stakes. This excluded rodents and birds. We followed the fates of fruits over a 2 week period. For *Lepidorrhachis*, we observed that green fruits were eaten by rats. In some baited areas, fruits, in which the red fleshy outer layer (the mesocarp and exocarp) had been removed or worn off, persisted on the forest floor (leaving only the seed and endocarp). So for *Lepidorrhachis*, we used caged and uncaged ripe red fruits along with two additional uncaged fruit categories at each plot. These categories were large green fruit and endocarp-only fruit. We observed Lord Howe currawongs (*Strepera graculina crissalis*, a diurnal corvid) remove ripe fruits from infructescences of *Lepidorrhachis* and regurgitate endocarps. As this bird may have removed fruits in our exclusion trials, the inclusion of endocarp-only fruits in the experiment allowed us to compare removal rates for fruits that were attractive to these birds (ripe red fruits) and fruits that were not (endocarp-only). The Lord Howe currawongs may occasionally handle the much larger fruits of *Hedyscepe* (Hutton pers observ.), but no endocarp-only fruits were available on the summit plateau.

In the July trial, the experiments were checked overnight and again at ~2 weeks after establishment, with the final data point used in the analyses. In the November trial, we checked removal and fruit loss at plots overnight, at 3–3.5 days and after 2 weeks. We used these temporal sampling data to examine the early rates of fruit loss.

To infer the fates of fruits we explored several possibilities. We spent time observing fruit caches in the day and night to monitor removal agents. We also examined the pattern of fruit mesocarp removal and fruit consumption in situ to infer likely agents.

Data analysis

We compared the population size structure in stands of each palm across baited and unbaited areas. For each species, we used nested 2 Factor ANOVAs (fixed factor rat baiting, with sites nested in rat baiting) to compare each size attribute in trunked plants. Species were not included as a factor as *Hedyscepe* is much larger than *Lepidorrhachis* and as we were interested in the nested site effect within a species. Cochran's Test was used to test for homogeneity of variances. Where heterogeneous variances were detected, the data were log transformed (Underwood 1997). Where ANOVAs were significant, individual means were compared using Student–Newman–Keuls tests (Zar 1974).

For the predator exclusion experiment, for each species, we compared the magnitude of fruit removal/loss across the treatment plots. We used a GLIM with four factors—time of experiment, rat baiting, caging treatment and sites (nested) with a binomial error structure. Removal from a plot was scored if there had been any seed removal as the plot was the unit of replication. In the November trial, we used a failure-time analysis (Fox 2001) to compare the rates of seed removal between baited and unbaited areas and different caging treatments, pooling data across plots and sites.

Results

Standing size structure

In trunked palms of both *Hedyscepe* and *Lepidorrhachis*, there was no significant difference between baited and unbaited areas for all size attributes, but there was variation among study sites (Table 1). In *Hedyscepe*, there was a significant difference in crown sizes ($F_{4,135} = 3.3$, $P = 0.01$), trunk lengths ($F_{4,177} = 5.4$, $P < 0.001$) and the number of leaf scars per trunk ($F_{4,170} = 2.7$, $P = 0.03$) across sites (Table 1). In *Lepidorrhachis*, there was significant variation among sites in crown sizes ($F_{4,211} = 3.5$, $P = 0.001$) and trunk lengths ($F_{4,294} = 2.8$, $P = 0.025$).

The size distribution of trunked plants was broadly similar across sites, although in *Hedyscepe* there were relatively more individuals in the largest size classes than in *Lepidorrhachis* (Figs. 1, 2). When plants without trunks were compared, there were clear differences between the population structures in the rat baited versus unbaited areas (Figs. 1, 2). Small juvenile palms (<25 cm) were only present in areas that were baited, with the exception of one *Hedyscepe* site (H2rat; Fig. 1). Large juveniles that did not yet have an aerial trunk and plants with a trunk that had clearly not yet flowered were present at all sites, although they were very scarce at one *Hedyscepe* site where rats were not baited (H1rat, Table 2). The *Hedyscepe* site from the summit of Mt Lidgbird was comparable to the unbaited Mt Gower sites as there were few plants without a trunk (Table 2). Densities of mature (0.06–0.4 m^{-2}) and juvenile plants (0.05–8.3 m^{-2}) varied across sites (Table 2).

Trunked *Lepidorrhachis* plants produced an average of 2.6 (±0.8) leaves each year (range 2.3–3.1). To infer an estimate of the time spent as a trunked *Lepidorrhachis* palm, we assumed plants produced between 2 and 3 leaf scars per year. This would suggest that each site contains a few very old individuals that have had trunks for 100–200 years (cf. Fig. 2). Most of the plants are estimated to have had trunks for less than 70 years.

Impact of rats on fruit survival

Fruit loss varied markedly between baited and unbaited areas. For *Hedyscepe*, there was no significant difference between the replicate experiment times and no significant interactions involving this term. No fruits were consumed in situ in this species. There were significant differences between baited and unbaited areas and between caging treatments, along with significant site variation. Some fruits were removed from all plots at one of the unbaited sites

Table 1 Summary size measurements for trunked palms sampled on Lord Howe Island

Species	Site	Baited for rats	Trunk Length (m)	Mean plant (±SE)		
				Crown size (m)	Leaf scars	Leaf scar interval (cm)
Hedyscepe	H1rat	No	4.01(0.34)	2.08(0.19)	193(26)	2.7(0.3)
	H2rat	No	2.73(0.33)	1.98(0.10)	138(32)	3.4(0.3)
	H3rat	No	2.05(0.27)	2.38(0.10)	87(22)	4.2(0.5)
	H4	Yes	2.63(0.33)	2.43(0.10)	115(25)	4.1(0.4)
	H5	Yes	2.39(0.35)	2.38(0.13)	148(34)	4.5(0.5)
	H6	Yes	3.03(0.32)	2.03(0.09)	208(39)	3.1(0.4)
	HLrat	No	2.79(0.21)	1.89(0.07)	170(14)	2.3(0.2)
Lepidorrhachis	L1rat	No	1.37(0.14)	1.73(0.05)	75(9)	2.1(0.2)
	L2rat	No	1.67(0.15)	1.85(0.08)	68(9)	2.5(0.2)
	L3rat	No	1.59(0.12)	1.63(0.07)	70(8)	2.4(0.1)
	L4	Yes	1.73(0.12)	2.02(0.06)	76(9)	2.8(0.2)
	L5	Yes	1.21(0.13)	1.95(0.08)	53(9)	2.9(0.3)
	L6	Yes	1.46(0.11)	1.80(0.05)	75(9)	2.3(0.1)

For each size measurement 30 *Hedyscpe* or 50 *Lepidorrhachis* trunked plants were sampled

(a total 54% of individual fruits removed) and from 85% of plots at the other unbaited site (a total 20% of individual fruits removed). One of the baited sites also had some fruit removed from 85% of plots (a total 22% of individual fruits removed), while the second baited site had removal from 45% of plots (a total 7% of individual fruits removed). There was evidence of rats scraping away the thin mesocarp and trying to remove the fibrous endocarp. Nocturnal observations revealed that rats dragged fruits away from the experimental plots. It is likely that fruits were consumed in caches and such caches with eaten fruits were observed in the habitat.

In *Lepidorrhachis,* there was a significant two way interaction between caging treatment and date of sampling (July or November), along with a significant difference between baited and unbaited areas and a significant nested site effect. In the unbaited areas, uncaged fruits were removed in all plots, except for 2 plots of green fruits. All red fruits and those with the flesh removed (endocarp-only) were taken in both July and November sampling. The removal of green fruits varied from 98% in July to 17% in November. Evidence that rats consumed fruits was indicated by the presence of chewed pieces of pericarps in situ, the presence of fresh rat scats in the plots and our nocturnal observations of rats feeding on fruits. While some ripe red fruits may have been taken and dispersed by Lord Howe currawongs, it is likely that rats are consuming fruits since there was a loss of both ripe red fruits and endocarp-only fruits in all the unbaited sites. Fruits with the mesocarp removed should not be attractive to currawongs. At these unbaited sites, no adult plants had ripe fruits on infructescences and no fruits with the mesocarp removed (endocarp-only) were present on the ground. In contrast, ripe fruits were common both on infructescences and on the ground in the baited areas. In baited areas, we found that there was some removal of ripe red fruits in all plots in November (a total 64–94% of individual fruits removed across sites) and in 85% of plots in July (a total 35–40% of individual fruits removed across sites). For fruits with only an endocarp, there was more variation between the two sampling seasons, with removal in 95% of plots in November (a total 24–96% of individual fruits removed across sites) compared to only 30% of plots in July (a total 6% of individual fruits removed across sites). Removal of green fruits was comparable across sampling seasons, 65% of plots in November (a total 14–25% of individual fruits removed across sites) and 55% of plots in July (a total 12–13% of individual fruits removed across sites). The losses in November at one baited site were directly attributed to rats as evidenced by large amounts of fruit remains in situ. This

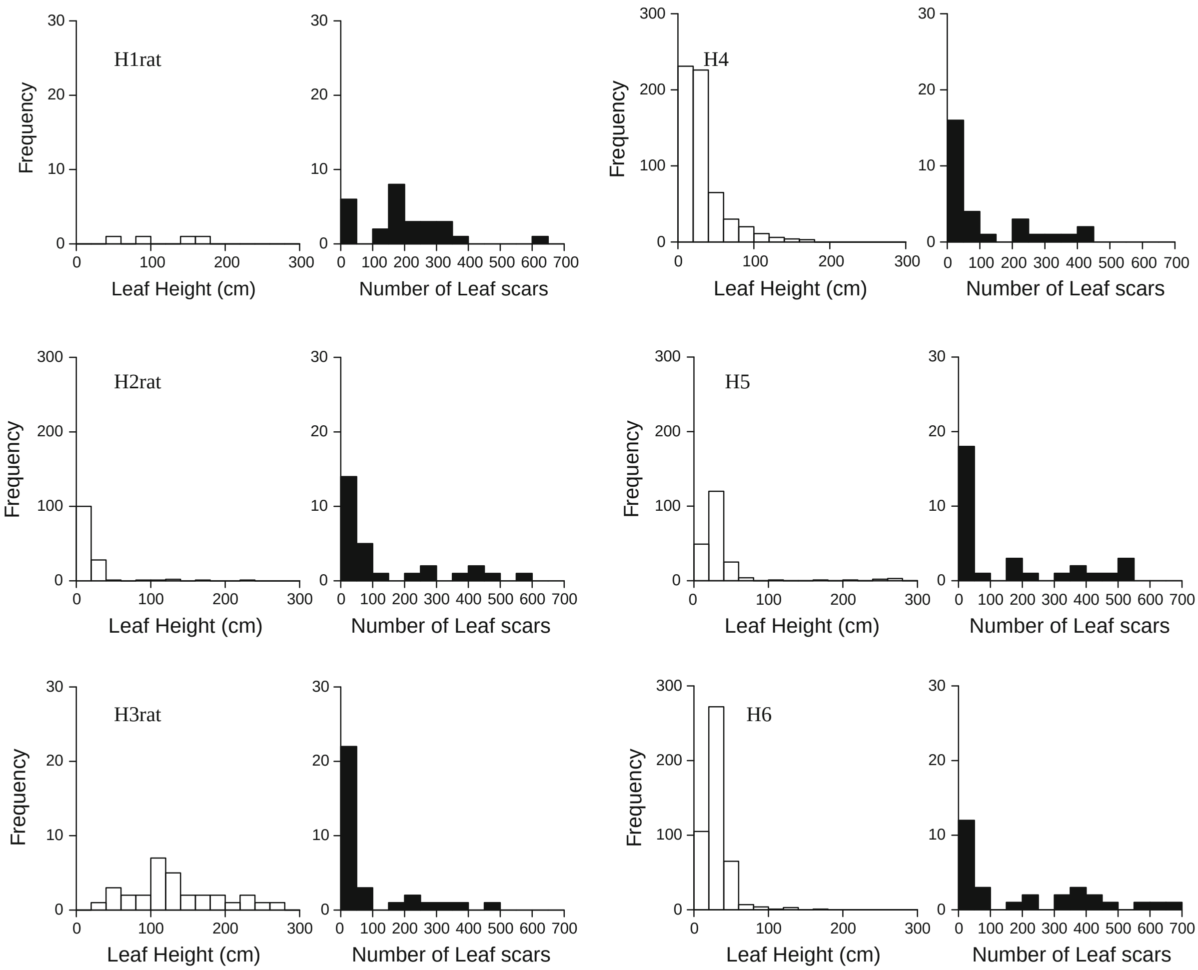

Fig. 1 Size distributions for *Hedyscepe canterburyana* of plant height for juvenile plants lacking a trunk (*open bars*) and the number of leaf scars in trunked individuals (*filled bars*). *rat* No rat baiting conducted at the site. *Note*: *Y* axis scale varies across sites

may reflect re-colonisation of this site by rats at the time.

In the November trial, there was some initial (overnight) rapid removal of ripe fruits of *Hedyscepe* in unbaited areas and then a slow rate of removal in both baited and unbaited areas (Fig. 3). In *Lepidorrhachis*, loss of ripe red fruits was rapid where rats were not baited (Fig. 4), with some 90% fruits lost within a day and all fruits gone within 3 days. Most of these fruits were consumed in situ by rats over the first night of the experiment, again supporting the conclusion that consumption by rats rather than fruit removal and dispersal by Lord Howe currawongs explains fruit losses. The loss of all endocarp-only fruits within 3 days was also likely due to rat predation since these fruits are not attractive to currawongs (Fig. 4).

Discussion

The introduction of rats (*Rattus rattus*) to the oceanic Lord Howe Island is likely to have increased the risk of extinction for the two endemic mountain palms. This is a consequence of rat predation of fruits which has the potential to limit recruitment in both palm species. Past observations highlight the lack of ripe fruits on *Lepidorrhachis* plants unless mesh caging was applied to exclude rats from developing fruits (Moore 1966; Pickard 1980). The paucity of small

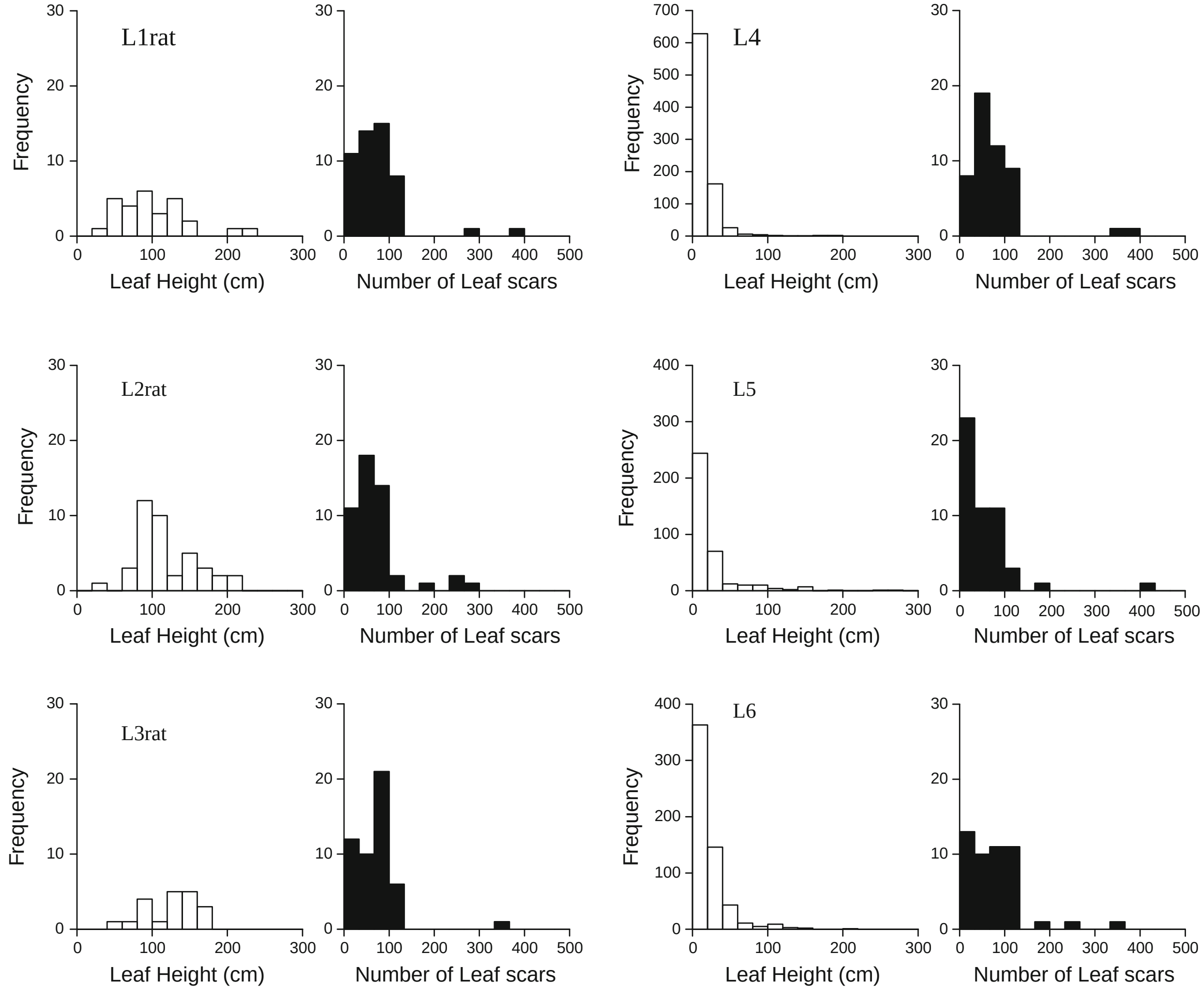

Fig. 2 Size distributions for *Lepidorrhachis mooreana* of plant height for juvenile plants lacking a trunk (*open bars*) and the number of leaf scars in trunked individuals (*filled bars*). *rat* No rat baiting conducted at the site. *Note*: *Y* axis scale varies across sites

juvenile plants in areas which have not been baited for rat control, both in our study plots and more generally throughout this unbaited area, supports the more general contention that the introduction of rats affects plant recruitment in a range of island ecosystems (Campbell and Atkinson 2002; Delgado García 2002; Towns et al. 2006; Meyer and Butaud 2009; Traveset et al. 2009). It is possible that rats also reduce seedling and juvenile growth as they have been observed eating palm leaf sheaths and causing leaf fall in both juvenile and adult palms consistent with similar damage observed on plants elsewhere (Traveset et al. 2009). The impact of rats is greatest in *Lepidorrhachis*, where fruit losses reached 100% and small juvenile plants (<50 cm) were extremely rare in the presence of rats. Any possible seed escape in *Lepidorrhachis* via dispersal by the Lord Howe currawong is negated by the loss of endocarp-only fruits (matching regurgitated fruits) in unbaited areas. For *Hedyscepe,* observed fruit losses were less (total of 20–54%), and while some seed escape may be occurring, only one out of four sites sampled on the mountain tops has an appreciable number of small juveniles (<50 cm; Table 2). Differences between the two palm species may relate to the fact that the fruits of *Hedyscepe* are up to 18 times bigger than *Lepidorrhachis* and rats may have more difficulty eating into *Hedyscepe* fruits as they have a thicker and very fibrous endocarp wall. Neither palm species can be considered the “living dead” (sensu Janzen

Table 2 Plant densities across sampled plots for *Lepidorrhachis mooreana* and *Hedyscepe canterburyana*

Species	Site	Baited for rats	Density (m^{-2})				
			Trunked plants		Juveniles with no trunks		
			Mature	Juv	Height (m)		
					<0.5	0.5–1	>1
Hedyscepe	H1rat	No	0.10	0.02	0	0.01	0.01
	H2rat	No	0.13	0.02	0.85	0.01	0.03
	H3rat	No	0.11	0.14	0.03	0.03	0.18
	H4	Yes	0.14	0.07	4.02	0.56	0.19
	H5	Yes	0.06	0.09	1.52	0.07	0.06
	H6	Yes	0.08	0.03	2.91	0.11	0.03
	HLrat	No	0.40	0.11	0.01	0.02	0.04
Lepidorrhachis	L1rat	No	0.34	0.06	0.04	0.09	0.10
	L2rat	No	0.24	0.06	0.01	0.09	0.15
	L3rat	No	0.35	0.04	0.01	0.04	0.11
	L4	Yes	0.19	0	8.13	0.13	0.08
	L5	Yes	0.12	0.10	2.38	0.19	0.11
	L6	Yes	0.25	0.04	5.41	0.28	0.14

All sites on Mt Gower, except HLrat from Mt Lidgbird

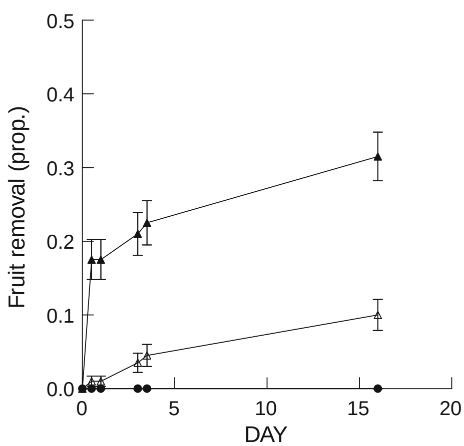

Fig. 3 Rate of fruit loss in *Hedyscepe canterburyana*, pooled across sites. Data are 1-(Kaplan–Meier estimates) with standard errors. *Filled symbols* are sites with no rat baiting, *symbols* are sites with rat baiting. *Vertical bars* are standard errors. Treatments are: Cage (*circle*); uncaged ripe fruit (*triangle*). No fruits were removed in the caged treatment

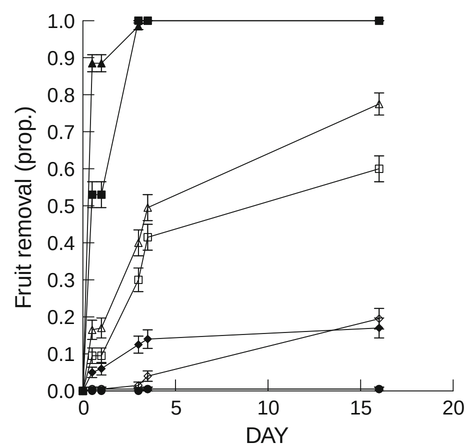

Fig. 4 Rate of fruit loss in *Lepidorrhachis mooreana*, pooled across sites. Data are 1-(Kaplan–Meier estimates) with standard errors. *Filled symbols* are sites with no rat baiting, *open symbols* are sites with rat baiting. *Vertical bars* are standard errors. Treatments are: Cage (*circle*); uncaged ripe fruit (*triangle*); uncaged green fruit (*diamond*) uncaged endocarp-only fruit (*square*)

1986) as there are juvenile plants over 50 cm in height at all sites, independent of the current rat baiting program on the island. Some episodic recruitment may occur as a result of sporadic seed escape from rats, possibly in relation to natural fluctuations of abundance within the rat population.

Rats reached Lord Howe Island some 90 years prior to this study and are reported to have spread rapidly (Billing and Harden 2000). Consequently, rat predation could have affected palm recruitment for a number of decades. Is this reflected in the estimated age structure of *Lepidorrhachis*? Plant age in palms has been inferred by the number of leaf scars (Sarukhán 1980; Enright and Watson 1992). In *Lepidorrhachis*, there were few plants (~6% of the population) with more than 120 leaf scars (Fig. 2). This represents some 40–60 years of trunk growth. The remainder of the trunked palms are more or less evenly distributed up to 100 or 120 leaf scars (Fig. 2). If individual mortality was constant across these size classes then this would suggest a declining population and may reflect a long term impact of rats on recruitment. Estimating plant age requires additional data on the time required for juvenile plants to grow large enough to produce a trunk, and this may vary with habitat quality and disturbance regime. This pre-trunk period typically takes decades in some palm species (e.g. 35–60 years, Enright 1985; Enright and Watson 1992), but is currently unknown for *Lepidorrhachis*. Further data on juvenile survival and growth are needed to clarify the age structure of the population.

Recovery of vegetation following removal of rats is not always straightforward (Mulder et al. 2009; Towns 2009). Rats may impact on nutrient cycling (through impacts on seabirds, Mulder et al. 2009) and the impacts of mice may increase if rats alone are removed (Angel et al. 2009). In our study area on Mt Gower, there has only been limited rat control in the last 20 years. There is a lack of small juveniles in unbaited areas at all sampled *Lepidorrhachis* sites and at 75% of the *Hedyscepe* sites. Baited areas are distinguished by the abundance of young juvenile palms, implying a restoration of plant recruitment and a re-establishment of the juvenile bank of palms (sensu Silvertown 1982). Successful growth to maturity of juvenile palms will probably be influenced by local canopy gap formation after tree death or tree fall in storms.

Long-term conservation of the endemic palm genera in this study may be compromised by a reduced capacity to establish a juvenile bank and to adapt to a changing climate. Both species occur in the unique cloud forests on the island (Harris et al. 2005) and changes to moisture regimes (e.g. through a reduction in cloud cover) with a changing climate may limit establishment opportunities in the future. Targeted control, or eradication of rats is essential to maximise the potential for long-term conservation of these species.

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Appendix 2

Auld TD, Leishman MR (2015) Ecosystem risk assessment for Gnarled Mossy Cloud Forest, Lord Howe Island, Australia. *Austral Ecology* **40**, 364–372.

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Ecosystem risk assessment for Gnarled Mossy Cloud Forest, Lord Howe Island, Australia

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Abstract Gnarled Mossy Cloud Forest is a globally unique ecosystem, combining floristic elements from Australia, New Zealand and New Caledonia. It is restricted to a very small area (28 ha) at elevations above 750 m on the summits of two mountains on Lord Howe Island in the Pacific Ocean, approximately 570 km off the east coast of Australia. Moisture derived from clouds is a key feature of the ecosystem. We assessed the conservation status of this ecosystem using the International Union for the Conservation of Nature Red List criteria for ecosystems. There has been no historical clearing of the ecosystem, but declines (with large uncertainty bounds) were estimated for two abiotic variables that are important in maintaining the component species (cloud cover and rainfall). Overall, we found the ecosystem to be Critically Endangered based on a restricted geographic distribution combined with continuing decline (criterion B1aii, iii, B1b, B1c and B2aii, iii, B2b, B2c). Decline was inferred from: a loss of moisture from declining rainfall and cloud cover due to climate change (affecting disturbance regimes, gap formation and species survival and recruitment); ongoing exotic rat predation on seeds and seedlings of several sensitive species that are structural components of the ecosystem (affecting survival and recruitment); and the fact that the ecosystem is considered to exist at only one location. This mirrors similar threats from exotic species and climate change to other Pacific island cloud forests. Eradication of rats from Lord Howe Island will reduce the immediate risk to this ecosystem; however, only global mitigation of greenhouse gases could alleviate risk from declining cloud cover and moisture availability.

Key words: moisture loss, rat predation, Red List, restricted distribution.

INTRODUCTION

Risk assessment criteria for ecosystems have been developed by the International Union for the Conservation of Nature (IUCN) (Keith *et al.* 2013). These criteria can be used to both identify those ecosystems most in danger of being lost and prioritize actions for protection and conservation management. The criteria have elements comparable with those used in red list criteria for species (Keith *et al.* 2013) and reflect broadly similar types of criteria used in some national listing criteria for ecological communities (e.g. in Australia, Nicholson *et al.* 2014).

Ecosystems of oceanic islands comprise many unique combinations of both flora and fauna (Mueller-Dombois & Fosberg 1998), making them priorities for conservation management. Isolated cloud forests are scattered across remote islands of the Pacific where they form highly diverse plant communities with high levels of endemism (Meyer 2010). While globally, cloud forest is thought to comprise some 12% of tropical forests (Mulligan & Burke 2005), in Australia and on oceanic islands of the Pacific, it is very restricted (Mueller-Dombois & Fosberg 1998; Meyer 2010; Scatena *et al.* 2010). Here we assess the conservation status of a cloud forest ecosystem endemic to Lord Howe Island. Lord Howe Island is a small (11 km by 0.6–2.8 km) oceanic island found approximately 570 km off the east coast of Australia, 1350 km from New Zealand and 1250 km from New Caledonia (Auld & Hutton 2004). The island varies in topography because of two steep rising southern mountains (up to 895 m a.s.l.) and is considered to be a remnant of a large shield volcano (McDougall *et al.* 1981). The climate of Lord Howe Island is humid-subtropical.

Lord Howe Island has a mix of floristic elements from mainland Australia, New Zealand and New Caledonia (Pickard 1983; Green 1994), and its entire flora and fauna are considered to have reached the island by long-distance dispersal (Auld & Hutton 2004). This dispersal trait, combined with the large topographic relief, has led to many of the species assemblages on the island being globally unique. A large proportion of the plant and invertebrate taxa on the island are endemic

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(105 vascular plant species (44% of the total flora of Lord Howe Island), Green 1994; 600 invertebrate species (approx. 37% of the total invertebrate fauna of Lord Howe Island), Cassis *et al.* 2003).

There have been a number of studies on the vegetation of Lord Howe Island (Maiden 1898; Oliver 1916; Pickard 1983; Mueller-Dombois & Fosberg 1998). Given that plants provide a significant component of the species diversity as well as a habitat resource for other species, we have here interpreted Pickard's (1983) vegetation communities as ecosystems. The 27-ha summit of Mt Gower and the narrow summit of Mt Lidgbird support an endemic cloud forest known as Gnarled Mossy Cloud Forest (Harris *et al.* 2005). In this paper, we assess the conservation status of the Gnarled Mossy Cloud Forest ecosystem using the IUCN Red List criteria for ecosystems (Keith *et al.* 2013) by addressing reduction in geographic distribution, restricted geographic distribution, environmental degradation and disruption of biotic processes. We develop a conceptual model of ecosystem dynamics that would lead to ecosystem collapse (*sensu* Keith *et al.* 2013) applicable to cloud forests globally but with special reference to the disruption to biotic or abiotic processes most relevant to Lord Howe Island. We then used this model to quantify measures of abiotic degradation and disruption of biotic processes.

Fig. 1. Gnarled Mossy Cloud Forest ecosystem (photo T. Auld).

Fig. 2. Summit plateau of Mt Gower with Gnarled Mossy Cloud Forest. The very narrow ridgetop of Mt Lidgbird can be seen at the back, left-hand side (photo T. Auld).

ECOSYSTEM DESCRIPTION

Classification

Regionally, this ecosystem is classified as a Critically Endangered Ecological Community 'Gnarled Mossy Cloud Forest on Lord Howe Island' under the New South Wales Threatened Species Conservation Act 1995. The ecosystem is currently recognized following the vegetation classification on Lord Howe Island by Pickard (1983) who described it as Gnarled Mossy Forest. Other studies describe the same ecosystem as Moss Forest (Oliver 1916), Cloud Forest (Mueller-Dombois & Fosberg 1998) and Mossy Cloud Forest (Harris *et al.* 2005). Recent work (Harris *et al.* 2005) has detailed the plant species composition and internal variation within the ecosystem, along with its conservation significance. Under the IUCN Habitats Classification Scheme (Version 3.1), the ecosystem is classified as '1. Forest/1.9 Subtropical/Tropical Moist Montane Forest'.

Characteristic native biota

Gnarled Mossy Cloud Forest on Lord Howe Island is a closed-canopy forest of 2–8 m height (Figs 1, 2), with its composition depending on aspect and whether it occurs on ridges or in drainage lines (Harris *et al.* 2005). The ecosystem occurs on the summits of Mt Gower and Mt Lidgbird (Fig. 3). On the summit of Mt Gower, the dominant plant species are *Zygogynum howeanum* and *Dracophyllum fitzgeraldii* (Pickard 1983; Harris *et al.* 2005). Associated trees include *Cryptocarya gregsonii, Elaeocarpus costatus, Leptospermum polygalifolium* ssp. *howense, Negria rhabdothamnoides*, *Pittosporum erioloma*, *Symplocus candelabrum*, and the palms *Hedyscepe canterburyana* and *Lepidorrhachis mooreana.* Tree ferns (*Cyathea* spp.), large tussock sedges (*Machaerina insularis* and *Gahnia howeana*), ferns *Blechnum fullagarii*, *Blechnum contiguum*, *Blechnum howeanum*, *Grammitis wattsi* and other ferns, mosses (e.g. *Echinodium hispidum*, *Spiridens vieillardii*; Brotherus & Watts 1915) and lichens (e.g. *Strigula* spp., *Byssoloma subdiscorans*, *Echinoplaca* spp., *Gyalectidium filicinum*, *Porina rufula*

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Fig. 3. Map of the two occurrences (shown as the shaded areas) of Gnarled Mossy Cloud Forest on Lord Howe Island. As existing threats are known to occur across both occurrences, it is considered that these occurrences constitute one location under the definitions of the International Union for the Conservation of Nature (IUCN) guidelines (Keith *et al.* 2013). Source of map data: Pickard (1983).

and *Trichothelium javanicum*; McCarthy *et al.* 1996) are abundant. Gnarled Mossy Cloud Forest on the summit ridgetop of Mt Lidgbird above 750 m elevation is much more exposed and restricted in area compared with the ecosystem on Mt Gower (Pickard 1983). A vegetation plot (10 m by 40 m) on the summit of Mt Lidgbird in Gnarled Mossy Cloud Forest had a dominant canopy of *H. canterburyana, C. gregsonii, Dysoxylum pachyphyllum, Negria rabdothamnoides, P. erioloma* and *Cyathea macarthurii*, along with *Grammitis diminuta, Carex* sp., *Olearia mooneyi, Rapanea myrtillina, Z. howeanum, Lordhowea insularis, Gahnia howeana, Coprosma lanceolaris, Dendrobium moorei, Coprosma putida, Macropiper hooglandii, Microsorium scandens, Asplenium milnei, Asplenium surragatum, Elatostema grande, Hymenophyllum* sp. (Hutton & Auld, unpubl. data, 2007).

Gnarled Mossy Cloud Forest on Lord Howe Island only occurs on the summit plateau and ridgetops of Mt Gower and Mt Lidgbird, and is readily distinguished from adjacent ecosystems that lack the extensive development of non-vascular epiphytes and several endemic mountain vascular plant species. Overall, some 86% of vascular plant species in the ecosystem are endemic to Lord Howe Island, and some 17% are endemic to the mountain summits on the island (Harris *et al.* 2005). *Dracophyllum-Metrosideros* scrub (of Pickard 1983 and Mueller-Dombois & Fosberg 1998) occurs on benches below the summits. Pickard (1983) notes that Gnarled Mossy Cloud Forest on Lord Howe Island is floristically distinct but close to *Dracophyllum-Metrosideros* scrub and *H. canterburyana* closed forest, neither of which are considered to be part of the Gnarled Mossy Cloud Forest ecosystem.

Gnarled Mossy Cloud Forest on Lord Howe Island is a key component contributing to the southern mountains biodiversity hotspot on Lord Howe Island (Department of Environment and Climate Change 2007), particularly for plants and invertebrates. Cassis *et al.* (2003) found that the assemblage of terrestrial invertebrates in the Gnarled Mossy Cloud Forest exhibits high species richness, high levels of endemism to Lord Howe Island and many species that are restricted to the Gnarled Mossy Cloud Forest ecosystem. It also forms important habitat for several vertebrates (DECC 2007) including the main breeding habitat for providence petrels (*Pterodroma solandri*) and refugial breeding habitat for the Lord Howe Island woodhen (*Tricholimnas sylverstis*).

Abiotic environment

Lord Howe Island as a remnant volcanic shield is geologically and topographically diverse (McDougall *et al.* 1981). The climate is temperate, and sea level parts of the island have a mean annual temperature of 19.2°C, ranging from 17°C–25°C in summer to 14°C–18°C in winter (Mueller-Dombois & Fosberg 1998). At sea level, average annual rainfall is 1717 mm, with a maximum of 2886 mm and a minimum of 998 mm (Mueller-Dombois & Fosberg 1998). Temperature decreases with altitude in the southern mountains (0.9°C for every 100 m rise in altitude; Simmons *et al.* 2012). Cloud forests on Pacific islands typically occur between 800 and 900 m a.s.l (Meyer 2010), and on Lord Howe Island, the Gnarled Mossy Cloud Forest ecosystem occurs from 750 to 875 m a.s.l. The annual rainfall in Gnarled Mossy Cloud Forest is thought to be much higher than at sea level (although this has not been quantified) and spread throughout the year (DECC 2007). The two southern mountains (Mts Gower and Lidgbird) obtain significant moisture from both rainfall and direct canopy interception of cloud water (horizontal precipitation or cloud stripping), and their peaks are often shrouded in cloud (Auld & Hutton 2004). Cloud forests are characterized by increased rainfall and cooler temperatures than forest with no cloud (Jarvis & Mulligan 2011), and this is thought to also apply to the Gnarled Mossy Cloud Forest ecosystem.

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Distribution

Gnarled Mossy Cloud Forest is confined to Lord Howe Island in New South Wales, Australia. On the island, it is restricted to the summit plateau of Mt Gower (some 27 ha) and in a greatly reduced form and extent on the narrow summit ridge of Mt Lidgbird (estimated to be less than 1 ha) (Pickard 1983) (Figs 2, 3). Gnarled Mossy Cloud Forest occurs above 750 m in elevation (Pickard 1983).

Key processes, interactions and threats

The ecosystem is sustained by a combination of cloud cover allowing moisture stripping by component species, relatively cool temperatures at >750 m elevation and an ocean-moderated climate. This cloud layer provides a source of precipitation (occult precipitation) and maintains the humidity required by about 86% of the island's endemic plant species including the profusion of epiphytes in the Gnarled Mossy Cloud Forest (Australian National University 2009). Ecosystem dynamics that could lead to collapse of the Gnarled Mossy Cloud Forest depend on two key ecological processes. These are likely increases in frequency and extent of disturbance regimes under climate change (e.g. through increased storm damage) and a reduction of survival and recruitment of component species in the ecosystem (e.g. through warming, desiccation and exotic species) (Fig. 4). Both factors will operate globally for cloud forest ecosystems (along with the major issue of loss of habitat), while local factors may also play a role (Fig. 4). As an example, increased desiccation is expected to reduce species survival and limit opportunities for recruitment of new individuals. This may result from combinations of reduced cloud cover or precipitation, increased warming or increased extreme storm activity that opens up the existing canopy. In particular, epiphytes may be very sensitive to changes in microclimate resulting from predicted global climate changes (Benzing 1998; Nadkarni 2010), yet these plants play a key role in light, hydrological and nutrient regimes in the forests in which they occur (Foster 2001).

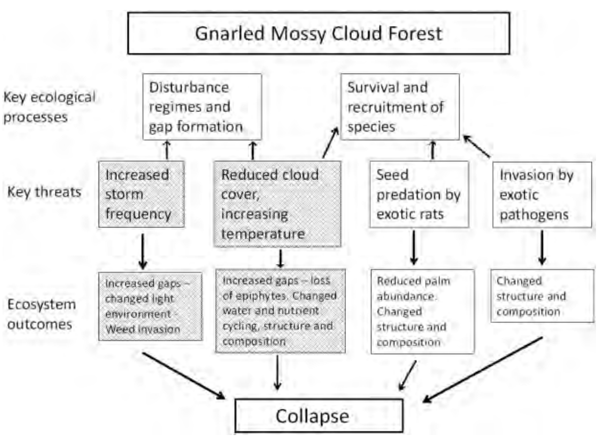

Fig. 4. Conceptual model of ecosystem dynamics leading to collapse for Gnarled Mossy Cloud Forest. Grey boxes represent global threats and outcomes for cloud forests, excluding loss of habitat. Unfilled boxes are local threats for Lord Howe Island (but may also be applicable to other cloud forests). Arrows indicate direction of transition between states.

Survival and recruitment of species will also be impacted by local factors, including for Lord Howe Island, the impact of exotic species such as rats, pathogens or weeds (Auld & Hutton 2004). Impacts of exotic species will also be a global concern for cloud forests and have been shown to be a major threat to other cloud forests of the Pacific (Meyer 2010). Exotics can selectively alter species composition, modify habitats and, in combination with changing moisture availability and warming temperatures, modify both the structure of the ecosystem and the species that can occur in the area. Increased storm damage, declining cloud cover, warming temperatures and impacts of exotic species will reduce survival and recruitment in component species in the ecosystem. This is likely to result in both a changed ecosystem composition and ultimately ecosystem collapse (Fig. 4).

Globally cloud forest ecosystems are threatened by changes to land use through clearing, alien species and climate change (Scatena *et al.* 2010). On Lord Howe Island, there are a number of threats to the Gnarled Mossy Cloud Forest ecosystem (NSW Scientific Committee 2011) (Fig. 4). Climate change is considered to be a major threat to the ecosystem. As the Gnarled Mossy Cloud Forest is confined to mountain summits, there is no bioclimatic zone for component species to move into with warming temperatures (Australian National University 2009; NSW Scientific Committee 2011). Decreases in cloud formation (timing, duration and frequency) on the mountains will impact on the moisture regime and species survival in the cloud forest (Auld & Hutton 2004) and may favour species from lower down the mountains that can better tolerate desiccation. The 'lift-cloud-base hypothesis' states that the climate of tropical mountains will gradually change because of an elevation in sea surface temperatures (Pounds *et al.* 1997, 1999; Still *et al.* 1999). Still *et al.* (1999) suggest that under a changing climate there are likely to be upward altitudinal shifts in the areas that experience cloud formations. Pounds *et al.* (1999) suggest that such a change may have contributed to frog and toad decline in a Costa Rican Cloud Forest. If this prediction holds for Lord Howe Island, then there may be reduced formation of clouds on the southern mountains and reduced moisture availability. The impacts of a rise of the cloud layer, caused by rising sea surface temperatures, constitute a major climate-related threat to the island's ecosystems. Simmons *et al.*

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(2012) estimated that sea level temperatures around Lord Howe Island have risen by some 0.6°C since 1940. Predicted changes in global mean air temperatures from global circulation models forecast a change of 1.5–6°C by 2100 (Intergovernmental Panel on Climate Change 2007). Australian National University (2009) suggests that average annual air temperature on Lord Howe Island is expected to rise (compared with 1990 levels) by 1.3 ± 0.6°C by 2030, although there is much uncertainty around such estimates and attempting to apply global projections to Lord Howe Island.

The exotic ship rat *Rattus rattus* has been on Lord Howe Island for some 90 years. It is known to have severe impacts on the two endemic palm genera (*Hedyscepe* and *Lepidorrhachis*) that occur in the Gnarled Mossy Cloud Forest (Baker & Hutton 2006; Auld *et al.* 2010), and results in a reduction in ground cover across areas impacted by rats. Rats limit recruitment in the palms and consume a large proportion of seeds and leaves of a number of other taxa (Auld & Hutton 2004; unpubl.). Hence, rats are likely to impact on recruitment in many plant species on Lord Howe Island. Some 7% of the summit plateau of Mt Gower is baited to reduce rat impacts, and there is a plan to try to eradicate rats across the whole island (Lord Howe Island Board 2009). There have been other introductions of exotic animals to Lord Howe Island. Pigs and goats were naturalized since the mid-1800s. Goats and possibly pigs had locally significant impacts on Gnarled Mossy Cloud Forest (Pickard 1983), but the long-term impacts are unknown. Both have now been eradicated from the island (DECC 2007).

Weeds are only a minor threat on the summit of Mt Gower, where a small number of weeds have been recorded within the Gnarled Mossy Cloud Forest ecosystem. Most are facilitated by disturbance and take advantage of cliff edges or areas of tree fall, lightning strike, tree death and other minor disturbances. These weeds may compete with native plants for recruitment in canopy gaps and cliff edges. The species composition and structure of the ecosystem will be modified if weeds are able to exclude natives. Weeds identified in Gnarled Mossy Cloud Forest on Mt Gower include: *Agrostis avenaceus*, *Arenaria serpyllifolia*, *Avena barbata*, *Bromus carthartius*, *Ehrharta erecta*, *Lolium perenne*, *Luzula longiflora*, *Paspalum* sp., *Poa annua*, *Polycarpon tetraphyllum*, *Potentilla indica*, *Pseudognaphalium luteoalbum*, *Rumex* sp., *Solanum nigrum*, *Sonchus oleraceus*, *Sporobolus africanus*, *Stellaria media* and *Vulpia bromoides.* On Mt Lidgbird, the more limited extent of Gnarled Mossy Cloud Forest along a narrow ridge (Figs. 2, 3) has allowed more aggressive weeds *Ageratina adenophora*, *Lilium formosanum* and *S. nigrum* to invade (NSW Scientific Committee 2011).

Several other potential threats could impact on species composition and structure in the Gnarled Mossy Cloud Forest. The exotic pathogen *Phytophthora cinnamomi* occurs on Lord Howe Island and could spread to the Gnarled Mossy Cloud Forest via walkers or birds, although education measures have been undertaken to minimize this risk. Currently, there are few data on the susceptibility of key Lord Howe Island endemic plants to this pathogen (see Auld & Hutton 2004). A number of potentially susceptible species are major structural dominants in the Gnarled Mossy Cloud Forest. Species occurring as part of the Gnarled Mossy Cloud Forest on Lord Howe Island and belonging to the Family Myrtaceae (*Metrosideros nervulosa* and *Leptospermum polygalifolium* ssp. *howense*) may be susceptible to exotic rust pathogens including myrtle rust, which is present on mainland NSW (NSW Scientific Committee 2011).

METHODS

To assess the Gnarled Mossy Cloud Forest Ecosystem against the IUCN Red List for ecosystems criteria (Keith *et al.* 2013), we searched the available literature for evidence of any threats to the ecosystem that may result in ecosystem decline. We also examined geographic distribution and both biotic and abiotic factors associated with the ecosystem in the light of the conceptual model of ecosystem dynamics that could lead to collapse for the Gnarled Mossy Cloud Forest (Fig. 4).

For decline, we examined historical vegetation reports (Maiden 1898, 1914; Oliver 1916; Pickard 1983; Green 1994; Mueller-Dombois & Fosberg 1998; Harris *et al.* 2005). For more recent changes, we inspected satellite imagery (Google Earth and 2011 air photo imagery). We used available Geographical Information System data layers for the distribution of Gnarled Mossy Cloud Forest (mapped from Pickard 1983) to estimate both the extent of occurrence and area of occupancy of the ecosystem. Extent of occurrence was estimated using a minimum convex polygon enclosing this distributional layer, while area of occupancy was estimated by determining the number of 10 × 10 km grids that the ecosystem covers.

To assess changes in abiotic features that directly impact on Gnarled Mossy Cloud Forest, we used two metrics based on collated data from the Australian Bureau of Meteorology from mid 1940s onwards. These metrics relate to how climatic moisture conditions may have changed (and the potential for future change). The two metrics were:

1. Frequency of cloud cover on the summits of the southern mountains where the Gnarled Mossy Cloud Forest ecosystem occurs. We estimated the number of days per annum where there was cloud cover on the summit of the two southern mountains of Lord Howe Island using data from 1946 to 2013. These peaks are observable from the Lord Howe Island meteorological station and cloud cover is recorded several times per day. As the Gnarled Mossy Cloud Forest ecosystem is restricted to elevations above 750 m, this metric allowed us to estimate the long-term changes in cloud cover directly relevant to this ecosystem. These data were used to calculate changes in the number of days of cloud cover (with plausible bounds) over the last 50 years and for the next 50 years. In cloud forests, the degree of cloud cover varies with elevation and distance from the coast (Jarvis

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& Mulligan 2011). As cloud forests are confined to habitats with generally >60% cloudy days per annum (Mulligan & Burke 2005) and data from Lord Howe Island suggested cloud cover was historically in this range (average over 78 years of 69%, annual range of 55–83%), we chose a threshold of collapse of 50% cloudy days per year for this index.

2. Changes to rainfall. The meteorological station, located just above sea level, can be used to estimate if there has been any decline in rainfall. We used data on annual rainfall for Lord Howe Island that had been analysed by Simmons *et al.* (2012) to make inferences about changing rainfall on the island that would also reflect changes to moisture availability in the Gnarled Mossy Cloud Forest ecosystem. Use of this index assumes that changes in rainfall at sea level would indicate a comparative level of change at the mountain top elevations of Gnarled Mossy Cloud Forest and that any decreases will reduce the persistence of species within the ecosystem. Again, comparisons were made between annual rainfall measures in the last 50 years and for the next 50 years. For rainfall, Pickard (1983) reported dying plant fronds and leaf fall on lowland trees and desiccation of herbs on Lord Howe Island during a dry period in 1977. Annual rainfall on Lord Howe Island in 1977 was 1071 mm, compared with the average of 1526 mm. 1977 was the second lowest annual rainfall recorded in the last 73 years (the lowest being in 1997 at 990 mm). Hence, we used a collapse threshold of 900 mm annual rainfall (below the lowest ever recorded).

Temperature increases have been identified for near sea level on Lord Howe Island (Simmons *et al.* 2012), and any increases in temperatures observed at sea level are likely to be reflected in temperatures on the southern mountains as Simmons *et al.* (2012) found an adiabatic lapse rate of some 0.9°C per 100 m increase in altitude on Mt Gower on Lord Howe Island. We did not use temperature as an abiotic variable as we had no data to inform the threshold of collapse of Gnarled Mossy Cloud Forest in relation to temperature. Instead, we examined the strength of the correlations between annual average minimum and maximum temperatures with both cloud cover frequency and annual rainfall to determine if temperature might be a useful predictor of these abiotic variables.

There is further potential abiotic degradation from any increases in storm damage from extreme events under climate change. Remote sensing data could also be used to estimate changes in storm frequency; however, no index of this is currently available.

For biotic degradation, we reviewed the impact of exotic rats on limiting recruitment of key species in the ecosystem and in changing the structure and composition of the ecosystem.

For assessment of criteria A and B, collapse was assumed to occur when the mapped distribution of the ecosystem declines to zero. For criterion C, ecosystem collapse was defined in relation to changes in cloud days (collapse at 50%) or precipitation (collapse at annual rainfall of 900 mm). Decreases in cloud days or precipitation lead to a reduction in the persistence of species within the ecosystem until the thresholds of collapse are reached. Under criterion D, ecosystem collapse was assessed based on changes in community composition, particularly loss of canopy dominants and characteristic epiphytes. We could not undertake an estimation of the probability of ecosystem collapse (criterion E), and this criterion was considered to be Data Deficient.

RESULTS

Criterion A – decline in distribution

There have been no observed changes in the extent of this ecosystem in the last 50 years (Pickard 1983). The remote location, steep terrain and conservation value of the southern mountains has ensured no clearing of the ecosystem. No changes are indicated since Pickard's 1983 vegetation classification based on inspection of recent satellite imagery (Google Earth and 2011 air photo imagery) and field traverses. The status of the ecosystem is therefore Least Concern under criterion A1.

No projections are available for the future distribution, although it is possible the current bioclimatic envelope for the ecosystem may shift sufficiently to cause ecosystem collapse. Further data on climatic conditions within the ecosystem are needed to examine this possibility. The status of the ecosystem is therefore Data Deficient under criterion A2.

There has been no observed change in the extent of this ecosystem since 1750 (Pickard 1983). The status of the ecosystem is therefore Least Concern under criterion A3.

Criterion B – distribution size

The extent of occurrence was estimated to be 20 km^2 based on a minimum convex polygon enclosing all occurrences mapped by Pickard (1983).

The area of occupancy of Gnarled Mossy Cloud Forest is estimated to be one 10×10 km grid cell.

Long-term monitoring data on both rainfall and cloud cover provide evidence for a continuing decline in abiotic components of the ecosystem (Australian National University 2009, Simmons *et al.* 2012, see below and Fig. 5). Additionally, rat predation on seeds and seedlings of several sensitive species (e.g. mountain palms) that are structural components of the ecosystem is inferred to result in continuing decline of the standing vegetation and seed banks (Auld & Hutton 2004; Auld *et al.* 2010). This rat predation on seeds and seedlings is likely to cause continuing reduction/elimination of recruitment of several key canopy species in the next 20 years. The distribution of this ecosystem (Mt Gower and Mt Lidgbird) is considered to be a single location, as the existing known threats occur across both remaining patches. This renders the ecosystem susceptible to stochastic processes such as tropical cyclones and wildfire within a short time period in an uncertain future.

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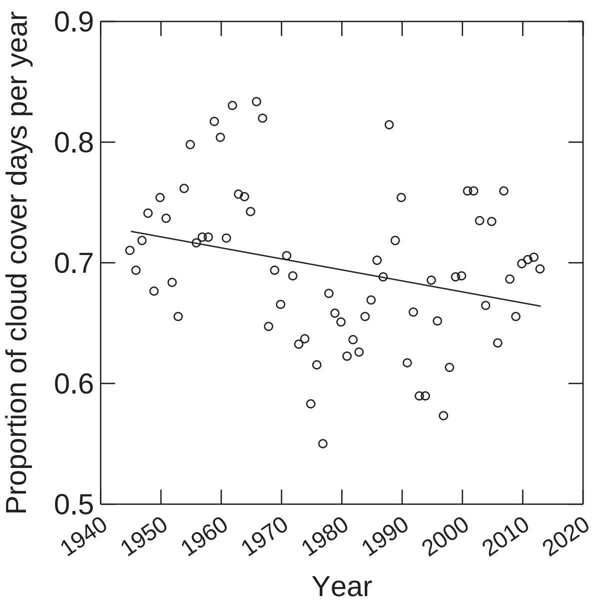

Fig. 5. Estimated change in the proportion of days per year with cloud cover in Gnarled Mossy Cloud Forest over 1945 to 2013. Regression is proportion cloudy days = 2.50 – 0.00091 × year. The standard error of the slope is 0.00038.

Table 1. Summary of the conservation assessment for Gnarled Mossy Cloud Forest against the IUCN criteria for ecosystems

Criterion	A	B	C	D	E	Overall
Subcriterion 1	LC	CR	LC-VU	DD	DD	CR
Subcriterion 2	DD	CR	VU-EN	DD		
Subcriterion 3	LC	VU	DD	DD		

CR, critical endangered; DD, data deficient; EN, endangered; IUCN, International Union for the Conservation of Nature; LC, least concern; VU, vulnerable.

The status of the ecosystem is therefore Critically Endangered under criteria B1aii, iii, B1b, B1c and B2aii, iii, B2b, B2c, and Vulnerable under B3 (see Table 1).

Criterion C – decline in abiotic processes and features

There was a trend for decline in the two moisture indices used. The extent of impact extends across 100% of the ecosystem for both indices. For cloud cover, ecosystem collapse is suggested to occur when there is cloud cover for less than 50% of the year (Mulligan & Burke 2005). In Costa Rica, Pounds *et al.* (1999) showed that increases in dry days (and hence a decline in mist frequency) was associated with increases in bird species from habitats below cloud forests, along with declines in populations of cloud forest anoline lizards and anurans. Cloud cover over the last 50 years declined an estimated 22% (95% Confidence Limit 4–38%) towards the threshold of collapse set at 50% cloudy days per year (R^2 = 8.1%, Fig. 5). This would imply a best estimate of least concern, but the 95% confidence limits of the estimate would include Least Concern to Vulnerable.

For annual rainfall, we found over the last 50 years there had been a decline of 31% (95% CL 4–79%) towards the collapse threshold. This would imply a best estimate of Vulnerable, but the 95% confidence limits of the estimate would include Least Concern to Endangered. Hence, the status of the ecosystem under criterion C1 is Least Concern to Vulnerable.

Both minimum and maximum temperatures at sea level increased in the last 50 years (Simmons *et al.* 2012). The long-term average maximum and minimum temperatures are 21.87°C and 16.93°C, respectively. The highest average yearly maximum temperature (22.6°C) was in 1973, and 4 of the warmest 5 years have been since 1998. We found poor correlations between annual rainfall and the proportion of cloudy days or temperature. The highest correlations were between cloud cover and average annual minimum temperature (–0.4) and average annual maximum temperature (–0.31), suggesting that increases in these temperature variables could be a factor in influencing cloud cover changes.

The status of the ecosystem under criterion C2 can be assessed by extrapolating the rate of change in cloud cover or rainfall over the next 50 years against the thresholds for collapse. This suggested that cloud cover would be reduced by 28% (95% CL range 4–60%) and annual rainfall by 44% (95% CL range 4–100%) relative to collapse thresholds over the next 50 years. Consequently, the status of the ecosystem under C2 would be predicted to be Vulnerable to Endangered (with a plausible range of Least Concern to Collapsed). The status of the ecosystem under criterion C3 (Historic decline) is Data Deficient.

Criterion D – decline in biotic processes and interactions

The ecosystem is subject to the impact of exotic rats. Rats damage key functional plant species in the ecosystem via predation on seeds and seedlings (Auld & Hutton 2004; Auld *et al.* 2010). Most of the area (93%) of Gnarled Mossy Cloud Forest is subject to impact by rats (7% is baited to reduce impact). The severity of impacts is not known for all species impacted, but for two palm species (Auld *et al.* 2010) it varies from 100% (ongoing recruitment failure) to >75% (recruitment failure at 75% of surveyed sites and significantly reduced at 25% of sites). Thus, the extent and severity of seed predation by rats is high for two key species, but the severity of seed predation by rats on other taxa in the ecosystem is uncertain.

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The ecosystem is also susceptible to *P. cinnamomi* and myrtle rust as several dominants in the canopy are likely to be impacted by these pathogens. *Phytophthora cinnamomi* is present on Lord Howe Island (Auld & Hutton 2004). No estimate of severity or impact is available.

The status of the ecosystem under criteria D1, D2 and D3 are all Data Deficient.

DISCUSSION

Unlike other global cloud forest ecosystems (Scatena *et al.* 2010), Gnarled Mossy Cloud Forest has not been subject to recent clearing or fragmentation. We found Gnarled Mossy Cloud Forest to be Critically Endangered based on a restricted geographic distribution combined with continuing decline in abiotic and biotic processes inferred from: a loss of moisture from declining rainfall and cloud cover due to climate change; ongoing exotic rat predation on seeds and seedlings of several sensitive species that are structural components of the ecosystem; and the single location of the ecosystem. These are likely to lead to reduced survival and recruitment in species in the ecosystem (Fig. 4). Hence, this ecosystem is impacted by similar threats to other Pacific island cloud forests (Meyer 2010).

We successfully applied several related indices of change in the climate that may affect the Gnarled Mossy Cloud Forest ecosystem. However, the sensitivity of relationships between the degree of decline in either cloud cover or rainfall, and species and ecosystem decline remains somewhat uncertain. Our estimates of thresholds for collapse are based on limited information and the estimates of decline in cloud cover and rainfall had large plausible bounds (e.g. resulting in 95% confidence limit estimates of Least Concern to Collapsed in C2). While cloud cover data have the most direct relevance to species survival in the ecosystem, average annual temperature changes were negatively correlated with cloud cover suggesting the 'lift cloud base hypothesis' (Pounds *et al.* 1997, 1999; Still *et al.* 1999) may be applicable to Lord Howe Island. It is possible that increases to temperature near sea level may be a suitable surrogate for changes in cloud cover in the Gnarled Mossy Cloud Forest ecosystem. Data on biotic processes and interactions were available for only two of the canopy palm species in the ecosystem. While we had data on both severity (75–100%) and extent (93%) for these species, uncertainty remains about the severity across other key structural taxa in the ecosystem (just how many species need to be impacted to drive the ecosystem to decline). As well, as mature plants may be long-lived, recruitment failure would need to consistently occur across decades (as is the case in the two palms; Auld *et al.* 2010). Factors influencing adult tree survival (such as reduced moisture availability, increased extreme weather and lightning strikes) will also be important estimating the severity of rat impacts.

Future prognosis for the ecosystem

A rodent eradication programme has been developed for Lord Howe Island (Lord Howe Island Board 2009; Wilkinson & Priddel 2011) and is planned to occur in the coming years. If successful, this has the potential to eliminate the major immediate threat to this ecosystem. If unsuccessful, regular rodent baiting across much of the distribution of the ecosystem would be needed, although this is not likely to be a long-term solution as the rodents gain resistance to the poisons. A reduction in rat impact is needed to both allow successful seed production and recruitment of new plants. As rats also consume leaves of developing plants, a period of a decade or more of minimal rat impacts would be needed to promote regeneration.

Phytosanitory guidelines have been developed for Lord Howe Island in an effort to reduce any risk of spread of the existing *P. cinnamomi* (DECC 2007) and limit the introduction of novel pathogens such as myrtle rust. An ongoing programme of early detection is needed to complement this. Weed impacts are currently minor except for the ecosystem occurrence on Mt Ligdbird, where large habitat edges favouring crofton weed are impacting on the ecosystem. Unfortunately, the remote and rugged nature of the terrain currently prevents any control efforts.

Any prevention of climate warming and reduction in cloud-derived precipitation will depend on global efforts to reduce greenhouse gas emissions. The current prognosis for this is not favourable (Peters *et al.* 2013).

Collapse of the Gnarled Mossy Cloud Forest Ecosystem would have cascade effects for many of the component species and others dependent upon this ecosystem. Visiting the ecosystem is also part of the popular tourist walk to Mt Gower. Decline and loss of this unique ecosystem would likely impact on the popularity of this walk and the tourism values of the island.

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Landbirds on Lord Howe Island, NSW

Survey report 2, September 2014

Prepared for the Lord Howe Island Board

by the Canberra Ornithologists Group

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7 April 2015

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Summary

This report describes a survey in September 2014 of landbirds on Lord Howe Island conducted by the Canberra Ornithologists Group (COG). The survey was the second of what is intended to be an annual assessment of the status of landbirds on the island. The survey will be repeated each September for at least the next three seasons (2015–2017). This and further surveys have been commissioned by the Lord Howe Island Board as part of the necessary monitoring processes associated with a plan to eradicate rodents from the island.

The purpose of the survey is to provide baseline information on the numbers and distribution of landbirds on Lord Howe Island. Point counts were chosen as the preferred method for the island survey. The data collecting protocol used is one we believe best fitted the limitations of time and effort available in the field. Transects surveys were conducted on five evenings, concentrating on the most important ground feeding species present in the settlement area.

As for the 2013 survey, forty-eight paired sites were selected across the survey area. The sites were stratified to represent various vegetation types and habitat zones with seven transects selected within the settlement area. From experience gained during the 2013 survey, four teams of two observers surveyed all paired sites in three days with all of sites resurveyed over the following three days.

The mean abundance, mean reporting rate, frequency and group size for each of the 16 species recorded during the survey was calculated. In addition, the 16 species were analyzed using a generalized linear mixed model allowing both fixed and random effects to be taken into account. Maps of species distribution for 14 species with sufficient data are compared with the observations obtained in 2013.

The most common bird was the Golden Whistler followed by the Silvereye. A noticeable reduction in all indices occurred for the next four most frequently reported species – Blackbird, Pied Currawong, Magpie-lark and Welcome Swallow.

In general, the habitat influences appear to be reasonable and generally reflect what we know about the biology of the species. The suggested potential differences between *Years* for some species (Buff-banded Rail, Magpie-lark, Welcome Swallow and Blackbird) need further exploration and additional observations before it can be suggested that we have detected truly significant differences between years.

The protocol for this baseline survey provides a rigorous survey method for obtaining data, giving statistically sound measures of significant changes in population numbers and distribution of species over time – particularly any changes occurring before and after the proposed rodent eradication for mid 2016.

Introduction

This report describes a survey in September 2014 of landbirds on Lord Howe Island (latitude 31° 33´S and longitude 159° 05´E). The survey was the second of intended annual assessments of the status of landbirds on the island conducted before the proposed rodent eradication program occurs. The survey will be repeated each September for at least the next three seasons (2015–2017).

This and the further surveys were commissioned by the Lord Howe Island Board as part of the necessary monitoring processes associated with a plan to eradicate rats and mice from the island. This eradication is now scheduled for mid 2016.

The purpose of the surveys is to provide baseline information on the numbers and distribution of landbirds on Lord Howe Island. Landbirds are here defined as those species that are either breeding residents on the island or visitors that are land-based. Specifically, all seabirds are excluded but shorebirds are not.

A rigorous survey method was required to provide data that can give a statistically sound measure of significant changes in population numbers and distribution – if they occur.

As indicated in the first report (Fullagar *et al.*, 2014) point counts were chosen as the preferred method for the island survey. Much of the vegetation is dense and often difficult to access; repeated line transects would have been difficult to follow in such circumstances. Point counts are easier to incorporate in a formally designed study, easier to locate and lay out, and they provide a more reproducible data set. As well, point counts are more efficient than transect counts because they allow for more data points (Bibby *et al.*, 1997).

We investigated the power of available statistical analyses achievable with this method of population assessment (Nicholls unpublished) and adopted the data collecting protocol we believe best fitted the limitations of time and effort available in the field. As an additional data set we did, however, use a simple transect procedure to assess the abundance of six species within the most closely settled area of the island. These transects were walked at dusk using the network of sealed roadways.

For a review of the historical records of birds on Lord Howe Island see Fullagar *et al.*, 2014.

Methods

Choice of survey sites

For practical reasons, determined by the time available for surveying and the number of teams we could muster, only the northern part of Lord Howe Island was included.
Mt Lidgbird and Mt Gower were excluded, as were Erskine Valley and any of the mountain slopes below the peaks beyond Mutton Bird Point and Little Island (see Figure 1).

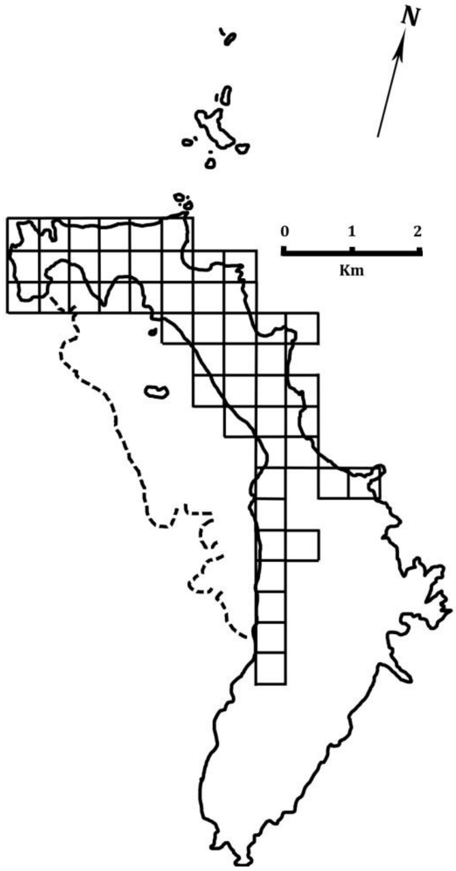

Figure 1. Grid cells, based on point counts, used for surveying distribution of landbirds on LHI, September 2014

The same forty-eight grid cells (see Figure 1) used in 2013 were surveyed again and each grid cell was allocated two count sites. The count sites were stratified to represent the various vegetation types and habitat zones. For a description of paired sites defined by vegetation and habitat classification (see Fullagar *et al.*, 2014).

Point count protocol

Our protocol involved four teams of two observers surveying over six days. Surveying was restricted to between sunrise and late morning. From experience gained during the 2013 survey it was possible to increase the number of sites surveyed per day. Each team had sufficient time to survey eight sites per day. All 96 sites could then be surveyed in three days with a repeat of all 96 sites over the following three days. Unlike 2013, the final day was not required. It is essential to retain this final day as a back-up in case of inclement weather.

The paired sites were a minimum of 100 metres apart but were similar in topography and vegetation (see Appendix A in the 2013 report for site details of geo-location, vegetation code, vegetation group and habitat zone, Fullagar et al. 2014) Three sites 19, 25 and 26 were repositioned to allow for easier access but all three remained in the same vegetation and habitat classification, see Appendix A for new geo-coordinates.

The count protocol at each site was to record the abundance of each species seen or heard within a 50-metre radius over a 10-minute period, with observers moving within the plot area if required. Team members would survey a pair of sites independently and simultaneously before swapping sites and again counting for 10 minutes.

All sites were visited four times, giving a total of 384 counts. No site was resurveyed by the same observer. Repeatability of counts at a site could be tested by comparing counts at sites on the same day and on different days. Such analyses have not been undertaken to date.

Only experienced observers were chosen for the field work. All team members were well-trained, expert bird watchers with considerable previous involvement with similar style field work.

In the field the location of the paired sites was arrived at by GPS. Due to difficulties of terrain and differences in vegetation it was often not possible to survey the exact pre-determined point. Observers were requested to survey as near as they could to the allocated point. On arrival a waypoint reading was taken of the actual point surveyed and subsequently compared with the allocated central point of the site. The average distance between these two locations was 8 metres so the survey site was still well within the appropriate vegetation group and habitat zone.

Statistical treatment of site counts

Several summary parameters were used as population indices and these will become useful for comparison with data collected in future.

- *Mean abundance* (A). The average number of individuals of a species seen per observation and defined as the sum of the number of individuals reported divided by the total number of observations (384).
- *Mean reporting rate* (R). Defined as the number of recorded occurrences divided by the total number of observations (384).
- *Frequency* (F). The site occupancy rate or incidence rate defined as the number of sites on which a particular species was recorded divided by the total number of sites (96).
- *Group size* (G). Defined as the sum of the number of individuals divided by the number of observations in which a species was recorded.

Statistical model

A generalized linear mixed model was the starting point for the analysis of the combined (2013 and 2014) data. We need to account for the non-normal distribution of the counts and the structural components of the survey design. We assume that the counts are drawn from Poisson distributions. The fixed effects explored are *Vegetation Group* (a three-level factor) derived from the *Vegetation type* (see Table 1, Fullagar *et al.*, 2014) and *Year* to test if there has been any detectable change over the twelve-month interval between surveys. The random effects include, *Site* (Site no.), *Zone* (in which the Count site is located), *Observer* (Observer identity) and *Day*, when the survey was performed. All models were fitted using the R software (R Core Team, 2014) and the package 'lme4' (Bates *et al.*, 2014). Confidence intervals were derived from the models using functions from the packages 'mle4' and 'boot' (Canty and Ripley, 2014).

Due to the difficulty in collecting reliable abundance data for Silvereyes, only presence or absence data are available. Appropriate models fitted to these data assume a binomial error structure and a logit link function.

Transect surveys

The same seven transects covered in September 2013 of variable length (ranging from 570 to 970 metres) were walked at a slow pace by a single observer twice (in one direction and then return) on five days. The transects followed sealed roads. To reduce the variability of speed of travel, each transect was set a specific duration for survey with a walking pace set at 2 km/hr.

Figure 2 provides a map of the Lord Howe Island core settlement area, showing the location of transects A–G. The green pointers indicate junctions, where more than one transect starts or finishes. The yellow pointers indicate transect end points. See Appendix B for a description of the start and finish points for each transect.

Figure 2. Map of core settlement area, LHI, with location of transects A–G

None of the observers walked the same transects twice with each observer covering five of the seven transects (see Table 1). For practical purposes only six species were targeted for the transect counts. The purpose of the transact counts was to survey most of the ground-feeding species present in the settlement area.

Table 1. Allocation of observers to transects, LHI core settlement, September 2014*

Observer	*Transects*						
	A	B	C	D	E	F	G
Ob1	0	0	2	2	2	2	2
Ob2	2	0	0	2	2	2	2
Ob3	2	2	0	0	2	2	2
Ob4	2	2	2	0	0	2	2
Ob5	2	2	2	2	0	0	2
Os6	2	2	2	2	2	0	0
Ob7	0	2	2	2	2	2	0
Length (m)	*750*	*970*	*900*	*570*	*820*	*970*	*670*

*Note: Observer not necessarily the same for 2013 and 2014.

Statistical analysis of transect data

There are two groups of potential predictors of the abundance of the observed species. The first group characterizes the observations in terms of physical characteristics of the transect (*Length*), the direction of the traverse (*Out* or *Return*) and the duration of the count (*Duration*) or the average speed of travel (*Speed*). These physical characteristics are all connected.

More individuals would be expected to be observed on longer transects, or during longer travel times or slower speeds of travel; there is no *a priori* reason to think that direction of travel should influence the number of individuals observed. Also, in this group is the *Year of observation* which potentially reflects changes over time scales of a year or more. The second group of predictors includes *Observer identity*, *Transect identity* and *Date of observation*.

It is recognized that there are observer differences in terms of ability to detect individuals of different species. It is also recognized that transect differences will favour more individuals on some transects relative to other transects and some days will be better than others for making observations.

We are not primarily interested in the effects of the second group of predictors but may need to account for the variability in observations that can be attributed to these factors. We do this by considering *Observer identity, Transect identity* and *Date of observation* as random effects. Of the first group *Year of observation* is of primary interest; the others may need to be accounted for to reduce the unexplained variation.

The response variable – the number of individuals per species observed per transect survey – can be considered a Poisson variable where the variance is equal to the mean. To model the observed data we need to fit a Generalized Linear Mixed Model to account for the variance structure of the residuals and the presence of both random and fixed effects. Models were fitted using R (R Core Team, 2014) and the package "lme4" (Bates *et a*l., 2014). Estimates of the mean number of individuals observed per transect and confidence intervals were derived from parametric bootstrapping techniques based on functions supplied with the package "nlme" based on the package "boot" (Canty and Ripley, 2014).

Species names

Species names used in this report follow current preferred internationally accepted nomenclature (see Appendix C). For simplicity, some of the common names have been shortened to conform with island usage.

Survey dates and weather conditions

The 2014 survey was conducted between 8 and 13 September. Teams were in the field soon after dawn each day and ready to start by about 0600. Teams often worked through until late morning. The time to complete a set of counts varied mostly due to the time taken to reach all allotted count sites.

The first day of the survey started overcast with a fresh breeze but soon improved to sunny and warm conditions. The next two days were fine and clear with a light breeze but became overcast in the afternoon of the third day of the survey with the passage of a weather front. The front produced rain overnight leading to a late start on the fourth day under cloudy and windy conditions that cleared as the day progressed. The remaining two days of the survey were sunny and warm. Some weather observations for the week are shown in Table 2.

Table 2. Selected daily weather observations, LHI, 7–14 September 2014

Date	*Day*	*Min °C*	*Max °C*	*Rain (mm)*	*Direction*	*Max. wind speed (km/h)*
7	Sun	14.4	18.8	0	E	46
8	Mon	14.8	18.7	0.2	E	41
9	Tue	15.5	19.2	0	N	30
10	Wed	16.3	20.2	0	WS	69
11	Thu	12.4	19.8	16.8	WSW	52
12	Fri	16.7	20.2	0	WSW	41
13	Sat	13.1	19.1	0	E	33
14	Sun	9.4	19.9	0	N	22

Source: Bureau of Meteorology website

Results and discussion

Site counts

The maximum number of times that any one species could be recorded was 384: the sum of 96 count sites each with four visits. Table 3 shows the distribution of the counts in the vegetation groups and habitat zones.

Table 3. No. of counts in three vegetation groups in five habitat zones, LHI*

Vegetation group	*Habitat zone*					***Total counts***
	1	*2*	*3*	*4*	*5*	
Lowland forest	104	24	32	16	32	**208**
Palm forest	8	56	8	0	32	**104**
Open	0	32	4	32	4	**72**
Total surveys	**112**	**12**	**44**	**48**	**68**	**384**

*For a definition of vegetation group and habitat zone see Report 1.

Abundance, reporting rate, frequency and group size

Table 4 shows the abundance, reporting rate, frequency and group size, irrespective of vegetation or habitat, for 16 birds recorded in 96 count sites on Lord Howe Island. The reporting rate is given in descending order.

As occurred in 2013, the most common bird in terms of reporting rate and abundance was the Golden Whistler. The number of Silvereye individuals in a survey plot was difficult to estimate given their flocking behaviour, their often quick passage through the survey plots and the fact that they were usually detected only by calls. For the Silvereye, only occurrence was analyzed and no estimate of abundance or group size was possible.

Again, as we found in the previous year, a noticeable reduction in all indices occurred for the next four most frequently reported species – Blackbird, Pied Currawong, Magpie-lark and Welcome Swallow – but for the rest all summary indices, except group size, were much smaller. Welcome Swallow was not included in the 2013 analysis.

Table 4. Abundance, reporting rate, frequency and group size for 16 bird species recorded at 96 count sites, LHI, 2014

Species name	*Abundance*	*Reporting rate*	*Frequency*	*Group size*
Golden Whistler	1.83	0.76	0.85	2.42
Silvereye		0.70	0.86	
Blackbird	0.42	0.23	0.47	1.79
Pied Currawong	0.36	0.23	0.53	1.52
Magpie-lark	0.29	0.16	0.34	1.82
Welcome Swallow	0.41	0.15	0.26	2.84
Sacred Kingfisher	0.12	0.10	0.27	1.15
Emerald Dove	0.13	0.09	0.27	1.36
Woodhen	0.09	0.07	0.20	1.33
Buff-banded Rail	0.08	0.05	0.11	1.63
Swamphen	0.07	0.04	0.07	1.86
Song Thrush	0.03	0.03	0.07	1.00
Masked Lapwing	0.03	0.02	0.06	1.44
White-faced Heron	0.02	0.02	0.06	1.17
Bar-tailed Godwit	0.04	0.01	0.01	7.00
Red-necked Stint	0.00	0.00	0.01	1.00

Table 5 shows the 2014 reporting rate, abundance and frequency for the most commonly reported species – the Golden Whistler, and the two species of greatest concern: the Woodhen and the Pied Currawong. The three indices for observations within the plot area are presented defined by vegetation and habitat zone.

Table 5. Reporting rate, abundance and frequency for the Golden Whistler, Woodhen and Pied Currawong, defined by vegetation group and habitat zone, LHI, 2014

Golden Whistler

	Reporting rate			*Abundance*			*Frequency*		
Vegetation group	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Habitat zone									
1	0.89	0.88		2.14	1.63		0.26	0.02	
2	0.96	0.89	0.03	2.38	2.54	0.03	0.06	0.14	0.01
3	1.00	0.63	0.25	2.47	0.88	0.25	0.08	0.02	0.01
4	0.88		0.25	2.38		0.44	0.04		0.03
5	0.91	0.81	0.25	2.25	1.69	0.25	0.08	0.08	0.01

Woodhen

	Reporting rate			*Abundance*			*Frequency*		
Vegetation group	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
Habitat zone									
1	0.00	0.00		0.00	0.00		0.00	0.00	
2	0.08	0.04	0.00	0.08	0.05	0.00	0.02	0.02	0.00
3	0.03	0.00	0.00	0.03	0.00	0.00	0.01	0.00	0.00
4	0.50		0.16	0.75		0.22	0.04		0.03
5	0.06	0.22	0.00	0.06	0.28	0.00	0.02	0.05	0.00

Pied Currawong

	Reporting rate			*Abundance*			*Frequency*		
Vegetation group	1	2	3	1	2	3	1	2	3
Habitat zone									
1	0.26	0.25		0.36	0.25		0.17	0.02	
2	0.13	0.23	0.00	0.17	0.29	0.00	0.02	0.06	0.00
3	0.31	0.00	0.00	0.34	0.00	0.00	0.06	0.00	0.00
4	0.50		0.09	1.44		0.19	0.04		0.02
5	0.25	0.50	0.00	0.28	0.91	0.00	0.06	0.07	0.00

Results were similar to the previous year for the Golden Whistler. The lowest reporting rate and abundance was in vegetation group 3 (Pasture, Dune, Golf course) within habitat zone 2 (Settlement) while the highest frequency was in vegetation group 1 *(Drypetes/Cryptocarya*) within habitat zone 1 (North Hills).

For the Woodhen, the highest reporting rate and abundance was in habitat zone 4 (Suburban) within vegetation group 1 (*Drypetes/Cryptocarya*). The highest reporting rate and abundance for the Pied Currawong was in habitat zone 4 (Suburban) within vegetation group 1 (*Drypetes/Cryptocarya*).

Generalized linear mixed model

Data from the 2013 and 2014 surveys have been combined and analyzed. Note that the model for Silvereye is fitted to the presence–absence data while for all other species the model is fitted to the abundance data. The results of the generalized linear mixed model are presented as follows:

- the significance of the fixed effects *Vegetation group* and *Year*, and the interaction between these two variables.
- the magnitude of the random effects
- the estimated abundances and confidence intervals derived from the appropriate model
- species-related information on issues with the fitting and interpretation of the model (see pp. 14–15).

Table 6 shows the significance of the fixed effects *Vegetation group* and *Year*, and their interaction for each of the species for which there are sufficient non-zero observations.

Table 6. Significance of fixed effects

Species	*Vegetation group*	*Year*	*Interaction*
Golden Whistler	<0.001	0.88	0.1
Silvereye	<0.001	0.74	0.52
Blackbird			<0.001
Pied Currawong	0.0002	0.99	0.7
Magpie-lark	0.57	0.03	0.06
Welcome Swallow			0.02
Sacred Kingfisher			0.67
Emerald Dove	<0.001	0.21	0.46
Woodhen	<0.001	0.23	0.79
Buff-banded Rail	0.52	0.02	0.37
Song Thrush			
White-faced Heron			

In Tables 6 and 7, cells left blank represent random effects considered to be insignificant and equal to zero.

The variance estimates for the random effects from the final model are fitted (see Table 7).

Table 7. Variance estimates for random effects

Species	*Count site*	*Habitat zone*	*Observer*	*Day*
Golden Whistler	0.4255		0.2285	
Silvereye	1.7379		0.1829	0.258
Blackbird	0.7675	1.7202		
Pied Currawong	1.119		0.1026	
Magpie-lark	0.6845	2.684	0.0728	
Welcome Swallow	1.35		0.1334	
Sacred Kingfisher				
Emerald Dove	0.6093	0.4455		
Woodhen		3.029		
Buff-banded Rail	3.25	34.35		
Song Thrush				
White-faced Heron				

Table 8 provides an estimated number of individuals found at count sites for three vegetation types. For four species, data are significantly different between years. For Silvereye, the estimated values are the probability of observing Silvereye not the number of individuals.

Table 8. Estimated number of individuals derived from the final fitted model

Species	*Year*	*Vegetation type*		
		Lowland forest	*Palm forest*	*Open*
Golden Whistler		2.21 (0.86 – 4.78)	2.05 (0.83 – 4.57)	0.29 (0.13 – 0.57)
Silvereye		0.87 (0.48 – 0.98)	0.78 (0.33 – 0.96)	0.49 (0.10 – 0.89)
Blackbird	2013	0.30 (0.02 – 2.02)	0.22 (0.13 – 2.00)	0.01 (0.01 – 0.04)
	2014	0.26 (0.02 – 1.74)	0.24 (0.01 – 1.33)	0.05 (0.00 – 0.26)
Pied Currawong		0.35 (0.08 – 1.42)	0.33 (0.05 – 1.43)	0.06 (0.02 – 0.28)
Magpie-lark	2013	0.32 (0.00 – 1.90)	0.32 (0.00 – 1.90)	0.32 (0.00 – 1.90)
	2014	0.21 (0.00 – 1.22)	0.21 (0.00 – 1.22)	0.21 (0.00 – 1.22)
Welcome Swallow	2013	0.03 (0.01 – 0.11)	0.01 (0.00 – 0.04)	2.40 (0.21 – 13.9)
	2014	0.03 (0.01 – 0.16)	0.07 (0.00 – 0.39)	3.05 (0.23 – 17.4)
Sacred Kingfisher				
Emerald Dove		0.15 (0.03 – 0.62)	0.22 (0.03 – 1.02)	0.00 (0.0 – 0.02)
Woodhen		0.09 (0.00 – 0.46)	0.26 (0.00 – 3.22)	0.04 (0.00 – 0.44)
Buff-banded Rail	2013	0.17	0.17	0.17
	2014	0.08	0.08	0.08
Song Thrush				
White-faced Heron				

Golden Whistler

From 503 records of Golden Whistler there were generally 2 individuals per count in the forest and 0.3 individuals in the Open group habitat. The interaction is not significant; the difference between years is not significant but the difference between habitats (Forest versus Open) is significant.

Silvereye

Note that a different mixed model is fitted to the Silvereye data due to the recording of presence or absence, not abundance. We collected a total of 522 records of Silvereye. The fixed effects interaction and the main effect *Year* were not significant. *Observer*, *Count site* and *Day* were significant random effects. The probability of recording Silvereye in the forest is nearly twice that of recording it in the Open vegetation.

Blackbird

From 163 records there was a significant fixed effect interaction so the two main effects are retained in the model. The significant random effects were *Count site* and *Habitat zone*. The interaction is due to small increases in the recorded abundance in the forests compared with an apparent sixfold increase in the Open vegetation in 2014 compared with 2013. The model is apparently not very stable and confidence intervals are not available.

Pied Currawong

Pied Currawong were recorded across all vegetation groups and less abundantly or frequently in the Open group. The interaction is not significant and the differences between the two years were not significant. The recorded abundance is positively associated with forest compared to that recorded in the open habitats.

Magpie-lark

There is some evidence from the 128 records that the fixed effects interaction is significant, but this model is not well fitted and the model without the interaction has been used to evaluate the random effects. Of the fixed main effects only *Year* was significant. There was an apparent reduction in the abundance in 2014 compared with 2013.

Welcome Swallow

From 103 recorded sightings there were a greater abundance of Welcome Swallow in the Open vegetation. The interaction is significant, hence the main effects have not been tested as they have to be retained in the model. The random effects are *Observer* and *Count site*. The interaction appears to be driven by the apparent tenfold increase in abundance recorded in the Palm forest in 2014 compared with 2013, whereas there was less than a doubling over the same period in the Open vegetation.

Sacred Kingfisher

The Sacred Kingfisher was recorded on 66 occasions and in all vegetation groups. The models are unstable and, while the evidence points towards there being no interaction between the fixed effects, we are unable to estimate the significance of *Year* or *Vegetation* *group*. Confidence intervals are not available as estimates of the means for either of the main effects are not reliable.

Emerald Dove

From 77 records, there was only one record of the Emerald Dove from the Open vegetation group. *Vegetation group* is the only significant fixed effect (see Table 6); the significant random effects are *Habitat zone* and *Count site* identity (see Table 7).

Woodhen

This species was recorded 46 times. Only *Vegetation group* of the fixed effects is significant, and *Habitat zone* is the important random effect. The evidence points to greater abundance in the Palm forest relative to the other two vegetation groups.

Buff-banded Rail

There appears to be sufficient data (52 records) to permit modelling the abundances, but the distribution is uneven. Rails were only recorded in habitat zones 2 and 4. As a consequence the fitted models are unstable. The evidence points to no significant *Vegetation group* effect and an apparent reduction in abundance of the Rail from 2013 to 2014. Due to the unstable nature of the model it is not possible, at present, to estimate confidence intervals for the estimated means given in Table 8.

Swamphen

There are only 33 records of Swamphen across the two surveys. This is below the 5% cut off suggested by Cunningham and Olsen (2009) and therefore no model has been fitted. No records were made in the Lowland forest or Palm forest.

Song Thrush

Of the 21 records, twenty are from the Palm forest and one from the Open vegetation.

Masked Lapwing

Of the 23 records of this species, 22 were in the Open vegetation group.

White-faced Heron

The number of records of White-faced Heron was low: 8 out of a total of 684. This is well below the 5% cut off point used by Cunningham and Olsen (2009).

Bar-tailed Godwit

This species was recorded three times, all from the Open vegetation group.

Red-necked Stint

This species was recorded only once in the two years of surveys and that record was in 2014 – from a *Count site* in the Open vegetation group.

It is recognized that generalized linear mixed models can be difficult to fit. In the present study the number of random effects contributes to the complexity of the models. The small number of individuals recorded also adds difficulties to the parameter estimation. For some species the estimated confidence intervals are clearly very wide and appear to be well outside the observed data. This reflects some of the complexities of these models. With additional data from more years, some of these difficulties can be expect to diminish.

A Poisson distribution has been assumed for the error structure. This is a reasonable first approximation. Additional work is needed to explore some alternative error structures and alternative random effects specifications.

In general, the habitat influences appear to be reasonable, and generally reflect what we know about the biology of the species. The suggested potential differences between years for some species (Buff-banded Rail, Magpie-lark, Welcome Swallow and Blackbird) need further exploration and additional observations before it can be suggested that we have detected truly significant differences between years.

To allow for a statistical comparison of the survey data pre- and post-rodent eradication, fixed effects such as *Vegetation type* and *Year* of survey together with random effects such as *Count site*, *Observer* and *Day* differences need to be taken into account.

Species distribution

Figures 3–6 show the 2014 frequency distribution of 14 species across the lowlands of Lord Howe Island. These distribution maps are based on the relative occurrence of each species derived from the accumulated site counts. Site counts have been distributed within a grid pattern extending across the survey area (see Figure 1). Distribution maps were not prepared for two species with too few data: Bar-tailed Godwit and Red-necked Stint. White-faced Heron and Welcome Swallow were omitted from the 2013 report, but in this report the 2013 and 2014 distribution maps for these species are shown.

The size of each dot corresponds to the number of times each species is recorded as present within each grid cell. In each cell there are two count sites, giving a possible score of eight if the species is seen on every count in the cell. The smallest dot indicates one or two occurrences, with increasing dot size (doubling in size with each increment) for three or four and five or six occurrences, leaving the largest dot to indicate a maximum of seven or eight out of the possible eight counts.

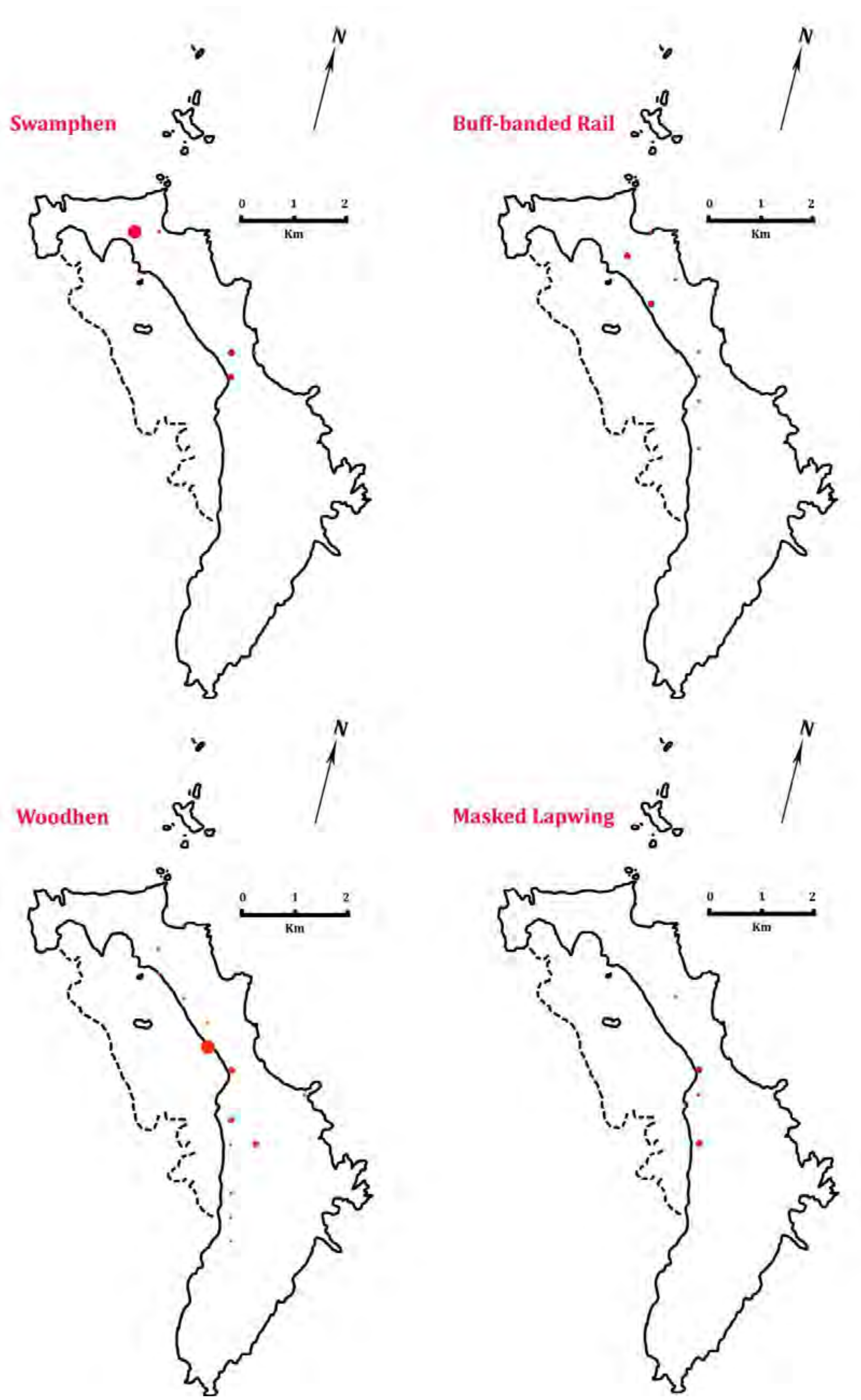

Figure 3. Distribution of Swamphen, Buff-banded Rail, Woodhen and Masked Lapwing, September 2014, across northern LHI, by frequency of occurrence at count sites

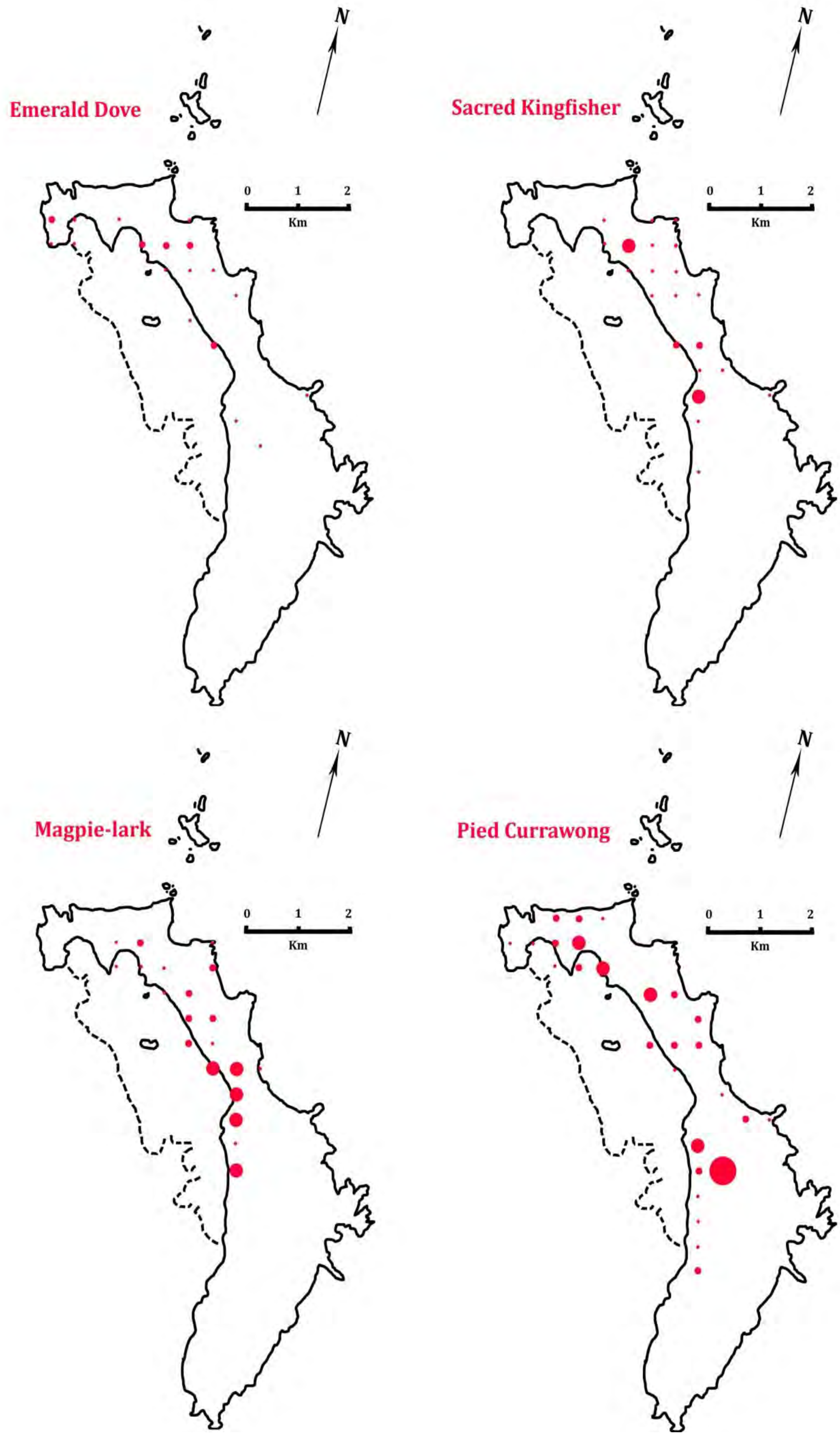

Figure 4. Distribution of Emerald Dove, Sacred Kingfisher, Magpie-lark and Pied Currawong, September 2014, across northern LHI, by frequency of occurrence at count sites

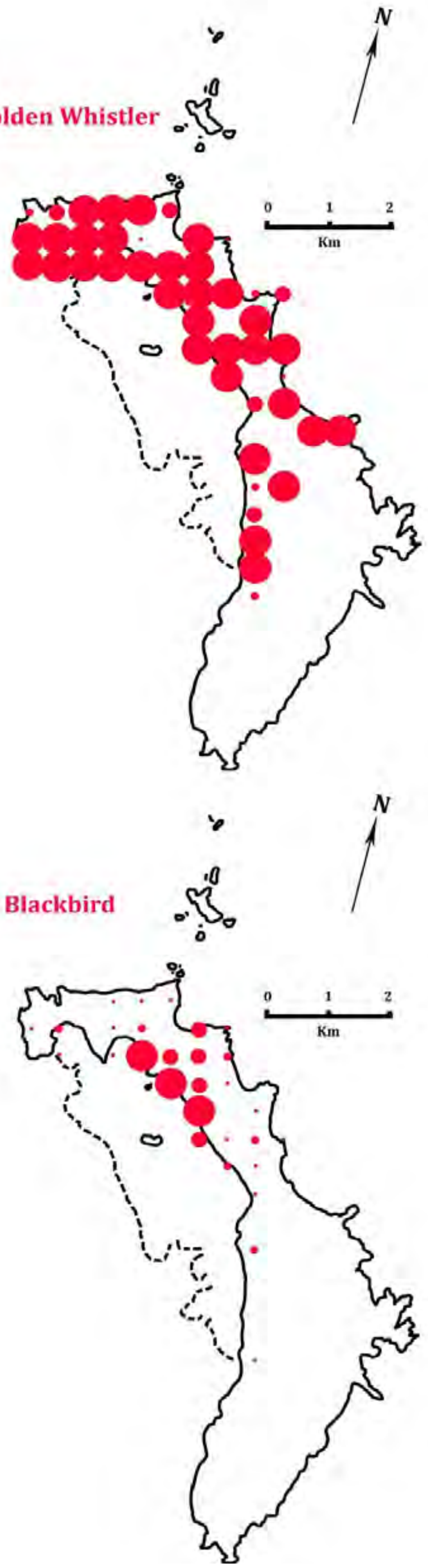

Figure 5. Distribution of Golden Whistler, Silvereye, Blackbird and Song Thrush, September 2014, across northern LHI, by frequency of occurrence at count sites

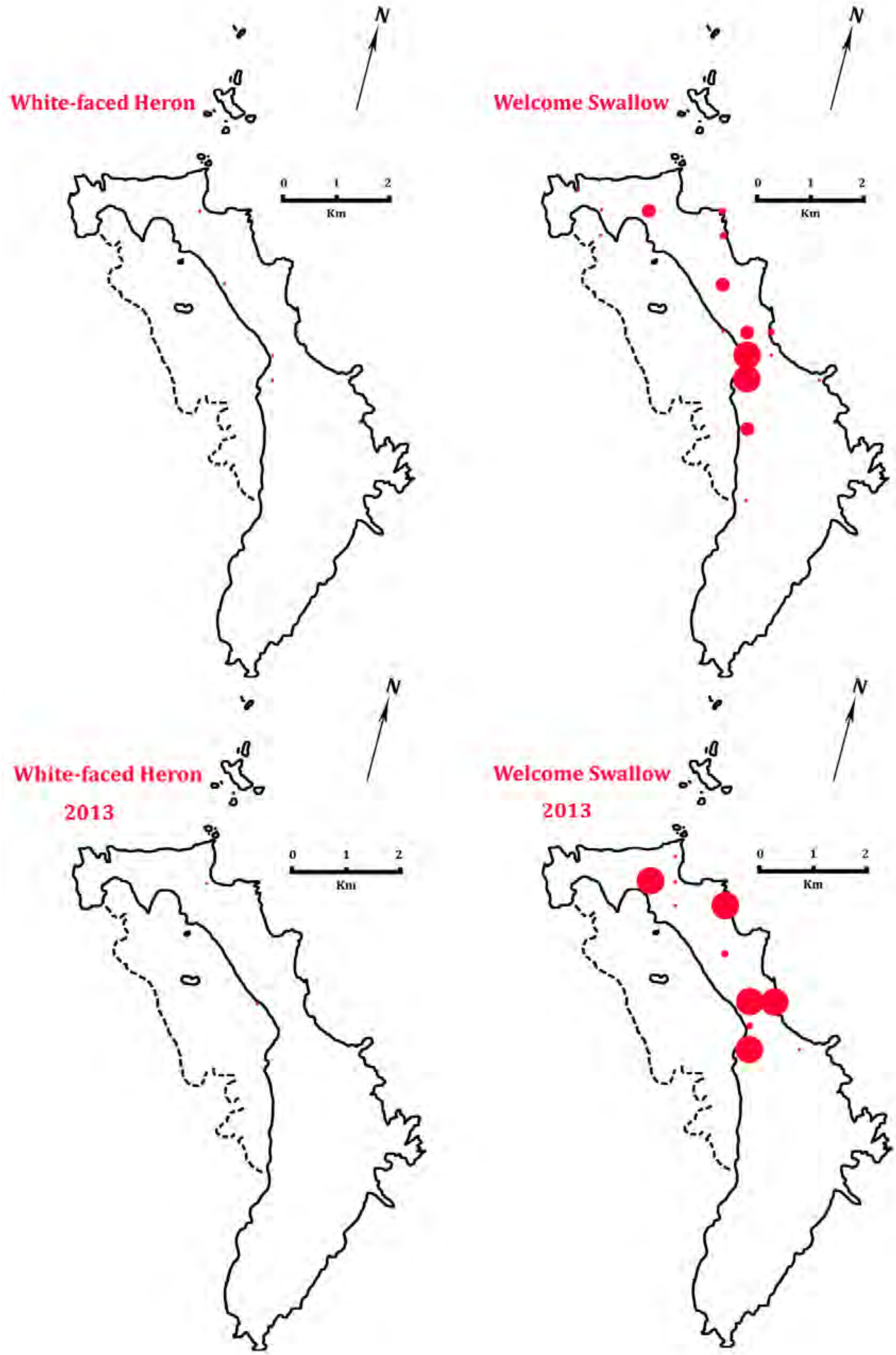

Figure 6. Distribution of White-faced Heron and Welcome Swallow, September 2013 and 2014 (upper), across northern LHI, by frequency of occurrence at count sites

Transect counts

In five days, seven observers recorded a total of 70 observations of the numbers of six species on the transects. As the speed of travel may influence the number of individuals counted – the faster the speed the fewer the number observed – the speed of travel for each transect was standardized to 2 km/hr in 2014.

In 2013, before standardization was applied, the average speed was 3.21 km/hr (range 1.94–4.47). In 2014, however, the average speed was 1.90 km/hr (range 1.54–2.16). Consequently, the variance in the speed of travel was significantly reduced (2013 variance 0.42, SD $\pm$ 0.64; 2014 variance 0.01, SD $\pm$ 0.11).

Song Thrush
No main fixed effects are significant (see Table 9). The magnitude of the estimates of the variances associated with the random effects are small, so the significance of these random effects were assessed by dropping each random effect one by one. The least significant random effect was removed and the remaining two tested by dropping each in turn. The selected final model had no fixed effects with only *Day* as the random effect. This model estimates the mean number of individuals per transect as 0.5 (95% confidence interval is 0.18 to 1.07).

Common Blackbird
Only *Direction* is significant, with the mean number of individuals recorded on the return traverse about four times greater that the outward observation. All three random effects are significant and retained in the model. The mean number of individuals seen on the outward journey is 9.4 (3.6 to 20.5) and for the return trip 13.6 (5.2 to 29.5). Note that there is a level of complexity here that is not fully clear. The confidence intervals are wide and substantially overlap, suggesting that there is no difference. However, a comparison of the two models, one with *Direction* and one without, clearly suggest otherwise. If one ignores the fixed effect, the estimated mean number of individuals is 10.4 (4.3 to 25.9).

Sacred Kingfisher
There is evidence that *Year* and *Duration* have an effect on the number of individuals observed (see Table 9); if *Year* is fitted then *Duration* does not contribute significantly to the model. The estimated number of individuals per transect in 2013 was 0.07 (0 to 0.18) and in 2014, 0.38 (0.16 to 0.67).

Woodhen
There is no evidence that *Year*, *Duration* or *Direction* are associated with the number of Woodhen recorded (see Table 9). *Transect (Identity*) is the only significant random effect. Based on this simple model the estimated number of Woodhen per transect is 0.22 (0.02 to 0.67) individuals.

Buff-banded Rail

There is no evidence that *Year*, *Duration* or *Direction* are associated with the number of Buff-banded Rail recorded (see Table 9). The two random effects, *Transect (Identity)* and *Day* appear to be significant while *Observer* is not significant. The estimated number of individuals per transect is 1.77 (0.36 to 5.63).

Emerald Dove

The only significant fixed effect is *Direction*. *Year* and *Duration* are not significant. *Transect (identity)* and *Day* have been retained as the random effects. The estimated number of individuals seen per transect on the outward count was 1.26 (0.49 to 2.54) and on the return count 0.50 (0.17 to 1.03) individuals.

Table 9 provides details of the significance of the fixed effects on the number of individuals of target species observed on the urban transects. The fixed effects were *Year* (2013, 2014), *Direction* (out, return) and *Duration*.

Table 9. Significance of fixed effects on the no. of individuals of target species observed on urban transects

Effect	*Song Thrush*	*Common Blackbird*	*Sacred Kingfisher*	*Woodhen*	*Buff-banded Rail*	*Emerald Dove*
Year	0.94	0.50	0.025	0.94	0.84	0.43
Direction	1.00	<0.001	0.45	0.51	0.15	<0.001
Duration	0.08	0.94	0.010	0.46	0.51	0.15

For most species there appears to be little difference in the abundance of the primary species recorded on the urban transects. The notable exception is the Sacred Kingfisher – more individuals were observed in 2014 compared with 2013. It remains one of the least abundant species recorded and, as such, it would be judicious to note the change but not draw inferences about annual variation at this stage.

Bird atlas data

Between 1 October 2013 and 28 January 2015 there were 4003 records entered on the Birdlife Australia database. These observations comprised 505 counts from 16 observers. There are 25 official BLA survey sites (LHI01-LHI25). The count protocol for the 25 Birdlife Australia sites can be found at

http://birdlife.org.au/documents/ATL-LHI-Lord_Howe_Bird_Monitoring_Site_Guide.pdf

The protocol for the remaining counts is unknown, with many counts simply designated "Lord Howe Island". Ignoring site LHI25, which is a count between Lord Howe Island and Ball's Pyramid, there were 2987 records from 413 counts. These counts were conducted by nine observers of which Observer # 68784 provided 86.5% of the observations from 90% of the surveys.

Between October 2013 and January 2015 counts were conducted regularly between October 2013 and July 2014 (see Table 10) with peaks in December 2013 and January 2014 and again in March 2014. There were virtually no surveys from August 2014 onwards. The majority of counts from other observers occurred in March 2014.

Table 10. No. of counts conducted by month from Observer #68784 compared with the no. conducted by eight other observers, October 2013–January 2015

	2013			*2014*												*2015*	
Ob-server	*O*	*N*	*D*	*J*	*F*	*M*	*A*	*M*	*J*	*J*	*A*	*S*	*O*	*N*	*D*	*J*	***Total***
#68784	30	37	80	79	38	33	40	19	10	8	0	0	0	0	0	0	***374***
Others	8	0	1	0	0	23	4	0	0	0	3	0	0	0	0	0	***39***

Table 11 gives the number of counts conducted at 24 Birdlife Australia sites between October 2013 and January 2015. The number of counts at LHI01-LHI12 sites are given above, while the number at LHI13-LHI24 sites are given below.

Counts at sites LHI03, LHI17 and LHI18 were made more frequently than at other sites, whereas counts at sites LHI08 to LHI12 and LHI19 to LHI24 were the least frequent.

Table 11. No. of counts conducted at 24 Birdlife Australia sites, October 2013–January 2015

Observer	*LHI01*	*LHI02*	*LHI03*	*LHI04*	*LHI05*	*LHI06*	*LHI07*	*LHI08*	*LHI09*	*LHI10*	*LHI11*	*LHI12*
# 68784	18	13	45	19	22	20	10	6	6	10	7	5
Others	4	3	7	2	0	1	5	2	2	2	0	0

Observer	*LH13*	*LHI14*	*LHI15*	*LHI16*	*LHI17*	*LHI18*	*LHI19*	*LHI20*	*LHI21*	*LHI22*	*LHI23*	*LHI24*
# 68784	20	20	14	10	49	57	7	7	6	1	1	1
Others	0	1	0	1	3	5	0	0	1	0	0	0

The large contribution by one observer and few observations by the remaining eight observers is evident in the BLA data. If similar survey efforts are applied pre- and post-eradication, then observations of the type provided by the current BLA data set is unlikely to be of use in modelling the eradication effects on the bird community of Lord Howe Island.

This is because counts conducted at different frequencies, in different ways by different observers, and not necessarily stratified to account for habitat differences, will not allow statistical inferences to be made with confidence.

Acknowledgements

The survey was conducted under an arrangement between the Lord Howe Island Board and the Canberra Ornithologists Group. The report was compiled by Peter Fullagar and Chris Davey with statistical input from A O (Nick) Nicholls. With his intimate knowledge of the flora and fauna of the island, Ian Hutton was responsible for the arrangements and logistical support on the island and he provided invaluable input. The survey teams were David and Kathy Cook, Michael Robbins, Christine Ledger, Gail Newmann, Ian Hutton, Peter Fullagar and Chris Davey all, apart from Ian Hutton, members of the Canberra Ornithologists Group.

We thank Birdlife Australia for providing us with a copy of records collected between October 2013 and January 2015 from the 25 Bird Monitoring Sites on the island. Finally, we thank David Priddel and Nicholas Carlile from the Office of Environment and Heritage, NSW Department of Premier and Cabinet, and the Lord Howe Island Board for their support.

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APPENDIXES

Appendix A. Geolocation, vegetation code, vegetation group and habitat zone for three sites whose position was moved from that in 2013

Site number	*Geolocation*		*Vegetation code*	*Vegetation group*	*Habitat zone*
	Latitude	*Longitude*			
19	31 31 00.1	159 02 52.7	1	1	1
25	31 30 49.1	159 03 21.5	1	1	1
26	31 30 49.3	159 03 25.8	1	1	1

Appendix B. Description of start point and turning point for all transects (A–G)

See Figure 2 for a map of the Lord Howe Island settlement area showing the seven transects. The protocol for these transect counts is also included here.

Description of each transect location

A. Intersection of Neds Beach Road and Lagoon Road to the bridge at Old Settlement Creek.

B. Intersection of Neds Beach Road and Lagoon Road to Neds Beach bathing huts.

C. Intersection of Anderson Road and Neds Beach Road to the corner at the top of Middle Beach Road.

D. Intersection of Anderson Road and Muttonbird Drive up to and along Skyline Drive down McGees Parade to the intersection with Anderson Road.

E. Intersection of Middle Beach Road and Lagoon Road up Middle Beach Road to Anderson Road turning right (S) and down Anderson Road to Bowker Avenue walking track (which is a little difficult to see but is on the W or right hand side of the road and marked by a small triangular trail marker).

F. Intersection of Middle Beach Road and Lagoon Road to the gate at the corner of the air-field at Windy Point.

G. Intersection of Ned's Beach Road with Lagoon Road to the intersection of Middle Beach Road and Lagoon Road (beside the LHI Museum).

Protocol for transect counts

1. Count only the six species of birds (Buff-banded Rail, Woodhen, Sacred Kingfisher, Emerald Dove, Blackbird and Song Thrush). Include all seen or heard on a slow walk from the defined start point to the defined finish point (outward count) and, as a new count, on the return walk to the start point (return count). Keep these two counts separate.

2. Count in the evening not before 17:00 in September – later in mid-summer.

3. Indicate which transect you have counted and include your name and the date.

4. Record the start and finish time for your outward count and your return count.

5. Count all individuals you detect both sides of the road. There is no particular limit on distance but it would be reasonable not to include calls from birds or sightings that are, say, more than 25 metres from the roadside. Do not worry that you might count the same individual or individuals that could have been be seen on another transect at the transect intersections. Just include them as part of your transect count, if you spot them.

Appendix C. Bird species recorded at 96 survey sites, LHI, 2014

Species nomenclature and names follow those recommended by the latest IOC listing (see Gill and Wright, 2006, revised 2013 as version 3.5). For some species we use a simplified alternative in this report.

Name used in this report	*IOC recommended name, if different*	*Scientific name*	*Subspecies*
White-faced Heron		*Egretta novaehollandae*	
Woodhen	Lord Howe Woodhen	*Gallirallus sylvestris*	
Buff-banded Rail		*Gallirallus philippensis*	
Swamphen	Purple Swamphen	*Porphyrio porphyrio*	
Masked Lapwing		*Vanellus miles*	*novaehollandiae*
Bar-tailed Godwit		*Limosa lapponica*	
White Tern[1]		*Gygis alba*	*candida*
Sooty Tern [1]		*Onychprion fuscatus*	*kermadeci*
Black Noddy[1]		*Anous minutus*	
Emerald Dove	Pacific Emerald Dove	*Chalcophaps longirostris*	*rogersi*
Sacred Kingfisher		*Todiramphus sanctus*	*vagans*
Pied Currawong		*Strepera graculina*	*crissalis*[2]
Golden Whistler	Australian Golden Whistler	*Pachycephala pectoralis*	*contempta*[2]
Magpie-lark		*Grallina cyanoleuca*	
Welcome Swallow		*Hirundo nigricans*	
Silvereye		*Zosterops lateralis*	*tephropleurus*[2]
Blackbird	Common Blackbird	*Turdus merula*	
Song Thrush		*Turdus philomelos*	
Red-necked Stint		*Calidris ruficollis*	

Notes: 1. Seabirds, so not analyzed

2. Endemic subspecies

Landbirds on Lord Howe Island, NSW

Survey report 1, September 2013

Prepared for the Lord Howe Island Board

by the Canberra Ornithologists Group

Peter Fullagar, Chris Davey, A O Nicholls and Ian Hutton

February 2014

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Summary

This report describes a survey in September 2013 of landbirds on Lord Howe Island conducted by the Canberra Ornithologists Group (COG). It was the first of what is intended to be an annual assessment of the status of landbirds on the island. The survey will be repeated each September for at least the next four seasons (2014–2017). This and the further surveys have been commissioned by the Lord Howe Island Board as part of the necessary monitoring processes associated with a plan to eradicate rodents from the island.

The purpose of the survey is to provide baseline information on the numbers and distribution of landbirds on Lord Howe Island. Point counts were chosen as the preferred method for the island survey. The data collecting protocol used is one we believe best fitted the limitations for time and effort available in the field. Transects surveys were conducted over two evenings to survey most of the ground-feeding species present in the settlement area.

The results of the survey are compared with a similar survey conducted by the Canberra Ornithologists Group in March 2007 and with an environmental survey of the island conducted in 1971–72.

Forty-eight paired sites were selected across the survey area, stratified to represent various vegetation types and habitat zones with seven transects selected within the settlement area. For the plots four teams of two observers surveyed all paired sites in four days with approximately 75% of sites resurveyed over the following three days.

The mean abundance, mean reporting rate, frequency and group size for each of the 16 species recorded during the survey was calculated. Maps of species distribution for 12 species with sufficient data are compared with the observations obtained in 1971-72 and in March 2007.

The most common bird was the Golden Whistler followed by the Silvereye. A noticeable reduction in all indices occurred for the next three most frequently reported species – Blackbird, Magpie-lark and Pied Currawong – but for the rest all indices, except group size, were much smaller.

The protocol for this baseline survey provides a rigorous survey method for obtaining data giving statistically sound measures of significant changes in population numbers and distribution of species between surveys – particularly before and after the proposed rodent eradication for mid 2015.

Introduction

This report describes a survey in September 2013 of landbirds on Lord Howe Island (latitude 31° 33´S and longitude 159° 05´E). It was the first of what is intended to be an annual assessment of the status of landbirds on the island. The survey will be repeated each September for at least the next four seasons (2014–2017).

This and the further surveys have been commissioned by the Lord Howe Island Board as part of the necessary monitoring processes associated with a plan to eradicate rats and mice from the island. This eradication is now scheduled for mid 2015.

The purpose of the survey is to provide baseline information on the numbers and distribution of landbirds on Lord Howe Island. Landbirds are here defined as those species that are either breeding residents on the island or visitors that are land-based. Specifically, all seabirds are excluded but shorebirds are not.

A rigorous survey method was required to provide data that can give a statistically sound measure of significant changes in population numbers and distribution – if they occur. This survey was the first of two surveys made before the eradication program occurs.

Point counts were chosen as the preferred method for the island survey. Much of the vegetation is dense and often difficult to access; repeated line transects would have been difficult to follow in such circumstances. Point counts are easier to incorporate in a formally designed study, easier to locate and lay out, and they provide a more reproducible data set. As well, point counts are more efficient than transect counts because they allow for more data points (Bibby *et al.,* 1997).

We investigated the power of available statistical analyses achievable with this method of population assessment (Nicholls unpublished) and adopted the data collecting protocol we believe best fitted the limitations for time and effort available in the field. As an additional data set we did, however, use a simple transect procedure to assess the abundance of six species within the most closely settled area of the island. These transects were walked at dusk using the network of sealed roadways.

In September 2013 the Canberra Ornithologists Group (COG) surveyed birds in the same areas of the northern section of Lord Howe Island that was surveyed in March 2007. The earlier study was intended as a practical trial of the field methods proposed for the 2013 study. The data collected in 2007, although from a different time of the year, has been used in this September report to compare frequency distributions of species mapped in both surveys.

By early July 2013, in conjunction with the Lord Howe Island Board and Birdlife Australia, 24 Bird Monitoring Sites (LHI01-LHI24) had been identified for the general public to monitor bird populations on the island. Although not part of the present survey, a summary of these observations is included to provide a full account of available data before and during the survey conducted by the Canberra Ornithologists Group in September 2013.

The historical record of birds on Lord Howe Island

Hutton (1991) provides a comprehensive review of the status of birds on Lord Howe Island up to 1990. McAllan *et al.* (2004) review all records up to the end of 2003 and provide a systematic list of all species recorded from the island.

From the time of the island's discovery in 1788, when several birds are clearly described (see Fidlon and Ryan, 1979), only occasional observations on the avifauna were reported for most of the nineteenth century, although specimens of several species were collected and deposited in museums within Australia and Europe (see McAllan *et al*., 2004). Early last century, however, Roy Bell was commissioned by Gregory M Mathews to collect bird specimens on the island as part of Mathews' major work on Australian birds (Mathews 1928; 1936). Bell collected extensively between 1912 and 1914 (unpublished MS) and his handwritten journal gives a clear indication of the species then present and some idea of their distribution and abundance. More recently, Hindwood (1940) describes the status of the surviving avifauna on Lord Howe Island following the disastrous accidental introduction of Black Rat (*Rattus rattus*) in 1918 when the trading vessel *Makambo* was stranded.

The next major study of birds on Lord Howe Island resulted from a broad environmental survey by the Australian Museum in 1971–2. The report by Recher and Clark (1974) includes a detailed review of the distribution and status of all birds on the island at that time (Fullagar *et al*., 1974). This 1971–2 environmental survey was designed to provide some basic ecological data for future planning decisions affecting the island (Hutton, 1991).

At the time of discovery in 1788 the species composition of the avifauna on Lord Howe Island probably included, with the exception of regular visitors and vagrants, a duck, seven petrels, a tropic-bird, a booby, four rails, five terns, two pigeons, a parakeet, a small owl, a kingfisher, a currawong, a gerygone warbler, a whistler, a fantail, two white-eyes, a thrush, and a starling. Of these birds, one of the rails, one of the pigeons, the parakeet, the small owl, the warbler, the fantail, one of the white-eyes, the thrush and the starling are now extinct. However, it seems unlikely that any seabirds became extinct on Lord Howe Island over this same period of two centuries.

Several species have been added to the avifauna of Lord Howe Island in historic times – either by natural colonization or in some instances by deliberate introduction. These include a duck (feral hybrids originating from New Zealand), a heron, a kestrel, a lapwing, a feral domestic pigeon, a large forest owl, the Magpie-lark, a swallow, two thrushes, and a starling (none of the last three species being the same as those that had become extinct). On balance, this number is slightly more than the number lost by extinction.

Methods

Choice of survey sites

For practical reasons, determined by the time available for surveying and the number of teams we could muster, only the northern part of Lord Howe Island was included. Mt Lidgbird and Mt Gower were excluded, Erskine Valley and any of the mountain slopes below these peaks beyond Mutton Bird Point and Little Island (see Figure 1).

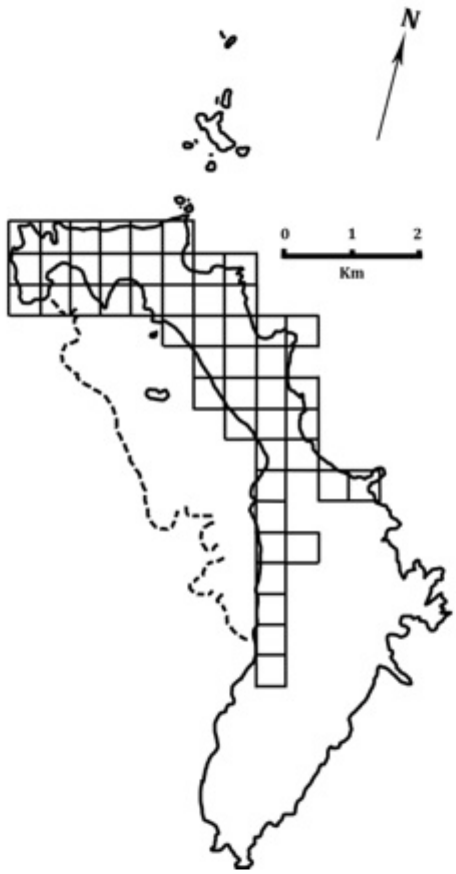

Figure 1. Grid cells, based on point counts, used for surveying distribution of landbirds on LHI, September 2013

Forty-eight paired sites were selected across the survey area, stratified to represent the various vegetation types and habitat zones. Vegetation types were taken from Pickard (1983). The vegetation maps produced by Pickard schematically represented the spatial distribution of the original vegetation, some of which has now been cleared or disturbed. The survey sites were distributed within 10 vegetation types and include both the original vegetation types and superimposed cleared or disturbed vegetation types. For simplicity, the 10 vegetation types were allocated to one of three vegetation groups – Lowland forest (1), Palm forest (2) and Open (3) – loosely based on vegetation structure (see Table 1).

Table 1. Vegetation classification of 96 sites on LHI, by code, group and number of sites

Vegetation type	*Vegetation code*[1]	*Vegetation group*	*Number of sites*
Drypetes australasica/Cryptocarya triplinervis	1	1	42
Drypetes australasica/Cryptocarya triplinervis (calcarenite variant)	2	1	1
Drypetes australasica/Cryptocarya triplinervis (exposed variant)	3	1	7
Cassinia tenuifolia-Poa poiformis	4	1	2
Howea forsterana	5	2	22
Pasture	6	3	14
Dune	7	3	2
Golf course	8	3	2
Cleistocalyx fullageri	9	2	2
Pasture/Howea forsterana	10	2	2

[1] Note: Calcarenite and exposed variants are treated as one type – giving a total of four paired sites.

In addition, the sites were grouped into five habitat zones representing various degrees of human settlement and activities that may affect the distribution of the avifauna (see Table 2).

Table 2. Habitat classification of 96 sites, LHI

Habitat zones	*Habitat zone*	*Number of sites*
North Hills	1	28
Settlement	2	28
Transect Hill	3	11
Suburban	4	12
South Hills	5	17

Point count protocol

Our protocol involved four teams of two observers surveying over seven days. Surveying was restricted to between sunrise and late morning. Each team had sufficient time to survey six sites per day. All 96 sites could be surveyed in four days. Approximately 75% of the sites were then resurveyed over the following three days.

The paired sites were a minimum of 100 metres apart but were similar in topography and vegetation (see Appendix A for site details of geolocation, vegetation and habitat type).

The count protocol at each site was to record the abundance of each species seen or heard within a 50-metre radius over a 10-minute period, with observers moving within the plot area if required. Team members would survey a pair of sites independently and simultaneously before swapping sites and again counting for 10 minutes.

Twenty-one of the paired sites were visited twice while 27 of the paired sites were visited four times. This gave a total of 300 counts (see Table 3). No site was resurveyed by the same observer. Repeatability of counts at a site could therefore be tested between two observers over a short period (10 minutes) for 21 paired sites, and over a short period (10 minutes) and a long period (one day or more) for four observers for 27 paired sites.

Only experienced observers were chosen for the field work. All team members were well-trained, expert bird watchers with considerable previous involvement with similar style field work.

Table 3. Number of surveys for 96 sites, LHI

Site numbers	*Number of sites*	*Number of surveys*
1–24	24	48
25–48	24	96
49–54	6	12
55–72	18	72
73–78	6	12
79–90	12	48
91–96	6	12
Total	**96**	**300**

Statistical treatment of site counts

Several statistical parameters were used as population indices and these will become useful for comparison with data collected in future.

- *Mean abundance* (A). The average number of individuals of a species seen per observation and defined as the sum of the number of individuals reported divided by the total number of observations (300).
- *Mean reporting rate* (R). Defined as the number of recorded occurrences divided by the total number of observations (300).
- *Frequency* (F). The site occupancy rate or incidence rate defined as the number of sites on which a particular species was recorded divided by the total number of sites (96).
- *Group size* (G). Defined as the sum of the number of individuals divided by the number of observations in which a species was recorded

  .

Site counts in March 2007

In March 2007 a trial of our survey method was completed by a larger group of observers. A total of 136 site counts was made ranging across the same areas counted in 2013. In 2007 there were seven teams, each of two or more observers. The sites chosen were not the same as those used in 2013, and the count protocol differed to the extent that there was a predetermined GPS location to which was added (in the field) a nearby site, of similar habitat, at least 100 metres distant from the predetermined count site. A fresh GPS location was recorded for all count sites as they were made. In other respects the count protocol did not differ greatly from that used in 2013; no sites were counted more than once.

Transect surveys

In September 2013 seven transects of variable length (ranging from 570 to 970 metres) were walked at a slow pace (ranging from 1.9 to 4.5 km/hr) by a single observer twice (in one direction and then return) on two days. The transects followed sealed roads.

Figure 2 provides a map of the Lord Howe Island core settlement area, showing the location of transects A–G. The green pointers indicate junctions, where more than one transect starts or finishes. The yellow pointers indicate transect end points. See Appendix B for a description of the start and finish points for each transect.

Figure 2. Map of core settlement area, LHI, with location of transects A–G

In general, no pair of observers walked the same two transects (see Table 4). For practical purposes only six species were targeted for the transect counts. The purpose of the transact counts was to survey most of the ground-feeding species present in the settlement area. It is envisaged that in future, however, transect surveys will be conducted every available evening and may include other species.

Table 4. Allocation of observers to transects, LHI core settlement, September 2013

Observer	*Av. speed (km/hr)*	*Transects*						
		A	*B*	*C*	*D*	*E*	*F*	*G*
Ob1	2.9	0	2	0	0	0	2	0
Ob2	2.6	0	2	0	0	0	2	0
Ob3	2.7	2	0	2	0	0	0	0
Ob4	3.1	0	0	2	2	0	0	0
Ob5	3.9	0	0	0	0	2	0	2
Ob6	4.0	0	0	0	2	2	0	0
Ob7	3.2	2	0	0	0	0	0	2
Transect length (m)		*750*	*970*	*900*	*570*	*820*	*970*	*670*

Statistical analysis of transect data

The potential predictors of the abundance of a species include transect number, observer, date, transect length, survey duration and speed. The nature of the predictors suggests that a multilevel or mixed model should be considered. In addition, the fact that the abundance estimates are simple counts of individual birds seen also suggests that a generalized linear model be fitted. The first three factors of the above list are categorical variables and could all be considered as random effects, while the last three are continuous variables and are probably better thought of as fixed effects.

Generalized linear mixed models were fitted to the count data of the following species: Blackbird, Buff-banded Rail, Emerald Dove and Song Thrush. Statistical software R (R Core Team, 2013) was used. The core packages were supplemented with “lme4” (Bates *et al.,* 2013) and “Arm” (Gelman and Yu-Sung, 2013) packages. A full model was fitted for each species and the random effects removed one by one and tested to establish which random effects contribute to the model. The fixed effects were then removed, again one by one and tested using a log likelihood ratio test.

The estimated number of individuals and 95% confidence limits were derived from the final fitted model taking into account the random effects, if necessary, following procedures outlined in Gelman and Hill (2007)**.**

Species names

Species names used in this report follow current preferred internationally accepted nomenclature (see Appendix C). For simplicity, some of the common names have been shortened to conform with island usage.

Survey dates and weather conditions

The 2013 survey was conducted between 8 and 14 September. Teams were in the field soon after dawn each day and ready to start by about 0600. Teams often worked through until late morning. The time to complete a set of counts varied mostly due to the time taken to reach all allotted count sites.

Most days were overcast with light winds, which generally blew from the W or N except on the second survey day (E) and on the sixth survey day (SSW). Light showers delayed departure by about an hour on the second morning; it was windy on the third and fourth mornings when conditions may have been marginal for optimal surveying at a few count sites because the rustle of tree leaves was noisy. However, detection of birds by call was probably not diminished significantly within the short range of 50 metres from an observer. Day five was a perfect surveying day – warm with no wind and a clear sky. It was again windy with the threat of rain on the last day but conditions were not so serious that we needed to abandon surveying. Some weather observations for the week are shown in Table 5.

Table 5. Selected daily weather observations, LHI, 7–14 September 2013

					Max wind gust		
Date	*Day*	*Min °C*	*Max °C*	*Rain (mm)*	*Direction*	*Speed (km/h)*	*Time*
7	Sat	11.2	20.5	0	W	28	08:54
8	Sun	17.4	21.0	0	WNW	31	12:08
9	Mon	14.7	20.8	3.6	E	52	04:55
10	Tue	16.6	21.9	0	NNW	43	19:47
11	Wed	18.9	22.3	0	N	57	03:17
12	Thu	12.1	21.0	0.4	NW	57	03:17
13	Fri	15.3	18.4	13.6	SSW	50	12:47
14	Sat	11.4	19.8	0	NNE	54	20:23

Source: Bureau of Meteorology website

Results and discussion

Site counts

The maximum number of times that any one species could be recorded was 300: the sum of 42 sites each with two visits and 54 sites each with four visits. Table 6 shows the distribution of the *sites* in the vegetation groups and habitat zones.

Table 6. No. of count sites in three vegetation types in five habitat zones, LHI

Vegetation group[1]	*Habitat zone*[2]					**Total count sites**
	1	*2*	*3*	*4*	*5*	
Lowland forest	26	6	8	4	8	**52**
Palm forest	2	14	2	0	8	**26**
Open	0	8	1	8	1	**18**
Total surveys	**28**	**28**	**11**	**12**	**17**	**96**

[1] See Table 1.
[2] See Table 2.

By contrast, Table 7 shows the distribution of *counts* within the 10 vegetation groups in the five habitat zones.

Table 7. No. of counts in three vegetation groups in five habitat zones, LHI

Vegetation group[1]	*Habitat zone*[2]					**Total counts**
	1	*2*	*3*	*4*	*5*	
Lowland forest	60	24	28	16	16	**144**
Palm forest	4	52	4	0	28	**88**
Open	0	32	4	28	4	**68**
Total surveys	**64**	**108**	**36**	**44**	**48**	**300**

[1] See Table 1.
[2] See Table 2.

Abundance, reporting rate, frequency and group size

Table 8 shows the abundance, reporting rate, frequency and group size, irrespective of vegetation or habitat, for 16 birds recorded in 96 survey sites on Lord Howe Island. The reporting rate is given in descending order.

The most common bird in terms of reporting rate and abundance was the Golden Whistler. The number of Silvereye individuals in a survey plot was difficult to estimate given their flocking behaviour, their quick passage through the survey plots and the fact that they were usually detected only by calls. For the Silvereye, only occurrence was analysed and no estimate of abundance or group size was possible.

A noticeable reduction in all indices occurred for the next three most frequently reported species – Blackbird, Magpie-lark and Pied Currawong – but for the rest all indices, except group size, were much smaller.

Table 8. Abundance, reporting rate, frequency and group size for 16 bird species recorded in 96 survey sites, LHI

Species Name	*Abundance*	*Reporting rate*	*Frequency*	*Group size*
Golden Whistler	1.65	0.71	0.88	2.33
Silvereye		0.69	0.83	
Blackbird	0.50	0.24	0.29	2.11
Magpie-lark	0.46	0.23	0.33	2.03
Pied Currawong	0.29	0.20	0.36	1.46
Emerald Dove	0.18	0.14	0.28	1.29
Buff-banded Rail	0.17	0.11	0.17	1.55
Sacred Kingfisher	0.11	0.09	0.18	1.19
Swamphen	0.13	0.06	0.10	2.05
Woodhen	0.08	0.06	0.11	1.21
Masked Lapwing	0.07	0.05	0.10	1.57
Song Thrush	0.04	0.04	0.08	1.18
Feral Pigeon	0.05	0.01	0.04	3.75
Feral Duck	0.05	0.01	0.02	5.00
White-faced Heron	0.01	0.01	0.02	1.00
Starling	0.01	0.01	0.02	1.50

Table 9 shows the reporting rate, abundance and frequency for the most commonly reported species, the Golden Whistler, and the two species of greatest concern: the Woodhen and the Pied Currawong. The three indices for observations within the plot area are presented defined by vegetation and habitat zone. For the Golden Whistler, the lowest reporting rate and abundance was in vegetation group 3 (Pasture, Dune, Golf course) within habitat zone 2 (Settlement) and 4 (Suburban), while the highest frequency was in vegetation group 1 *(Drypetes/Cryptocarya*) within habitat zone 1 (North Hills).

For the Woodhen, the highest reporting rate and abundance was in habitat zone 4 (Suburban) within vegetation group 1 (*Drypetes/Cryptocarya*) and group 3 (Pasture, Dunes, Golf course). The highest reporting rate and abundance for the Pied Currawong was in habitat zone 4 (Suburban) within vegetation group 1 (*Drypetes/Cryptocarya*).

Table 9. Reporting rate, abundance and frequency for the Golden Whistler, Woodhen and Pied Currawong, defined by vegetation group and habitat zone

Golden Whistler									
	Reporting rate			Abundance			Frequency		
Vegetation Group	1	2	3	1	2	3	1	2	3
Habitat zone									
1	0.88	1.00		1.92	2.25		0.27	0.02	
2	0.92	0.79	0.09	2.38	2.10	0.09	0.06	0.14	0.03
3	0.96	1.00	0.50	2.39	2.50	1.50	0.08	0.02	0.01
4	0.88		0.29	1.94		0.39	0.04		0.04
5	0.75	0.68	1.00	1.81	1.50	1.75	0.07	0.07	0.01

Woodhen									
	Reporting rate			Abundance			Frequency		
Vegetation Group	1	2	3	1	2	3	1	2	3
Habitat zone									
1	0.02	0.00		0.02	0.00		0.01	0.00	
2	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.01	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.38		0.21	0.56		0.21	0.03		0.03
5	0.06	0.14	0.00	0.06	0.18	0.00	0.01	0.02	0.00

Pied Currawong									
	Reporting rate			Abundance			Frequency		
Vegetation Group	1	2	3	1	2	3	1	2	3
Habitat zone									
1	0.23	0.00		0.27	0.00		0.09	0.00	
2	0.13	0.08	0.03	0.25	0.12	0.06	0.02	0.04	0.01
3	0.25	0.50	0.25	0.32	0.50	0.25	0.04	0.01	0.01
4	0.75		0.00	1.38		0.00	0.04		0.00
5	0.19	0.43	0.00	0.19	0.68	0.00	0.02	0.07	0.00

Species distribution

Figures 3–5 show the 2013 frequency distribution of 12 species across the lowlands of Lord Howe Island. These distribution maps are based on the relative occurrence of each species derived from the accumulated site counts. Site counts have been distributed within a grid pattern extending across the survey area (see Figure 1). For most grids there are two paired counts available, but for some only a single count was within the grid. For one grid three paired count sites were included. Correction for differences in the number of paired site counts for each grid were taken into account, bearing in mind that some paired sites were counted twice and others four times during this survey (see Methods). Distribution maps were not prepared for four species with too little data: White-faced Heron, Feral Duck, Feral Pigeon and Starling.

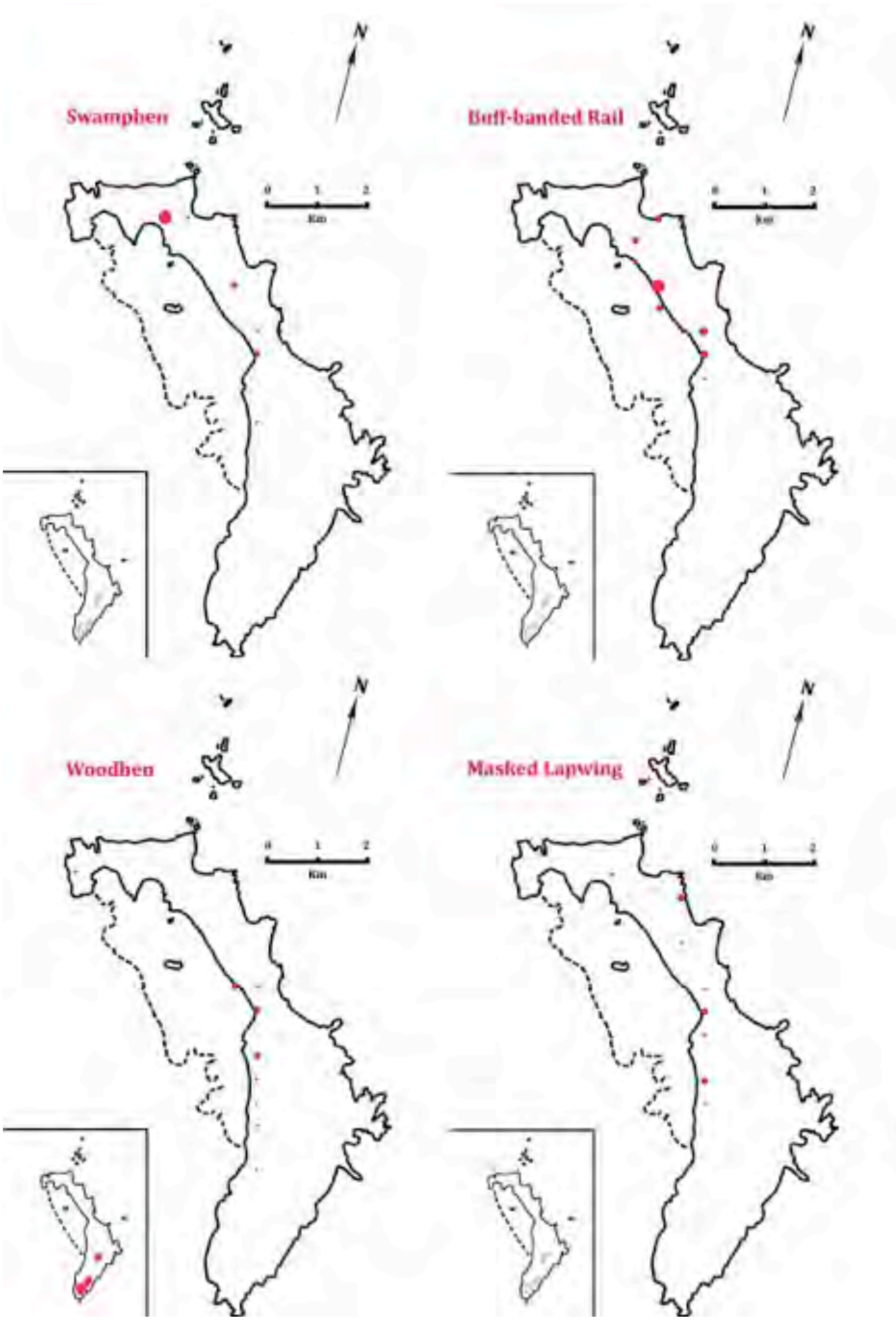

Figure 3. Distribution of Swamphen, Buff-banded Rail, Woodhen and Masked Lapwing, September 2013, across northern LHI, by frequency of occurrence at count sites

The size of each dot corresponds to the number of times each species is recorded as present within each grid cell. The smallest dot indicates a single occurrence, with increasing dot size for 2–4 and 5–7 occurrences, leaving the largest dot to indicate a maximum of 8 out of 8 counts. On each species map the vignette (lower left) shows the distribution of that species as recorded in 1971–2 (reproduced from Fullagar *et al*., 1974). Note that the Swamphen, Buff-banded Rail and Masked Lapwing did not occur on Lord Howe Island at that time.

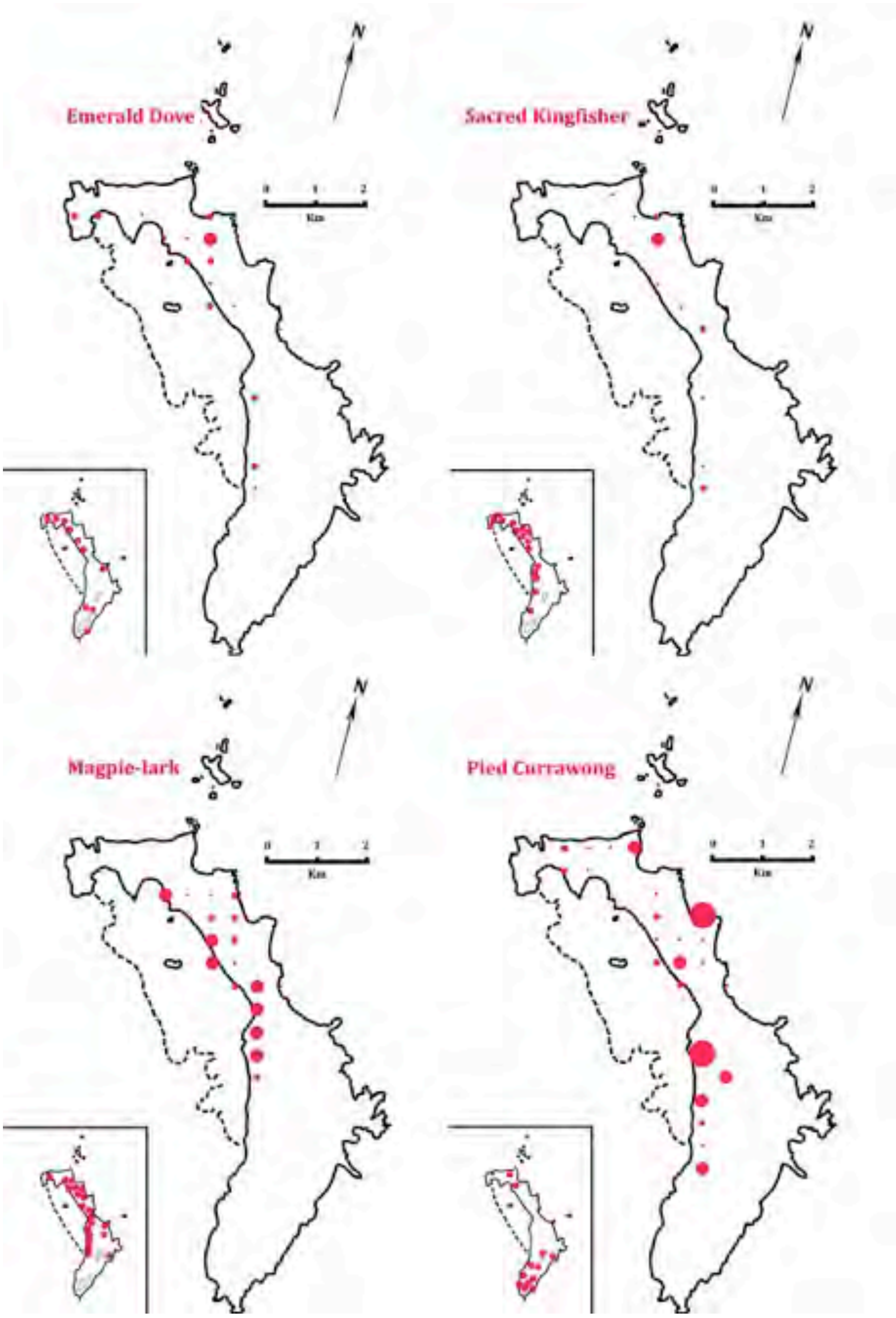

Figure 4. Distribution of Emerald Dove, Sacred Kingfisher, Magpie-lark and Pied Currawong, September 2013, across northern LHI, by frequency of occurrence at count sites

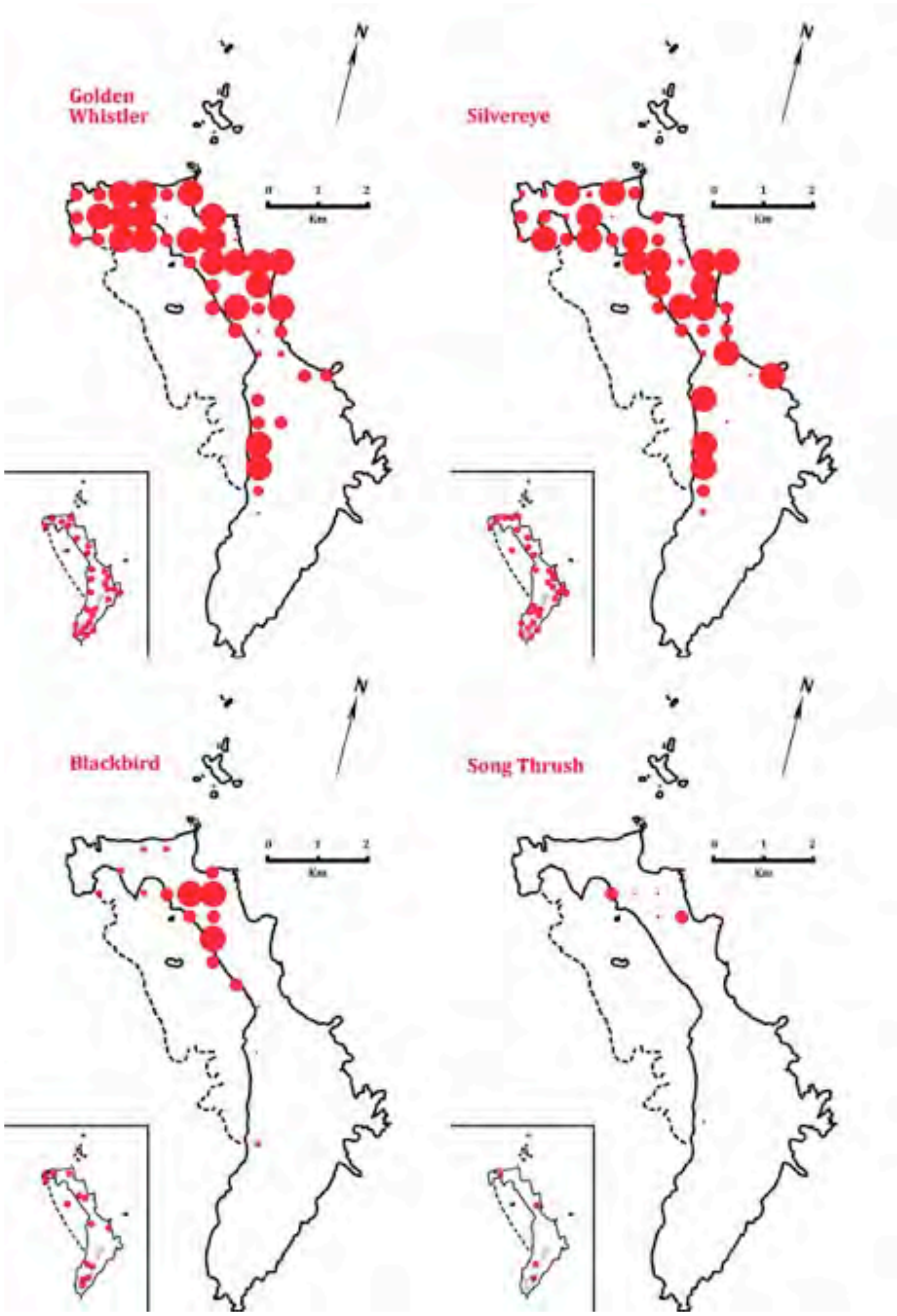

Figure 5. Distribution of Golden Whistler, Silvereye, Blackbird and Song Thrush, September 2013, across northern LHI, by frequency of occurrence at count sites

Count sites in 2007 were distributed within a pattern of grid cells similar to those used for the 2013 mapping (see Figure 6).

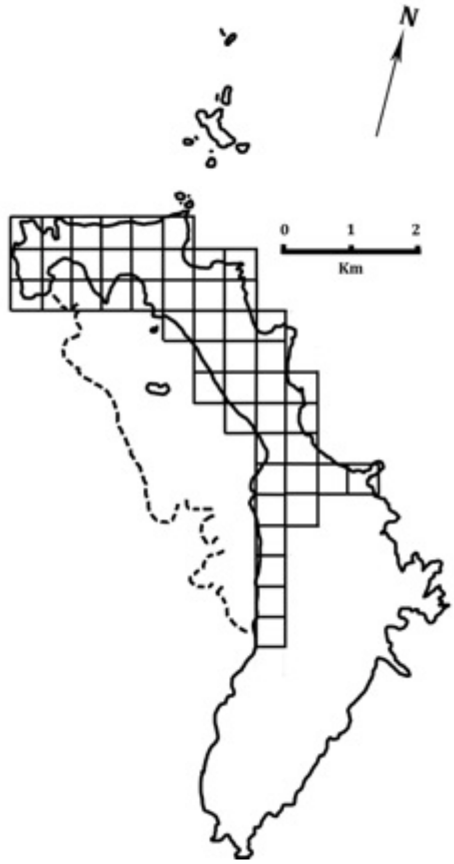

Figure 6. Grid cells used for surveying distribution of landbirds on LHI, based on March 2007 point counts

Maps prepared from data collected in March 2007 are shown in Figures 7–9. The original intention in 2007 was that each grid cell would be represented by two paired counts giving a total of four counts for the grid. However, in preparing the maps in Figures 7–9, allowance had to be made for grids with less than two paired counts (25 grid cells had only one paired count, two grids had only one count and one had three counts) with proportional adjustments made to the available numbers to make them comparable with grids having four counts.

The size of each dot corresponds to the number of times each species is recorded as present within each grid cell. The smallest dot indicates a single occurrence with increasing dot size for 2 and 3 occurrences leaving the largest dot to indicate a maximum of 4 out of 4 counts.

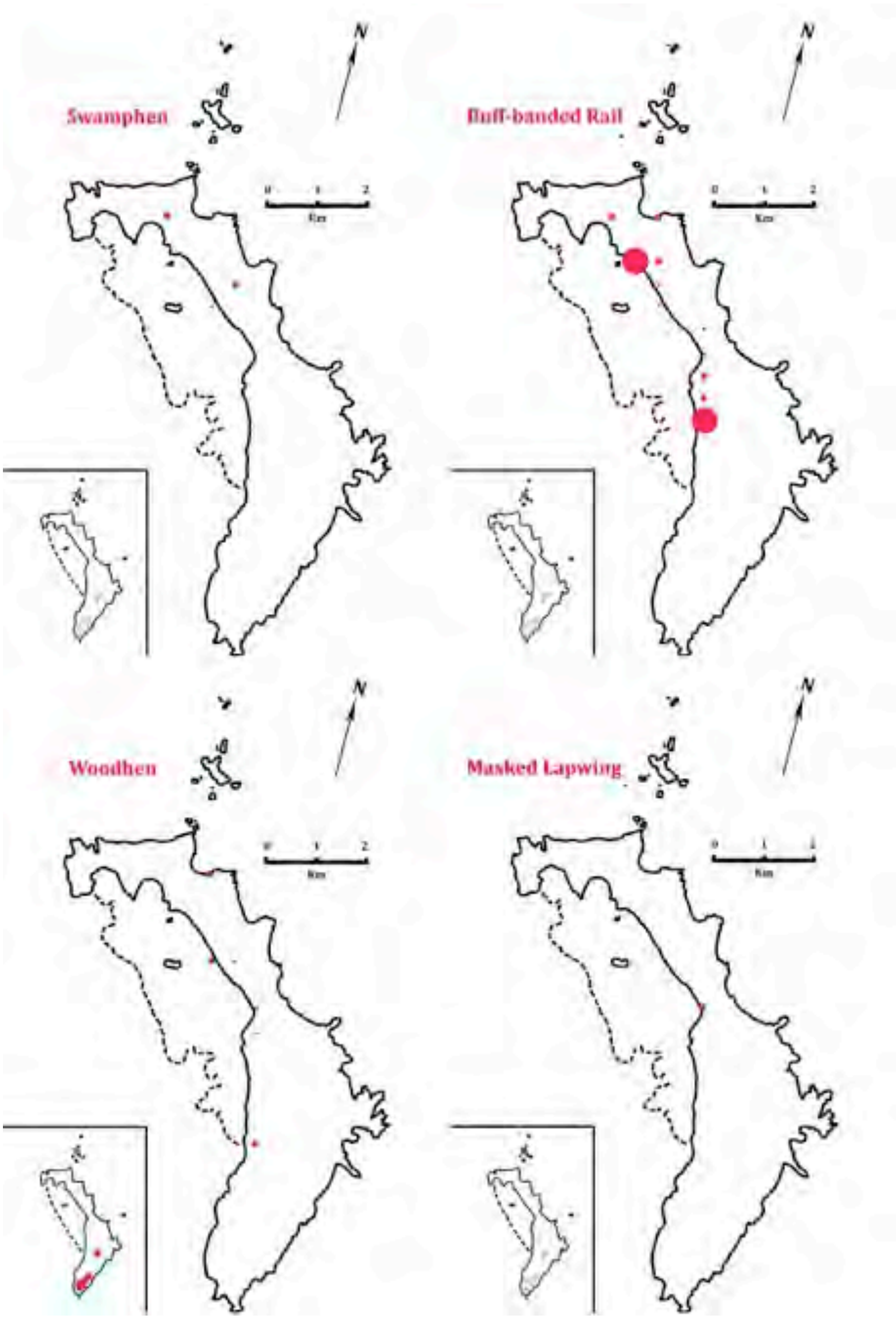

Figure 7. Distribution of Swamphen, Buff-banded Rail, Woodhen and Masked Lapwing, March 2007, across the northern areas of LHI, by frequency of occurrence at count sites

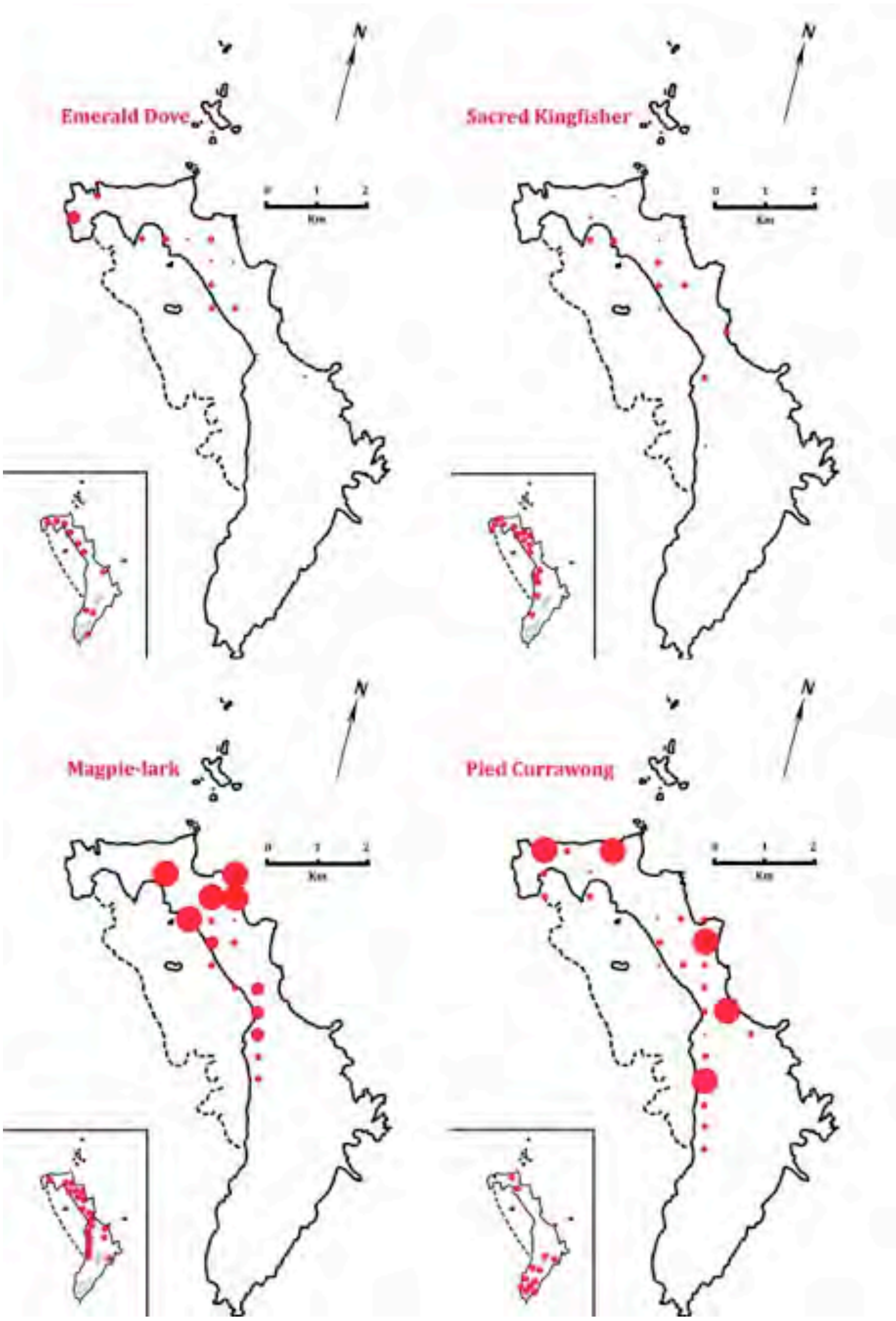

Figure 8. Distribution of Emerald Dove, Sacred Kingfisher, Magpie-lark and Pied Currawong, March 2007, across northern LHI, by frequency of occurrence at count sites

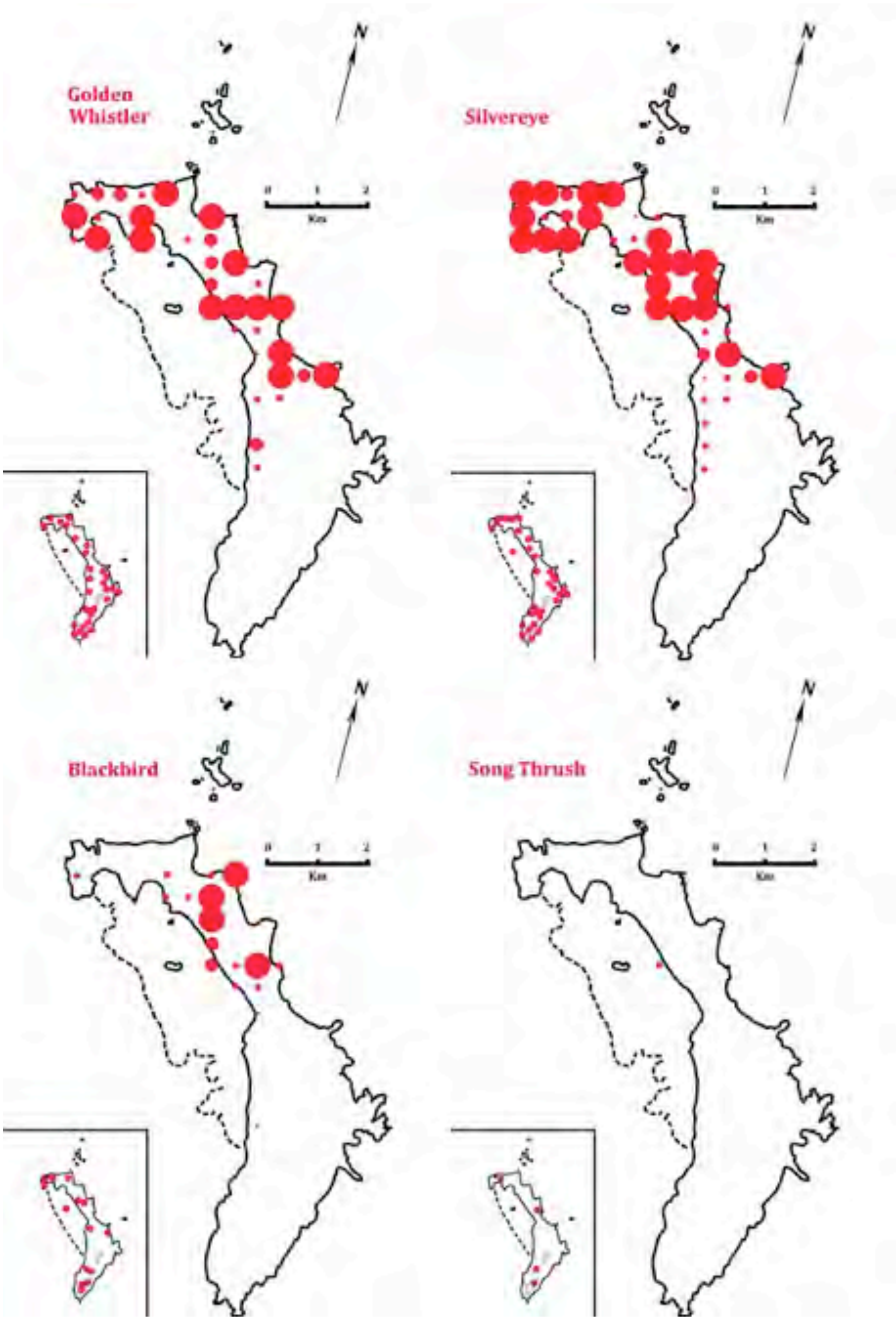

Figure 9. Distribution of Golden Whistler, Silvereye, Blackbird and Song Thrush, March 2007, across northern LHI, by frequency of occurrence at count sites

The most widespread species were Magpie-lark, Pied Currawong, Golden Whistler, Silvereye and Blackbird and their distribution was not very different when comparing data from 2007 with 2013. Magpie-larks avoid the mountain areas of the southern parts of the island but all the other species are widespread (see 1971–2 maps). The Silvereye is clearly the most widespread landbird on Lord Howe Island.

Again, the distribution patterns of Emerald Dove and Sacred Kingfisher differed little between the 2007 and 2013 maps. They are far less abundant landbirds, with the Sacred Kingfisher restricted to lowland areas, but not so the Emerald Dove (see 1971–2 maps).

Swamphen, Buff-banded Rail and Masked Lapwing only occur on the island's lowlands. None of the three species was present in 1971–2. The maps indicate that the Buff-banded Rail and the Woodhen were sparsely distributed in 2007 and 2013. Both species were also far less frequently detected across the lowlands than most other landbirds.

The Woodhen in 1971–2 had a restricted distribution range (as it had been for many years), to the summit plateau of Mt Gower, with a single record from Mt Lidgbird. It is now patchily distributed across the lowlands with only a small number present in the northern hills at North Bay. Most Woodhens occur within the closely settled parts of the lowlands and particularly in the lowland forests at the southern end of the surveyed area. The least widespread landbird was the Song Thrush. This seems to have been always so with few seen in 2007 and as far back as 1971–2.

During the 2013 survey, 20 Woodhen and 10 Pied Currawong were held in captivity in a trial of methods needed for securing these species during the proposed rodent eradication.

Transect counts

The average duration of a transect walk was 16 minutes (range 9–30 minutes). This gave a total of 28 observations of the number of individuals of six species. Table 10 presents the raw mean number of individuals per species per transect walked and the frequency of a species recorded.

Table 10. Frequency and mean no. of individuals of six species, LHI core settlement transects, September 2013

Species	*Frequency*	*Mean*
Emerald Dove	14	0.8
Buff-banded Rail	18	1.7
Woodhen	4	0.2
Sacred Kingfisher	2	0.1
Blackbird	28	10.1
Song Thrush	7	0.5

There is a significant difference in observer walking speed (P< 0.001, see Figure 10) which may lead to differences in survey effort not related to the transect length. There is a faster speed on the second date compared with the first (3.0 compared with 3.4 km/hr, P<0.01).

The Blackbird was most frequently seen (on all occasions) and the most abundant species. The Buff-banded Rail, Emerald Dove and Song Thrush were the next most frequently recorded species and probably recorded sufficiently frequently to permit analysis. The other two species – Sacred Kingfisher and Woodhen – were recorded infrequently and formal analysis is probably not warranted.

Generalized linear mixed models were fitted to the four most abundant species. In all cases there were no significant influences due to the fixed effects, the direction of traversing the transect, the duration of the observation period or the length of the transect.

Table 11 presents the estimated mean number of the four most frequently seen individuals per transect. The estimates and confidence limits are based on the results of fitting a generalized linear mixed model.

Table 11. Estimated mean no. of the four most abundant species from transect counts, and 95% confidence limits

Species	*Mean*	*Lower limit*	*Upper limit*
Blackbird	9.88	7.78	12.41
Buff-banded rail	1.72	1.27	2.26
Emerald Dove	0.75	0.49	1.11
Song Thrush	0.50	0.28	0.83

The boxplot in Figure 10 shows the variation in speed walked by the seven observers. The bold horizontal line indicates the median speed walked. The box also outlines the 25% and 75% quantiles, with the whiskers representing the minimum and maximum respectively.

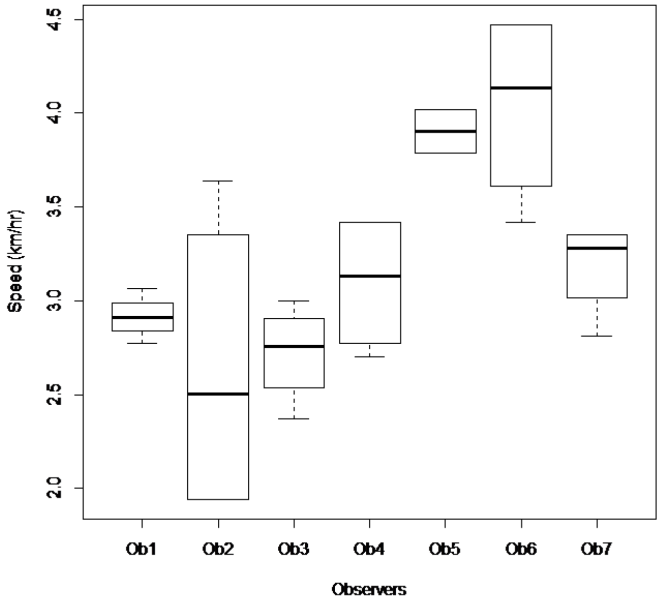

Figure 10. Boxplot showing variation in speed walked by the seven observers

Bird atlas data

Data submitted by early November 2013 to Birdlife Australia indicated that, by the end of September, 119 survey forms had been submitted by volunteers from the 24 survey sites. Between October and November 2012, 30 forms had been submitted. None were submitted between December 2012 and March 2013, with the remaining 89 submitted from 20 sites for the period from June onwards. The monitoring sites were officially launched in July 2013.

Between October 2012 and September 2013, surveys had been conducted by six volunteer observers with one survey conducted by an observer whose identity was not recorded.

The 24 sites could be surveyed at any time of the day. Sixteen were surveyed by enumerating the abundance for each species over a 20-minute period within defined but variable areas or along set tracks of variable length. These sites are termed '20-minute search' sites. Three of these sites include a short track terminating in recording birds from a lookout point (sites LHI15, LHI16, LH19). The remaining eight sites, termed 'General area search' are designed to record species and their abundance over variable time periods, but all within the same day with varying but defined areas. The '20-minute search' sites are designed to monitor the bush birds, while the 'General area search' sites are designed to monitor waders and waterbird populations. For a detailed description of the Birdlife Australia monitoring sites see http://birdlife.org.au/documents/ATL-LHI-Lord_Howe_Bird_Monitoring_Site_Guide.pdf

In all cases, surveys appear to have been conducted by the recommended method except for site LHI10 where four surveys were conducted as a ’20-minute search’ rather than as a ‘General area search’.

Acknowledgements

The survey was conducted under an arrangement between the Lord Howe Island Board and the Canberra Ornithologists Group. The report was compiled by Peter Fullagar and Chris Davey with statistical input from A O (Nick) Nicholls. Ian Hutton was responsible for the arrangements and logistical support on the island and provided invaluable input with his intimate knowledge of the flora and fauna of the island. The survey teams were Lia Battisson, Ian Hutton, Martyn Moffat, Mark Allen, Kathy Walter, John Goldie, Peter Fullagar and Chris Davey all, apart from Ian Hutton, members of the Canberra Ornithologists Group.

We thank Birdlife Australia for providing us with a copy of records collected between October 2013 and September 2014 from the 24 Bird Monitoring Sites on the island. Finally, we thank David Priddel and the Lord Howe Island Board for their support

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APPENDIXES

Appendix A. Location, vegetation code and group, habitat zone and number of surveys for each of the 96 survey sites, LHI

	Geolocation		*Vegetation code*	*Vegetation group*	*Habitat zone*	*No. of surveys*
Site number	*Latitude*	*Longitude*				
1	31 31 09.2	159 02 27.8	1	1	1	2
2	31 31 06.7	159 02 25.2	1	1	1	2
3	31 31 16.8	159 02 31.0	1	1	1	2
4	31 31 12.8	159 02 31.0	1	1	1	2
5	31 31 05.8	159 02 21.4	1	1	1	2
6	31 31 04.3	159 02 24.7	1	1	1	2
7	31 31 00.4	159 02 24.8	4	1	1	2
8	31 30 56.9	159 02 23.0	4	1	1	2
9	31 31 01.2	159 02 31.7	5	2	1	2
10	31 31 00.3	159 02 37.3	5	2	1	2
11	31 30 57.4	159 02 39.8	1	1	1	2
12	31 30 54.7	159 02 37.3	1	1	1	2
13	31 30 56.1	159 02 56.5	1	1	1	2
14	31 30 52.9	159 02 57.7	1	1	1	2
15	31 30 52.2	159 03 04.4	1	1	1	2
16	31 30 50.1	159 03 01.6	1	1	1	2
17	31 30 58.3	159 03 05.2	1	1	1	2
18	31 31 02.9	159 03 09.0	1	1	1	2
19	31 31 05.0	159 02 55.2	1	1	1	2
20	31 31 04.5	159 02 59.4	1	1	1	2
21	31 31 02.0	159 03 03.4	1	1	1	2
22	31 30 59.3	159 03 01.0	1	1	1	2
23	31 31 08.1	159 03 11.3	3	1	1	2
24	31 31 11.0	159 03 09.1	3	1	1	2
25	31 30 52.5	159 03 20.3	1	1	1	4
26	31 30 55.0	159 03 25.0	1	1	1	4
27	31 30 52.9	159 03 39.6	3	1	1	4
28	31 30 49.6	159 03 39.7	3	1	1	4
29	31 31 08.1	159 03 46.4	6	3	2	4
30	31 31 10.9	159 03 44.0	6	3	2	4
31	31 31 06.0	159 03 34.4	6	3	2	4
32	31 31 05.8	159 03 30.4	6	3	2	4
33	31 31 15.7	159 03 29.5	5	2	2	4

34	31 31 18.7	159 03 30.1	5	2	2	4
35	31 31 23.8	159 03 44.6	5	2	2	4
36	31 31 21.3	159 03 47.0	5	2	2	4
37	31 31 09.8	159 04 04.7	1	1	2	4
38	31 31 07.1	159 04 09.1	1	1	2	4
39	31 31 08.9	159 04 19.2	10	2	2	4
40	31 31 12.1	159 04 16.3	10	2	2	4
41	31 31 17.1	159 04 18.9	6	3	2	4
42	31 31 21.3	159 04 18.9	6	3	2	4
43	31 31 19.1	159 04 01.0	5	2	2	4
44	31 31 22.4	159 03 59.4	5	2	2	4
45	31 31 29.0	159 04 06.3	5	2	2	4
46	31 31 32.2	159 04 10.4	5	2	2	4
47	31 31 33.6	159 03 51.2	5	2	2	4
48	31 31 28.1	159 03 50.3	5	2	2	4
49	31 31 32.1	159 04 21.7	5	2	2	2
50	31 31 35.6	159 04 23.8	5	2	2	2
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61	31 32 07.3	159 04 20.4	1	1	3	4
62	31 32 07.6	159 04 23.4	1	1	3	4
63	31 32 21.0	159 04 29.5	1	1	4	4
64	31 32 24.7	159 04 34.6	1	1	4	4
65	31 32 18.5	159 04 40.1	6	3	4	4
66	31 32 20.2	159 04 45.1	6	3	4	4
67	31 31 59.9	159 04 37.7	3	1	3	4
68	31 32 03.4	159 04 38.6	3	1	3	4
69	31 32 07.8	159 04 49.6	3	1	3	4
70	31 32 10.8	159 04 53.1	2	1	3	4
71	31 32 17.2	159 04 50.3	7	3	3	4
72	31 32 32.4	159 04 59.4	7	3	5	4
73	31 33 05.1	159 04 32.3	6	3	4	2

74	31 33 03.1	159 04 37.5	6	3	4	2
75	31 33 09.8	159 04 58.1	9	2	5	2
76	31 33 09.4	159 04 54.4	9	2	5	2
77	31 33 19.0	159 04 43.9	1	1	5	2
78	31 33 23.4	159 04 40.5	1	1	5	2
79	31 33 30.9	159 04 36.9	5	2	5	4
80	31 33 34.5	159 04 35.8	5	2	5	4
81	31 33 43.6	159 04 34.2	5	2	5	4
82	31 33 40.6	159 04 35.3	5	2	5	4
83	31 33 58.0	159 04 32.9	5	2	5	4
84	31 34 03.2	159 04 31.5	5	2	5	4
85	31 32 33.6	159 04 40.9	6	3	4	4
86	31 32 33.2	159 04 45.6	6	3	4	4
87	31 32 46.7	159 04 40.5	8	3	4	4
88	31 32 43.4	159 04 41.5	8	3	4	4
89	31 32 52.0	159 04 42.0	1	1	4	4
90	31 32 55.1	159 04 39.7	1	1	4	4
91	31 32 37.4	159 04 54.2	1	1	5	2
92	31 32 37.7	159 04 57.7	1	1	5	2
93	31 32 42.3	159 05 06.2	1	1	5	2
94	31 32 43.9	159 05 10.7	1	1	5	2
95	31 32 49.3	159 05 26.8	1	1	5	2
96	31 32 52.7	159 05 27.4	1	1	5	2

Appendix B. Description of start point and turning point for all transects (A–G)

See Figure 2 for a map of the Lord Howe Island settlement area showing the seven transects. The protocol for these transect counts is also included here.

Description of each transect location

A. Intersection of Neds Beach Road and Lagoon Road to the bridge at Old Settlement Creek.
B. Intersection of Neds Beach Road and Lagoon Road to Neds Beach bathing huts.
C. Intersection of Anderson Road and Neds Beach Road to the corner at the top of Middle Beach Road.
D. Intersection of Anderson Road and Muttonbird Drive up to and along Skyline Drive down McGees Parade to the intersection with Anderson Road.
E. Intersection of Middle Beach Road and Lagoon Road up Middle Beach Road to Anderson Road turning right (S) and down Anderson Road to Bowker Avenue walking track (which is a little difficult to see but is on the W or right hand side of the road and marked by a small triangular trail marker).
F. Intersection of Middle Beach Road and Lagoon Road to the gate at the corner of the airfield at Windy Point.
G. Intersection of Ned's Beach Road with Lagoon Road to the intersection of Middle Beach Road and Lagoon Road (beside the LHI Museum).

Protocol for transect counts

1. Count only the six species of birds (Buff-banded Rail, Woodhen, Sacred Kingfisher, Emerald Dove, Blackbird and Song Thrush). Include all seen or heard on a slow walk from the defined start point to the defined finish point (outward count) and, as a new count, on the return walk to the start point (return count). Keep these two counts separate.

2. Count in the evening not before 1700 in September – later in mid-summer.

3. Indicate which transect you have counted and include your name and the date.

4. Record the start and finish time for your outward count and your return count.

5. Count all individuals you detect both sides of the road. There is no particular limit on distance but it would be reasonable not to include calls from birds or sightings that are, say, more than 25 metres from the roadside. Do not worry that you might count the same individual or individuals that could have been be seen on another transect at the transect intersections. Just include them as part of your transect count, if you spot them.

Appendix C. Bird species recorded in 96 survey sites, LHI, 2013

Species nomenclature and names follow those recommended by the latest IOC listing (see Gill and Wright, 2006, revised 2013 as version 3.5). For some species we use a simplified alternative in this report.

Name used in this report	*IOC recommended name, if different*	*Scientific name*	*Subspecies*
Feral Duck[1]		*Anas platyrhynchos*	
White-faced Heron		*Egretta novaehollandae*	
Woodhen	Lord Howe Woodhen	*Gallirallus sylvestris*	
Buff-banded Rail		*Gallirallus philippensis*	
Swamphen	Purple Swamphen	*Porphyrio porphyrio*	
Masked Lapwing		*Vanellus miles*	*novaehollandiae*
Pacific Golden Plover		*Pluvialis fulva*	
Bar-tailed Godwit		*Limosa lapponica*	
White Tern		*Gygis alba*	*candida*
Sooty Tern		*Onychprion fuscatus*	*kermadeci*
Feral Pigeon		*Columba livia*	
Emerald Dove	Pacific Emerald Dove	*Chalcophaps longirostris*	*rogersi*
Sacred Kingfisher		*Todiramphus sanctus*	*vagans*
Pied Currawong		*Strepera graculina*	*crissalis*[2]
Golden Whistler	Australian Golden Whistler	*Pachycephala pectoralis*	*contempta* [2]
Magpie-lark		*Grallina cyanoleuca*	
Welcome Swallow		*Hirundo neoxena*	
Tree Martin		*Hirundo nigricans*	
Silvereye		*Zosterops lateralis*	*tephropleurus*[2]
Starling	Common Starling	*Sturnus vulgaris*	
Blackbird	Common Blackbird	*Turdus merula*	
Song Thrush		*Turdus philomelos*	

Note:

1. Includes hybrids with Pacific Black Duck, *Anas superciliosa*
2. Endemic subspecies

Lord Howe

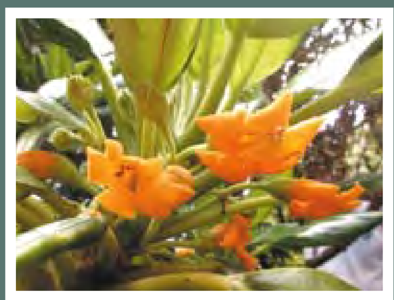
ISLAND BOARD

Lord Howe Island Rodent Eradication Project

NSW Species Impact Statement
February 2017
Appendix H - LHI Biodiversity Management Plan

LORD HOWE ISLAND

BIODIVERSITY MANAGEMENT PLAN



Australian Government

Lord Howe
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Requests for information or comments regarding the Lord Howe Island Biodiversity Management Plan are best directed to:

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Biodiversity Conservation Section,
Climate Change and Environment Protection Group, North East
Department of Environment and Climate Change (NSW)
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Cover photography:

Lord Howe Island
Photo: Ian Hutton

Sooty Tern (*Sterna fuscata*) Photo: Michael Murphy

Pumpkin Tree (*Negria rhabdothamnoides*) Photo: Ian Hutton

Lord Howe Placostylus (*Placostylus bivaricosus*) Photo: Michael Murphy

This plan should be cited as follows:

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October 2007

DECC 2007/469

Executive Summary

The Lord Howe Island Biodiversity Management Plan encompasses threats and management actions relevant to the Island group's overall biodiversity, with a particular focus on rare and significant species and communities of the LHIG. This approach enables holistic and cost-effective management of the Lord Howe Island Group's biodiversity. The Lord Howe Island Biodiversity Management Plan also constitutes the formal National and NSW Recovery Plan for threatened species and communities of the Lord Howe Island Group. As such, it considers the conservation requirements of these species within the Group.

This plan identifies the actions to be taken to ensure the long-term viability of threatened and significant species and communities of the Lord Howe Island Group in nature and the parties who will undertake these actions.

The recovery actions detailed in this plan include: *(i) implementing the Lord Howe Island Board quarantine policy, (ii) protecting existing native vegetation, (iii) on-ground eradication and control of weeds, (iv) revegetation of priority sites, (v) control and/or eradication of introduced vertebrate and invertebrate fauna, (vi) research and monitoring into species' ecology and management options, (vii) monitoring the impacts of climate change, (viii) captive breeding and reintroductions, (ix) surveys of potential habitat, (x) community awareness.*

It is intended that the Biodiversity Management Plan will be implemented over a 10-year period.

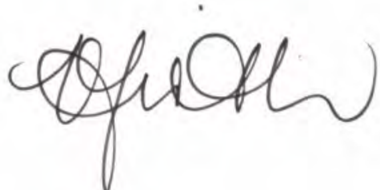
The Lord Howe Island Biodiversity Management Plan is presented in two documents. This document consists of the main body of the plan, while the second document contains the appendices that accompany the main plan (appendices document). A list of the appendices contained in the appendices document is provided on the contents page.

LISA CORBYN

Director General
Department of Environment and Climate Change

PHIL KOPERBERG

Minister for Climate Change, Environment and Water



VERITY FIRTH

Minister Assisting the Minister for Climate Change, Environment and Water

Acknowledgments

Many people have been involved in the preparation of this Plan. We thank all contributors for their input and patience with the development of this document.

Contributors from Lord Howe Island include: staff from the Lord Howe Island Board (Nick Rigby, Murray Carter, Chris Haselden, Jenni Le Cussan, Sean Thompson, Terry Wilson); the Lord Howe Island Recovery Team (Nick Rigby, Ian Hutton, Bill Retmock, Lynn Baker, Winston Ponder, Tony Auld); Lord Howe Island community members, particularly Esven Fenton, Dean Hiscox, Pixie O'Rourke, Bill Retmock, Judy Riddle and Jack Schick.

Department of Environment and Climate Change (DECC) contributions were made by Tony Auld, Anni Blaxland-Fuad, Michael Drielsma, Simon Ferrier, Guy Hodgson, John Hunter, Glen Manion, Kellie Mantle, Alecs Maric, David Priddel, Shane Ruming, Jill Smith, Barry Cohn and Elizabeth Brown. Species profiles (Appendix 5) were written by Dianne Brown, Dean Hiscox, Ian Hutton, Michael Murphy and Sean Thompson.

Australian Museum staff including Gerry Cassis, Hal Cogger, Louise Meades, Winston Ponder and Chris Reid contributed their research and expertise to the Plan.

The Commonwealth Department of Environment and Water Resources contributions were made by Veronica Ritchie.

Funding was through the Australian Government's Natural Heritage Trust, the DECC, and the Lord Howe Island Board.

The Plan was prepared and written by Dianne Brown, Lynn Baker, Katrina McKay and Michael Murphy (DECC).

Contents

Tables

Figures

Appendices (available in a separate document)

1 Introduction

The rich biodiversity of the Lord Howe Island Group (LHIG) supports a high level of endemic and significant species and communities. In addition, due to its isolated geographic location, small size and limited access, there are a number of identifiable and common threats to biodiversity on the LHIG. This combination of unique biota and common threats provides the opportunity to manage species and communities via a multi-species, threat-based biodiversity plan. This holistic approach was chosen in contrast to producing a number of single species recovery plans, which is less efficient in terms of resources for preparation, implementation and prioritisation of management actions.

The LHIG falls under the jurisdiction of the New South Wales (NSW) State government. The Lord Howe Island Board (LHIB) is responsible for the care, control and management of Lord Howe Island, offshore islands and neighbouring coral reefs in accordance with the *Lord Howe Island Act* 1953 (LHI Act). All land is vested in the Crown; there is no freehold title.

The Lord Howe Island Biodiversity Management Plan (LHI BMP) has been prepared by the Department of Environment and Climate Change (DECC) in conjunction with the Lord Howe Island Recovery Team and the LHIB. The attainment of the objectives of the LHI BMP are subject to budgetary and other constraints affecting the parties involved.

1.1 Scope of document

The LHI BMP encompasses all islands within the LHIG (Figure 1).

The LHI BMP encompasses threats and management actions relevant to the Island group's overall biodiversity and in particular, rare and significant species and communities of the LHIG.

A number of terrestrial species and ecological communities occurring on the LHIG are listed as Critically Endangered, Endangered or Vulnerable under the *Threatened Species Conservation Act* 1995 (TSC Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act). To the extent that those species are restricted to the LHIG or where the LHIG constitutes the major habitat of the species, this LHI BMP constitutes the formal National and NSW Recovery Plan for them.

Flora species addressed by the LHI BMP are those species that are:

- threatened;
- endemic; or
- have a distribution restricted to the LHIG or where the LHIG is the only Australian location.

Fauna species addressed by the LHI BMP are all native terrestrial species including land birds, endemic and threatened invertebrates, endemic reptiles and a native mammal. Sea birds are included where the LHIG constitutes a significant part of their habitat or breeding location. Appendix 1, contained in the appendices document lists all species addressed by the LHI BMP, while Appendix 5 (appendices document) provides profiles of these species.

This plan does not relate directly to the management of the coral reefs and marine environments associated with the LHIG. These areas are managed through zoning and operational plans developed by the NSW Marine Parks Authority, under the *Marine Parks Act* 1997. The LHI BMP is complementary to these zoning and operational plans.

The LHI BMP is intended to provide an holistic approach to future management of the biodiversity of the LHIG, assisting with the prioritisation of actions, and presenting management information in one document.

The plan identifies significant ecological areas, biodiversity 'hot spots', threatened areas and priority management sites for the LHIG. It identifies the actions to be taken to ensure the long-term viability in nature of species covered by the plan, and the parties who will undertake these actions.

1.2 Interaction with other documents

There are two existing recovery plans for LHI species: the Lord Howe Woodhen (*Gallirallus* *sylvestris*) and the Lord Howe Island Placostylus (*Placostylus bivaricosus*) (a land snail). The LHI BMP does not replace these Recovery Plans, but complements them by including species-specific management actions, as well as incorporating the species covered by individual Plans in holistic management actions. These actions have been prioritised across all relevant species and communities. The individual Plans will be incorporated into this plan when they are due for review.

This plan constitutes only the LHIG component for threatened species where the LHIG is not the only Australian location. This applies to several species of sea bird and a threatened plant.

The LHI BMP provides a wide scope of management actions, the biodiversity benefit of these actions, and priorities for management. Specific management actions may receive different priorities at different times depending on the availability of funding and opportunistic project proposals.

1.3 Description of the Lord Howe Island Group

The LHIG is located 760 kilometres north east of Sydney. This island group, known for its spectacular beauty, supports an extraordinary array of terrestrial and marine ecosystems and landscapes.

The uniqueness and international importance of the LHIG was formally recognised in 1982, when it was inscribed on the World Heritage Register.

The LHIG (Figure 1) consists of a main island (Lord Howe Island) that is surrounded by smaller outlying groups of islands and rocks. The most distant of these is the 551 m high pinnacle of Balls Pyramid, 23 km to the south east of Lord Howe Island.

Lord Howe Island is approximately 11 km long, 2.8 km wide at its widest point and is roughly crescent shaped, enclosing a coral reef lagoon on the south-west side. The total area of the island is 1455 hectares (Hutton 1991).

Lord Howe Island was first sighted in 1788, and European settlement occurred in 1834. There is no archaeological evidence of earlier inhabitants (Pickard 1983). Lord Howe Island is the only island within the LHIG on which settlement has occurred. The settlement area is restricted to the central lowlands and covers approximately 15% of the island.

Most of the island (87%) has retained its original vegetation (Hunter 2002), with almost 75% of Lord Howe Island and all the other islands within the LHIG protected under the Permanent Park Preserve (PPP). This preserve has a similar status to that of a National Park, the main difference being that the PPP is managed by the LHIB rather than the DECC.

Geology and geomorphology

The LHIG is a relatively young island group. It is part of the largely submerged Lord Howe Island Rise, a volcanic undersea ridge 160 km–300 km wide and rises from ocean depths of over 1.8 km. This rise separates the Tasman and the New Caledonian Basins.

Lord Howe Island is thought to be the remnant of a large shield volcano on the western edge of the Rise. The present land mass is thought to represent two periods of volcanic activity. The northern hills (the Malabar Hill – Mount Eliza chain) and the central Hills (Transit Hill and Intermediate Hill) of Lord Howe Island are remnants of the earlier volcanics (about 6.9 million years ago), and are estimated to be 700 m lower than when they formed (Hutton 1998). The later activity took place about 6.3 million years ago, and produced the basalt flows which constitute the two southern mountains; Mount Gower (875 m) and Mount Lidgbird (777 m) (Green 1994).

The most common volcanic rocks found on the island are basalt and the associated breccia.

Marine erosion has greatly reduced the size of the island to an estimated 2.5% of that which was originally formed (Hunter 2002). A result of this erosion is a spectacular landscape of mountains, cliffs, hills and offshore islands.

Successive ice ages, causing a variation in sea level, led to deposits of wind blown coral and shell debris on the low-lying, flat areas (Pickard 1983). Percolating rainwater cemented these into sedimentary rock known as aeolian calcarenite. The Lord Howe occurrence of aeolian calcarenite is the most significant anywhere on the NSW coast (Smith 2002). Some of the deposits have been dated to over 130,000 years old and contain fossils of bird bones and eggs, land and marine snails, and the now extinct horned turtle *Meiolania platyceps* (Green 1994).

Small swamps are a significant feature of lowland parts of the island and are a result of recent beach deposits which have built up across drainage lines on the island (Smith 2002).

Flora and fauna

The diverse landscape of mountains, valleys, hills, lowlands and seacliffs of the LHIG provide a diverse array of habitat types supporting many distinctive flora and fauna assemblages. Many of the species that occur within the island group are endemic (occur nowhere else in the world).

Many of the flora and fauna species from the LHIG have affinities with species known from the surrounding islands of New Zealand, New Caledonia, Australia and other Pacific Islands (Manidis Roberts 2000; Hunter 2002; Smith 2002).

While many organisms arrived by long distance dispersal by wind and sea to colonise the island group, there is also a strong Gondwanan element in the biota, dating back to the split between Australia and New Zealand. Floristically, the LHIG is closest to Norfolk Island (Hunter 2002), however, both the LHIG and Norfolk Island flora are more closely related to New Zealand and New Caledonia than they are to Australia. The snail fauna shows clear affinities with the Solomon Islands, Fiji, New Caledonia and New Zealand (Hunter 2002). Section 3 of this plan provides further detail of the flora and fauna of the LHIG.

Climate

The LHIG has a climate that is moderated by oceanic air currents and mild sea temperatures. The LHIG winters are wet and cool, with an average daily maximum of 18^{0}C and average daily minimum of 13^{0}C. The lowest temperature recorded from the settlement area of the island is 6^{0}C, and no frost has ever been recorded (LHIB 2002).

Summers have less rainfall, and are mild or warm, averaging a daily maximum of 25 ^{0}C and an average daily minimum of 13 ^{0}C. Temperatures on the high plateau of Mount Gower are 6–8 ^{0}C cooler than at sea level (LHIB 2002).

The mean annual rainfall of the lowlands is 1650 mm, with a pronounced maximum in mid-winter. The rainfall in the mountainous southern half of the island is considerably higher due to orographic cloud and rainfall influences (LHIB 2002). Humidity on Lord Howe Island is high throughout the year.

The island is generally windy, more so in the afternoons. The salt-laden wind comes predominantly from the south-east and north-east and the mean wind speed is highest in late winter and spring (LHIB 2002).

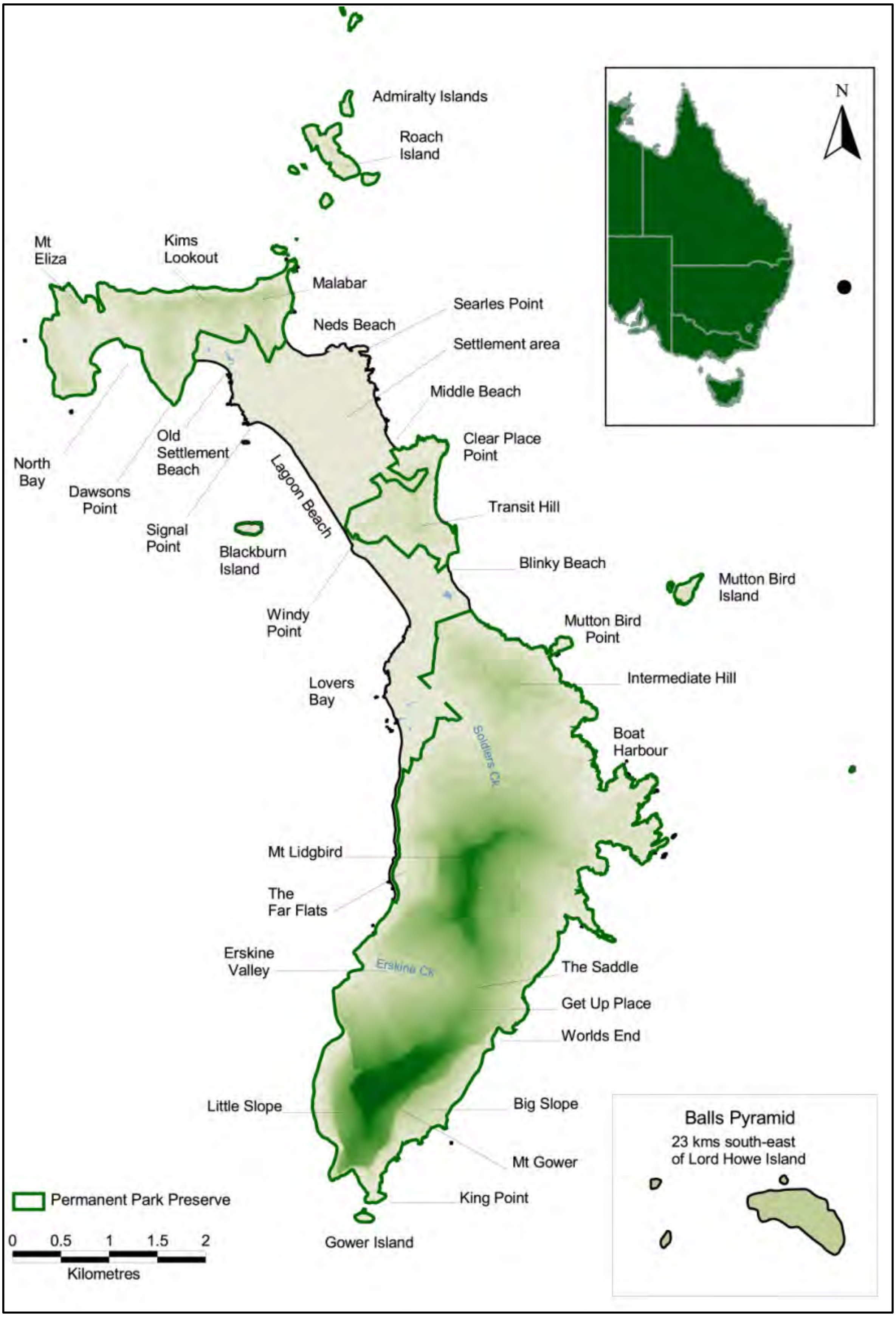


Figure 1. The Lord Howe Island Group

2 Legislative Context

The LHI BMP constitutes the Recovery Plan for LHIG species and ecological communities that are listed as Critically Endangered, Endangered or Vulnerable under the TSC Act and the EPBC Act. There are eight flora, 21 fauna and one ecological community listed on the NSW TSC Act that are covered by this plan. Seven fauna species and one flora species are listed as threatened on the EPBC Act, as well as 58 birds listed as protected migratory species on the EPBC Act, 41 of which are irregular visitors to, or vagrants on, the LHIG (Table 1). Appendix 1 (appendices document) lists all species recorded for the LHIG and their conservation status.

Table 1. Summary of the NSW *Threatened Species Conservation Act* 1995 and Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999 listings

	TSC Act	EPBC Act	
	threatened	threatened	migratory
Flora	8	1	
Fauna	21	11	58
Ecological communities	1		
TOTAL	30	12	58

The LHI BMP intends to address any additional species, populations or communities that may be listed under the TSC or EPBC Acts during the ten years duration of the plan. It is proposed that as a species, population or community is listed, the intention to use this plan for the recovery plan for the entity will be advertised. Where necessary, addenda will be attached to the current plan and submissions during exhibition periods will be considered.

Once this plan has been approved by the NSW Minister for the Environment, it is the intention of the Director General of the DECC to forward it to the Australian Minister of the Environment and Water Resources for adoption.

2.1 Recovery plan preparation, exhibition and implementation

The TSC Act and the EPBC Act provide a legislative framework to protect and encourage the recovery of threatened species, populations and ecological communities.

Under the TSC Act the Director General of the DECC has a responsibility to prepare and adopt a Threatened Species Priorities Action Statement, which will establish priorities for the recovery of threatened species, populations and communities and for threat abatement for key threatening processes. Recovery plans and threat abatement plans will be required to be prepared in accordance with the priorities established by a Priorities Action Statement. The EPBC Act also includes specific requirements for both the matters to be addressed by recovery plans and the process for preparing recovery plans. This plan satisfies the provisions of the TSC Act and EPBC Act.

The draft LHI BMP was placed on public exhibition between 22 December 2006 and 22 February 2007 and submissions were invited from the public.

All submissions to this plan were considered and a summary of those submissions was provided to the NSW Minister for the Environment prior to final approval of the plan.

The TSC Act requires that a government agency must not undertake actions inconsistent with a Recovery Plan. The EPBC Act additionally specifies that the Australian Government must not take any action that contravenes a Recovery Plan. The actions identified in this plan for the recovery of the threatened and significant species of the LHIG in NSW are the responsibility of the LHIB, the Lord Howe Island recovery team and the DECC. Other public authorities may also have statutory responsibilities relevant to the conservation and protection of Lord Howe Island threatened species.

For species listed under the NSW TSC Act, any proposal that is likely to have a significant impact on these species must prepare a Species Impact Statement, and the concurrence of the DECC is required. For those species that are listed nationally under the EPBC Act, any proposal that is likely to have a significant impact on these species should refer the action to the Australian Government Minister for the Environment and Water Resources for consideration. The Minister will then decide whether the action requires EPBC Act approval. This is in addition to any state or local government approval required.

2.2 Consultation with the Lord Howe Island community

The people of Lord Howe Island are deeply connected to the LHIG and its history. They play an integral part in the way in which the island is managed. Many members of the Lord Howe Island community have assisted in the preparation of this plan.

The Lord Howe Island community will have an important role in the successful implementation of this plan. In addition to the consultation processes that have taken place in the preparation of the preliminary draft plan, the draft LHI BMP was made available for the Lord Howe Island community to provide comment. These comments were considered during the finalisation of this plan.

2.3 Critical Habitat

The TSC Act makes provision for the identification and declaration of Critical Habitat. Under the TSC Act, Critical Habitat may be identified for any endangered species, population or ecological community occurring on NSW lands. Once declared, it becomes an offence to damage Critical Habitat (unless the action is specifically exempted under the provisions of the TSC Act) and a Species Impact Statement (SIS) is mandatory for all developments and activities proposed within declared Critical Habitat. To date, Critical Habitat has not been declared for any LHIG species. The declaration of Critical Habitat is not considered to be a priority for LHIG species at this stage, as other mechanisms provide for their protection.

2.4 Habitat Critical to Survival

The EPBC Act requires that habitat critical to the survival of a threatened species or community, and the actions needed to protect that habitat must be included in a recovery plan. Habitat critical to survival has been identified in the LHI BMP, including habitat that meets the essential life cycle requirements of a species or community under normal conditions, and habitat requirements during periods of stress. Habitat critical to survival also includes corridors that freely connect populations, and provide sufficient habitat to meet a species genetic diversity and long-term evolutionary development requirements, or any other essential function.

2.5 Key Threatening Processes

As of August 2007 there are 12 Key Threatening Processes (KTPs) listed under either the TSC Act or the EPBC Act considered to be relevant to the LHIG. These KTPs are outlined in more detail in Section 4 and Table 6.

2.6 Other conservation measures

The TSC Act includes provision for other measures that may be taken to conserve threatened species and their habitat, including the making of a Stop Work Order or Joint Management Agreement.

Additionally, the LHIG is listed as a World Heritage site and therefore must be managed in accordance with the provisions of the EPBC Act pertaining to World Heritage sites.

2.7 Additional relevant NSW Legislation

Lord Howe Island Act 1953

The LHI Act was enacted to make provision for the care, control and management of the LHIG and to establish the LHIB.

The PPP is established under Section 19A of the LHI Act. It covers approximately 75% of the island, and includes all offshore islands and Balls Pyramid. The PPP is managed in accordance with a Plan of Management. This Plan of Management (NSW NPWS 1986) is currently being updated.

Additional NSW legislation relevant to the conservation and recovery of threatened species and ecological communities recorded from LHIG includes the following:

- *National Parks and Wildlife Act* 1974;
- *Environmental Planning and Assessment Act* 1979;
- *Local Government Act* 1993;
- *Rural Fires Act* 1997; and
- *Rural Fires and Environmental Assessment Legislation Amendment Act* 2002.

3 Overview of Species

3.1 Introduction

The LHIG supports a diverse terrestrial flora and fauna with a high degree of endemic species and communities. Many biogeographical relationships are discernible, with components of the terrestrial flora and fauna exhibiting affinities with eastern Australia, New Zealand, Norfolk Island and New Caledonia (Hedley 1893; Manidis Roberts 2000; Cassis *et al.* 2003).

Appendices which provide the full list of species and profiles of the target species addressed in this plan are provided in a separate document (Appendix 5 of the appendices document).

3.2 Flora species

There are 239 species of indigenous vascular plant recorded from the LHIG, of which 113 (47%) are endemic. The high degree of endemism is illustrated not only at the species level, but also at the generic level, where there are five endemic vascular plant genera (*Negria, Lordhowea, Howea, Lepidorrhachis* and *Hedyscepe)* (Hunter 2002).

The non-vascular flora of terrestrial and freshwater habitats (bryophytes, lichens and freshwater algae) is less well known, but is also considered to be diverse with many endemic species. For example, 105 species of mosses are known, 21 (20%) of which are endemic (Ramsay 1984).

New species of endemic vascular and non-vascular plants from the LHIG continue to be described.

Approximately 271 species of vascular flora have naturalised (introduced species that are reproducing in the wild) on the LHIG since settlement. Some of these, including Bitou Bush (*Chrysanthemoides monilifera)*, Ground Asparagus (*Asparagus aethiopicus*), Climbing Asparagus (*Asparagus plumosus*), Bridal Creeper *(Asparagus asparagoides*), Cherry Guava (*Psidium cattleianum*), Sweet Pittosporum (*Pittosporum undulatum*), Kikuyu Grass (*Pennisetum clandestinum)*, Crofton Weed *(Ageratina adenophora*) and Tiger Lily (*Lilium formosanum*), pose serious problems as environmental weeds, and 18 species are declared noxious for the LHIG (Table 7). Around 400 additional species occur in cultivation within the settlement area. Many of these have the potential to become weeds. Weeds are discussed more fully in Section 4.3. Table 2 provides a summary of the number of vascular flora species in each of four categories, while Appendix 1 (in the appendices document) is a comprehensive list of the vascular flora species known from the LHIG.

3.3 Vegetation communities

The vegetation communities of the LHIG have been described by Pickard (1983) and Hunter (2002). Many of these communities are unique to the LHIG, are dominated by endemic species, or have highly restricted distributions within the island group. Pickard (1983) identified seven structural formations and 25 vegetation associations, with a number of subformations and alliances, and another four physiographic units to identify cliffs and shorelines. Closed forest is the most extensive structural formation, covering over half of the main island and extending from the lowlands to the mountain tops. The remaining natural vegetation cover consists of scrubs, herbfields, grasslands and the vegetation of exposed cliff and littoral terrains.

Thirty four vegetation communities are defined for the LHIG for the purposes of this plan (Appendix 1) (appendices document). These are based on Pickard (1983) with refinements by Hunter (2002) and Hutton (pers. comm.).

Eighteen vegetation communities of the LHIG are considered to be of particular conservation concern, due to threatening processes that are causing, or likely to cause their decline (Table 3).

Table 2. Summary of vascular flora species known from the Lord Howe Island Group

Species group	Number
Indigenous species (endemic)	113
Indigenous species (non-endemic)	126
Introduced species (naturalised)	c. 271
Introduced species (non-naturalised i.e. in cultivation)	c. 400
Total	c. 910

Table 3. Vegetation communities of particular conservation concern of the Lord Howe Island Group

Community	Status/threat
Closed forest communities	
Blackbutt (*Cryptocarya gregsonii*) Closed Forest	Restricted distribution; threatened by Crofton Weed
Greybark-Blackbutt (*Drypetes deplanchei-Cryptocarya triplinervis*) Closed Forest on calcarenite/coral sand	Extent of clearing/fragmentation; weed invasion
Big Mountain Palm (*Hedyscepe canterburyana*) Closed Sclerophyll Forest	Climate change
Kentia Palm (*Howea forsteriana*) Closed Sclerophyll Forest on calcarenite/coral sand	Extent of clearing; fragmentation
Sallywood (*Lagunaria patersonia*) Closed Swamp Forest*	Restricted distribution; extent of clearing
Lowland Mixed Closed Forest	Threatened by weed invasion
Hotbark-Fitzgeraldii (*Zygogynum howeanum-Dracophyllum fitzgeraldii*) Gnarled Mossy Closed Forest (Cloud Forest)	Restricted distribution; climate change
Scrub communities	
Mangrove (*Aegiceras corniculatum*) Closed Scrub	Restricted distribution; grazing and trampling; weed invasion; climate change
Alyxia squamulosa – Coprosma inopinata Dwarf Scrub	Very restricted distribution, weed invasion
Saltbush (*Atriplex cinerea*) Dwarf Scrub	Very restricted distribution
Mangrove (*Avicennia marina* v. *australasica*) Open Scrub	Very restricted distribution
Mixed Fern and Herb	Restricted distribution; weed invasion, particularly by Crofton Weed & Tiger Lily; climate change
Fitzgeraldii-Mountain Rose (*Dracophyllum fitzgeraldii-Metrosideros nervulosa*) Closed Scrub	Climate change
Grass communities	
Poa poiformis Grassland	Restricted distribution on main island; invasion by Kikuyu; risk of Kikuyu reaching offshore islands
Specialised landform communities	
Coral Sand Beach and Dune Community	Moderately restricted distribution; clearing; disturbance
Waterfall Cliff Community	Threatened by weed invasion, particularly Crofton Weed
Aquatic communities	
Upland Freshwater Instream Community	Restricted distribution; climate change
Lowland Freshwater Instream Community	Restricted distribution; clearing, grazing and trampling; climate change

* Listed as an Endangered Ecological Community on the TSC Act.

3.4 Vertebrate fauna

Typical of remote oceanic islands, the terrestrial vertebrate fauna of the LHIG is dominated by birds. One hundred and eighty two species of birds are recorded from the LHIG, of which 20 are resident landbirds, 14 are breeding seabirds, 17 are regular visitors and 120 are vagrants (McAllan *et al.* 2004). At the time of European settlement the native avifauna consisted of 26 species of land bird (including 13 migratory waders) and 13 species of sea bird (refer to Table 4 and Appendix 1). Thirteen (50%) of the land birds were endemic species or subspecies. Eleven of the sea bird species continue to have important breeding populations in the LHIG, with Lord Howe Island reputed to have more sea bird species breeding in higher numbers than anywhere else in Australia (P. Fullagar, in Hutton 1998). Two species of birds are classified as locally extinct as they are only known from subfossil remains (McAllan *et al.* 2004). In contrast to the sea birds, nine of the land bird species have become extinct in the period since human settlement (all endemic species or subspecies). The most recent extinction was the Lord Howe subspecies of Southern Boobook (*Ninox novaeseelandiae albaria)*, which was last recorded in the 1950s.

An additional 18 land bird species and five sea bird species have established populations on the LHIG since settlement, either through intentional human introduction or unassisted colonisation.

Two species of reptile (the Lord Howe Island Gecko *Christinus guentheri* and the Lord Howe Island Skink *Cyclodina lichenigera)* and two species of microchiropteran bat complete the indigenous terrestrial vertebrate fauna of the LHIG at the time of European settlement. The two reptiles also occur on Norfolk Island. One of the bats, the Lord Howe Long-eared Bat (*Nyctophilus howensis)* was endemic but is thought to be extinct, while the surviving bat species the Large Forest Bat (*Vespadelus darlingtoni*) is also found widely in south eastern Australia.

Five species of mammal, two species of reptile and a species of frog have been introduced to the LHIG since settlement and established feral populations. Two of the introduced mammals (the Feral Cat and Feral Pig) have since been eradicated, while a third (the Feral Goat) has been reduced to a few wild non-reproductive animals.

Three species of freshwater fish (two eels and a galaxias) occur on the LHIG. All three species are catadromous (spend their adult life in freshwater but spawn in marine waters) and all have wider distributions, including the Australian mainland. The marine fish of the LHIG are outside the scope of this plan.

Appendix 1 (appendices document) lists all the vertebrate fauna species known from the LHIG and Table 4 summarises information on the groups of native vertebrate fauna.

3.5 Invertebrate fauna

The following information has been extracted from Cassis *et al.* (2003). The terrestrial invertebrate fauna of the LHIG is characterised by relatively high species richness and high endemism with up to 60% of some groups comprising endemic species. More than 1600 terrestrial invertebrate species have been recorded, including 157 land and freshwater snails, 464 beetles, 27 ants, 183 spiders, 21 earthworms, 137 butterflies and moths and 71 springtails. The rate of discovery of new species remains high, indicating that numerous endemic species are yet to be discovered.

Information concerning declines and extinctions amongst the indigenous invertebrate fauna since European settlement is incomplete. Cassis *et al.* (2003) provides a preliminary assessment of the conservation status of the Formicidae (ants), Coleoptera (beetles) and Araneae (spiders), identifying one endemic ant and ten endemic beetles which may be extinct and six endemic ants, 38 endemic beetles and nine endemic spiders at risk of extinction (Appendix 2, appendices document). The majority of beetles classified as presumed extinct were large, often flightless species. Other invertebrates thought to be extinct or 'at risk' include a number of land snails and freshwater snails, as well as an earthworm, a phasmid and a cockroach.

Introduced invertebrate species currently comprise about 5% of the recorded invertebrate fauna, including ten land snails and slugs, at least 19 beetles, at least four ants, four spiders, five earthworms and six butterflies and moths. Some introduced invertebrate species are restricted to the settlement area, as they are dependent on human habitation, exotic garden plants or exotic pasture, while others are now widely distributed in natural habitats across the main island and at least some of the offshore islands.

3.6 Current TSC Act and EPBC Act listings

A number of species and ecological communities on the LHIG are listed as threatened under the TSC Act and/or the EPBC Act, and additional species and ecological communities may warrant consideration for listing in the future. Under the TSC Act, the Schedules must be regularly reviewed. Amendments to the TSC Act allowing for species and communities to be listed as Critically Endangered will probably mean that a number of species and communities currently listed as Endangered may be upgraded to Critically Endangered within the life of this plan.

A summary of the threatened flora, fauna and vegetation communities of the LHIG is provided in Table 5.

Flora and communities

Eight flora species from the LHIG are listed as Endangered under the TSC Act. One vegetation community from the LHIG (Sallywood (*Lagunaria*) Swamp Forest) is listed as an Endangered Ecological Community under the TSC Act. One flora species is listed under the EPBC Act.

Fauna

Thirty five species of birds are listed on the TSC Act, three as Endangered and 23 as Vulnerable, with the remainder (9) listed as Presumed Extinct. Of the 26 extant threatened species, 10 are classified as vagrants or irregular visitors, four of the resident or breeding threatened species are landbirds (one Endangered and three Vulnerable) and 12 are sea birds. Two of the listed species that breed on the LHIG (the Vulnerable Black-winged Petrel (*Pterodroma nigripennis*) and the Vulnerable White Tern (*Gygis alba*)) are recent colonisers, arriving on the LHIG in the 1940s (Hutton 1991).

Twelve bird species are listed under the EPBC Act, one Endangered sea bird, two Vulnerable landbirds and nine Extinct landbirds. Another 43 birds (eight resident or regular visitors and 35 irregular visitors or vagrants) are listed as protected migratory species under the EPBC Act.

The Lord Howe Island Gecko and Lord Howe Island Skink are listed as Vulnerable under both the TSC Act and EPBC Act, while the endemic Lord Howe Long-eared Bat is listed as Presumed Extinct under the TSC Act and EPBC Act.

Four LHIG invertebrate species, the Lord Howe Island Placostylus (a land snail), the Lord Howe Island Wood-feeding Cockroach (*Panesthia lata*) the Lord Howe Island Earthworm (*Pericryptodrilus nanus*), and the Lord Howe Island Phasmid (*Dryococelus australis*) are listed as Endangered under the TSC Act. The Lord Howe Island Phasmid and Lord Howe Island Placostylus are also listed as Critically Endangered under the EPBC Act. The Lord Howe Island Ground Weevil (*Hybomorphus melanosomus*) is listed as Presumed Extinct under the TSC Act.

Table 4. Summary of vertebrate species (excluding domestic animals) of the LHIG

Group	Endemic native species (presumed extinct in brackets)	Native species (presumed extinct in brackets)	Non-native species* (residents or regular visitors)	Vagrants/irregular visitors
Land birds	4 (9)	13	18	83
Sea birds	0	11 (2)	5	37
Mammals	1	1	3	6#
Reptiles	0	2	2	3#
Amphibians	0	0	1	0
Freshwater Fish	0	3	0	0
Total	**14**	**45**	**29**	**129**

* species that have established since settlement; # marine species

Table 5. Summary of threatened flora, fauna and communities of the LHIG (August 2007)

	Flora	Communities	Land birds	Sea birds	Vagrants	Reptiles	Mammals	Invertebrates	TOTAL
TSC Act									
Critically Endangered									
Endangered	8	1	1		2			4	16
Vulnerable			3	12	8	2			25
Presumed Extinct			9				1	1	11
TOTAL									**52**
EPBC Act									
Critically Endangered	2							1	3
Endangered					2			1	3
Vulnerable			2	2	1	2			7
Extinct			9						9
TOTAL									**22**
Protected Migratory									43

3.7 Biodiversity hot spots

The richness of biodiversity of the LHIG is unevenly distributed across the landscape and patterns of biodiversity richness can be identified. Areas where species richness or endemicity are high are known as biodiversity "hot spots". Hot spot analysis assists with the prioritisation of management actions that will maximise the overall benefits to the biodiversity of the LHIG. A GIS database of species distributions was used to conduct a hot spot analysis. Due to database size constraints, Balls Pyramid was not included in the GIS hot spot analysis.

Flora

The southern mountains are a hot spot for the flora of the LHIG. Within the southern mountains, 56% of the total number of threatened and endemic flora of the LHIG occur, while 33% of LHIG threatened and endemic flora occur only in this region. The northern and central hills region, in contrast, contains 22% of all threatened, endemic and restricted flora of the LHIG.

The southern mountains are considered a high conservation priority by Auld and Hutton (2004) as they contain the majority of endemic species, and significant endemic plant communities such as Cloud Forest (Hotbark-Fitzgeraldii forest), Big Mountain Palm forest (*Hedyscepe canterburyana*) and Blue Plum (*Chionanthus quadristamineus*) closed forest.

Several Endangered plant species (*Carmichaelia exsul*, *Coprosma inopinata*, *Geniostoma huttonii*, *Polystichum moorei* and *Xylosma parvifolium*) are confined to the southern mountains, while two of the three known populations of the Endangered *Calystegia affinis* occur there. Three of the five endemic plant genera of the LHIG only occur in the southern mountains. There are also a number of significant non-vascular plants in the area, particularly on the mountain summits.

Figure 2 illustrates flora species richness for the LHIG. Mounts Gower and Lidgbird both are indicated with the highest overall species richness, with relatively high species richness in adjacent parts of the southern mountains. Conversely, the northern hills and central lowlands generally display relatively low levels of species richness. Areas of endemicity display similar patterns to that of overall species richness, i.e. the highest levels of endemicity in the southern mountains.

Vegetation communities

As well as flora, the southern mountains are also a hot spot for vegetation communities, both in terms of richness and endemicity. Thirty four of the 44 vegetation communities (77%) for the LHIG occur in the southern mountains, with 17 (39%) of these being restricted to the southern mountains. In contrast, the northern hills have 24 vegetation communities, three of which are unique to this area, while the central lowlands, which includes the settlement area, has 16 vegetation communities, one (Sallywood Swamp Forest Endangered Ecological Community) of which is unique to this area.

Vertebrate fauna

Overall patterns of native fauna distribution are less clear than for flora. Due to the diverse nature of fauna habitats, fauna were analysed in assemblages, namely; sea birds, vertebrates other than sea birds (land birds, reptiles, mammal) and invertebrates.

Sea bird species richness (Figure 3) is highest on the offshore islands, cliffs of the northern hills and down through Searles Point to Middle Beach and Clear Place. Muttonbird Point, Gower Island, the southern tip of the main island and much of the coastline is also highlighted as rich habitat for sea birds. Balls Pyramid is also recognised as being a significant area for sea birds.

Patterns of species richness for vertebrates other than sea birds are less obvious (Figure 4). High species richness is indicated for much of the shoreline areas. This is due to the inclusion of shore birds in this group. Other areas of high species richness are scattered throughout the main island. These areas are most likely triggered by the distribution of land birds such as the Lord Howe Woodhen and the Emerald Ground-dove (*Chalcophaps indica*). Creeklines are highlighted due to the presence of the Long-finned Eel (*Anguilla reinhardtii*), the Short-finned Eel (*Anguilla australis*) and the freshwater fish Common Jollytail (*Galaxias maculatus*).

Invertebrate fauna

For invertebrates, distinctive patterns of endemicity, species richness and dissimilarity (distinctiveness of species assemblages) are apparent (Cassis *et al.* 2003) (Figures 5 and 6). Overall levels of endemism for the four groups of invertebrates studied (ants, spiders, beetles and snails) are highest in the southern mountains. However, individual groups show more complex patterns. For example, the beetle group has a high level of endemism in parts of the central lowlands, the northern hills and the southern mountains. Spiders show high levels of endemism in the southern mountains and also on the Admiralty Islands to the north of the main island. The highest areas of ant endemism are limited to the southern mountains, particularly Mount Lidgbird. Snails and ants display a high level of local endemism in the southern mountains. The summits of Mounts Gower and Lidgbird have the highest invertebrate endemism.

Species richness patterns for invertebrates are more complex, with high levels of species richness located in parts of the southern mountains, the northern hills, Steven's Reserve and Transit Hill. Areas with the greatest average dissimilarity occur in the southern mountains, Transit Hill, headlands of the northern hills and the Admiralty Islands.

Specific vegetation types are significant to the distribution of snails, namely the Cloud Forest on the summits of Mounts Gower and Lidgbird, Tea Tree (*Melaleuca howeana*) vegetation around the base of the southern mountains, and Curly Palm (*Howea belmoreana*) vegetation around the base of Mount Lidgbird.

For spiders, Leafy Flat Sedge (*Cyperus lucidus*) on Roach Island, Tea Tree, Cloud Forest and Big Mountain Palm occurring on the slopes of the southern mountains above 600m are significant to their distribution.

Beetle distribution is influenced by elevation and geology and, to a lesser extent, vegetation type. The most significant vegetation types for beetle distribution are Cloud Forest and Fitzgeraldii-Mountain Rose closed scrub at mid altitudes in the southern mountains.

Three vegetation types have a significant influence on ant distribution. These are Five-leaf Morning Glory-Pig Face (*Ipomoea cairica-Carpobrotus glaucescens)* on Roach Island, and Curly Palm around Mount Lidgbird and the northern hills, and Scalybark (*Cleistocalyx fullageri)* at higher altitudes on the northern hills and southern mountains. The Boat Harbour breccia geology also significantly influences ant fauna composition.

Summary of hot spot areas

Overall, the southern mountains display the highest levels of species richness and endemicity for flora, vegetation communities, invertebrates, and, to a lesser extent, vertebrate fauna.

It is important to recognise, however, that significant species and patterns of species occur outside these areas. Other hot spot areas include Balls Pyramid, the eastern settlement area, the northern hills, offshore islands, Steven's Reserve and Transit Hill.

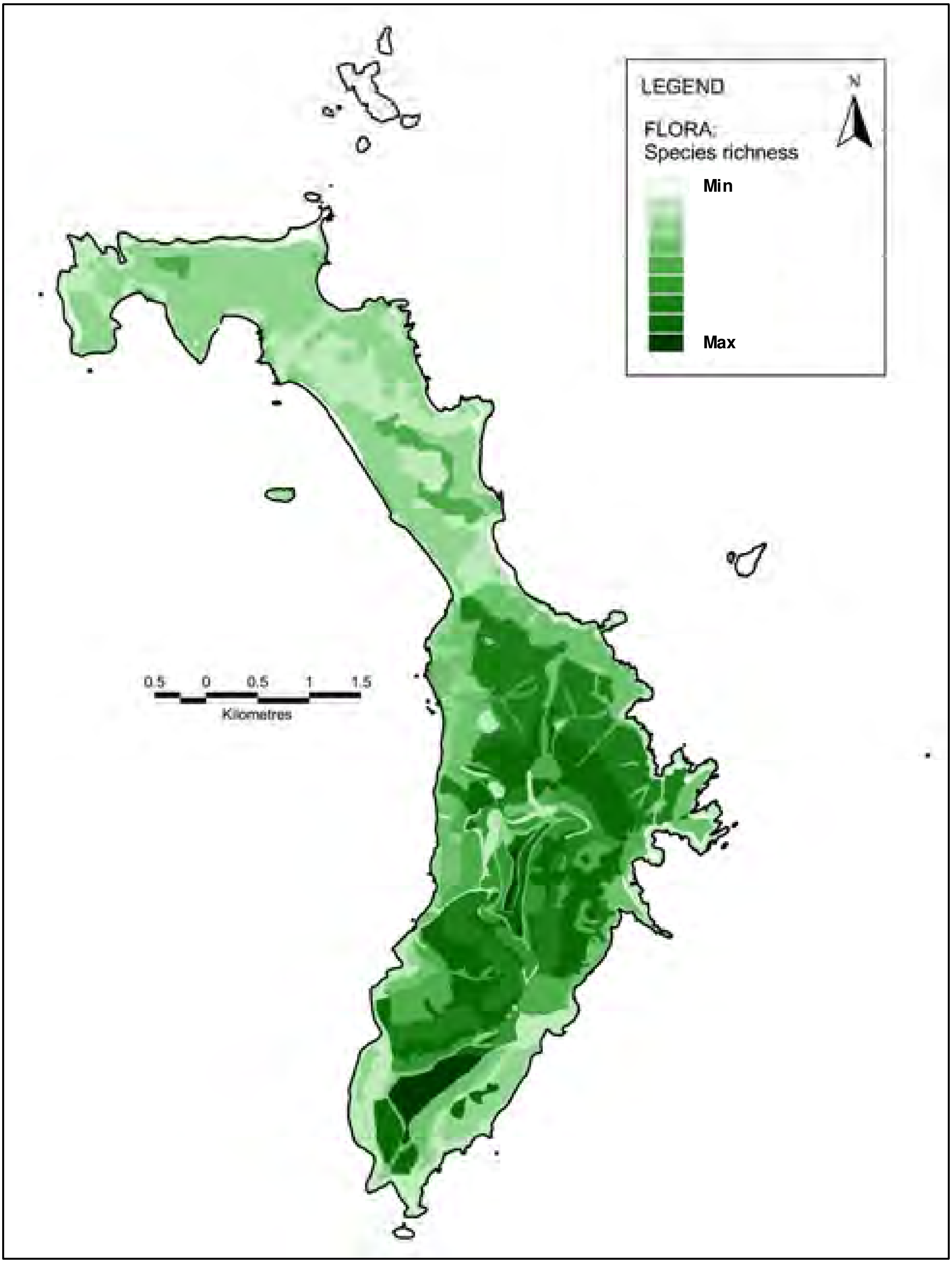


Figure 2. Flora species richness of the Lord Howe Island Group

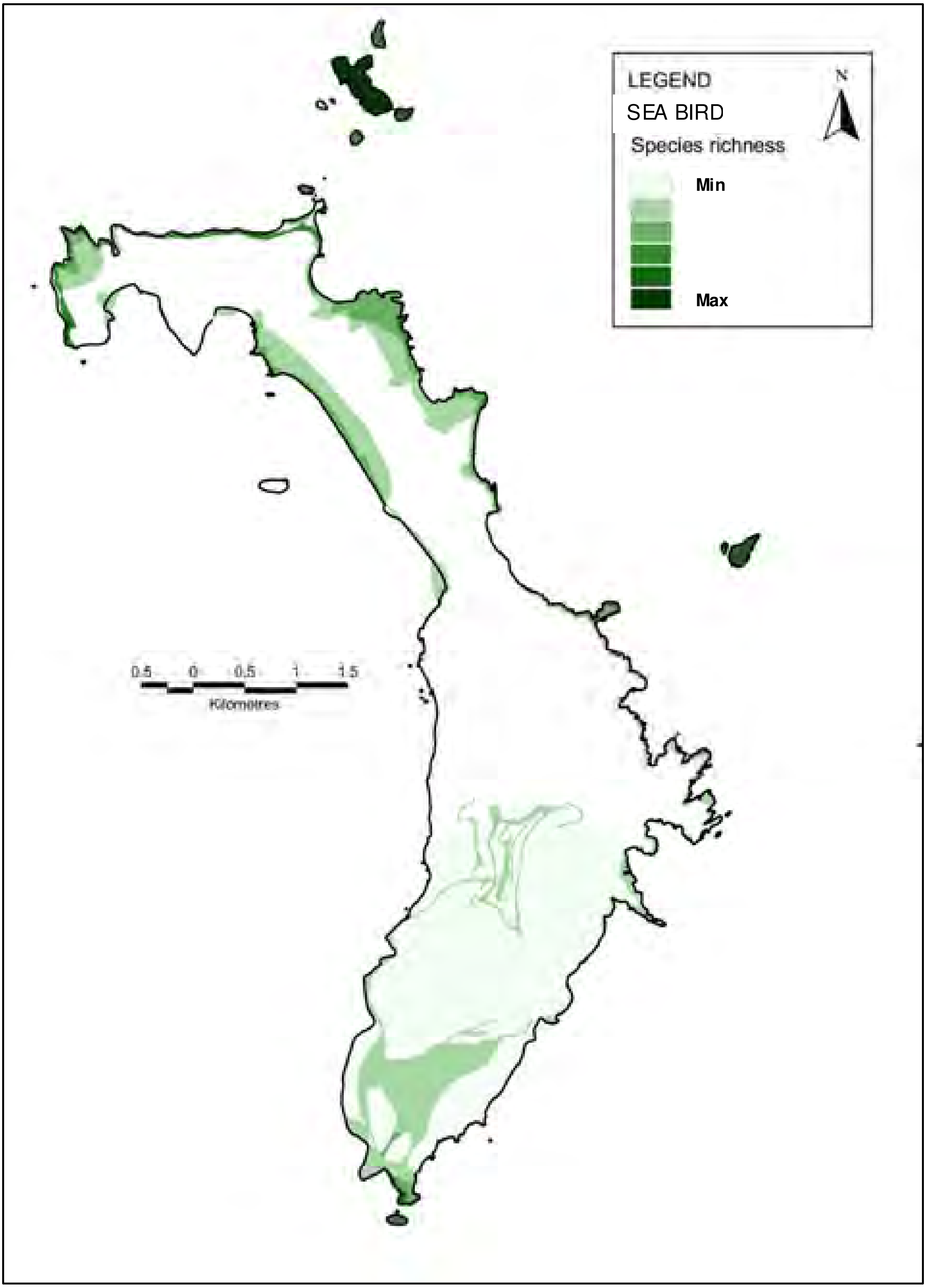


Figure 3. Sea bird species richness for the Lord Howe Island Group

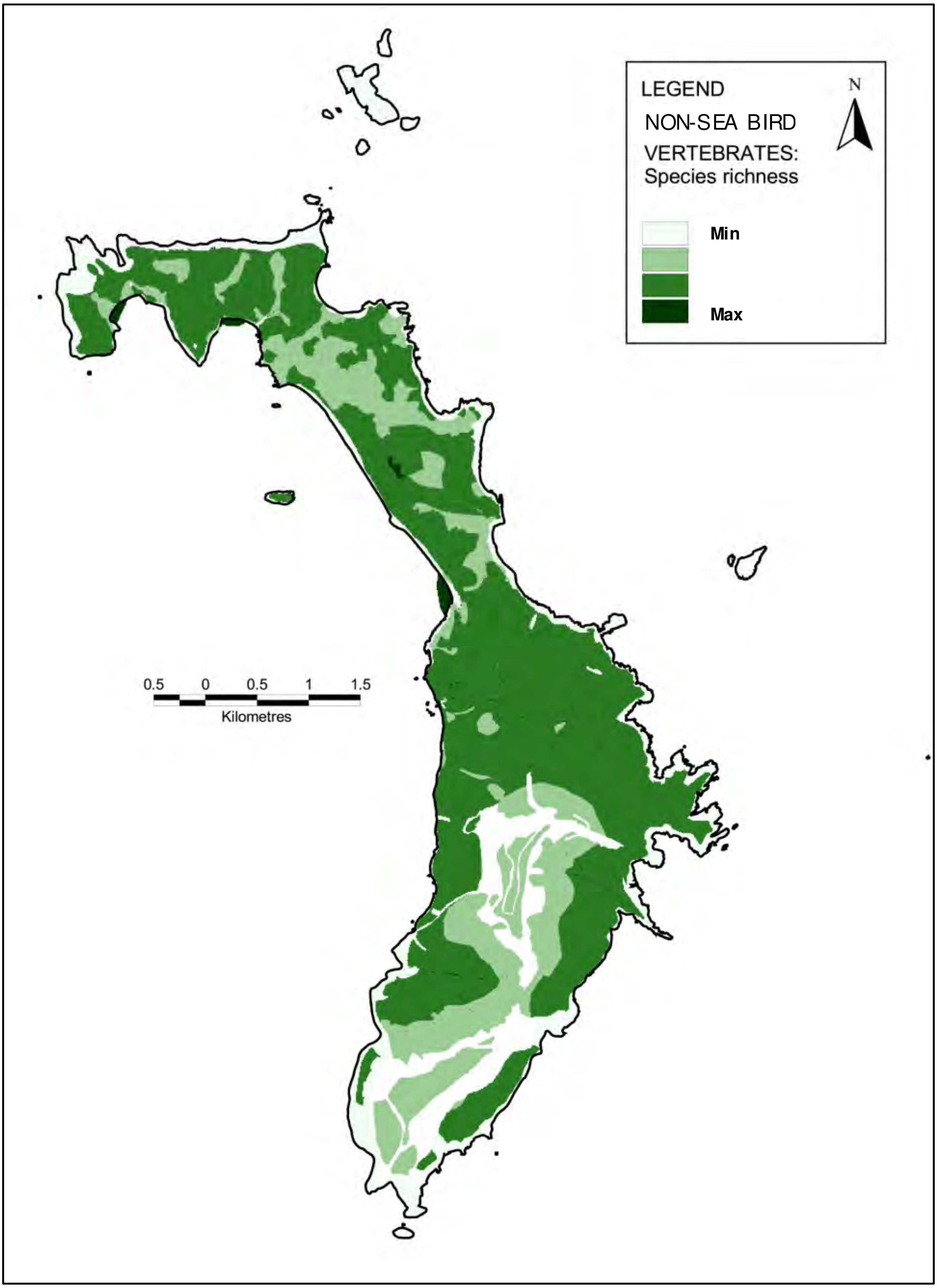


Figure 4. Non-sea bird vertebrate species richness of the Lord Howe Island Group.

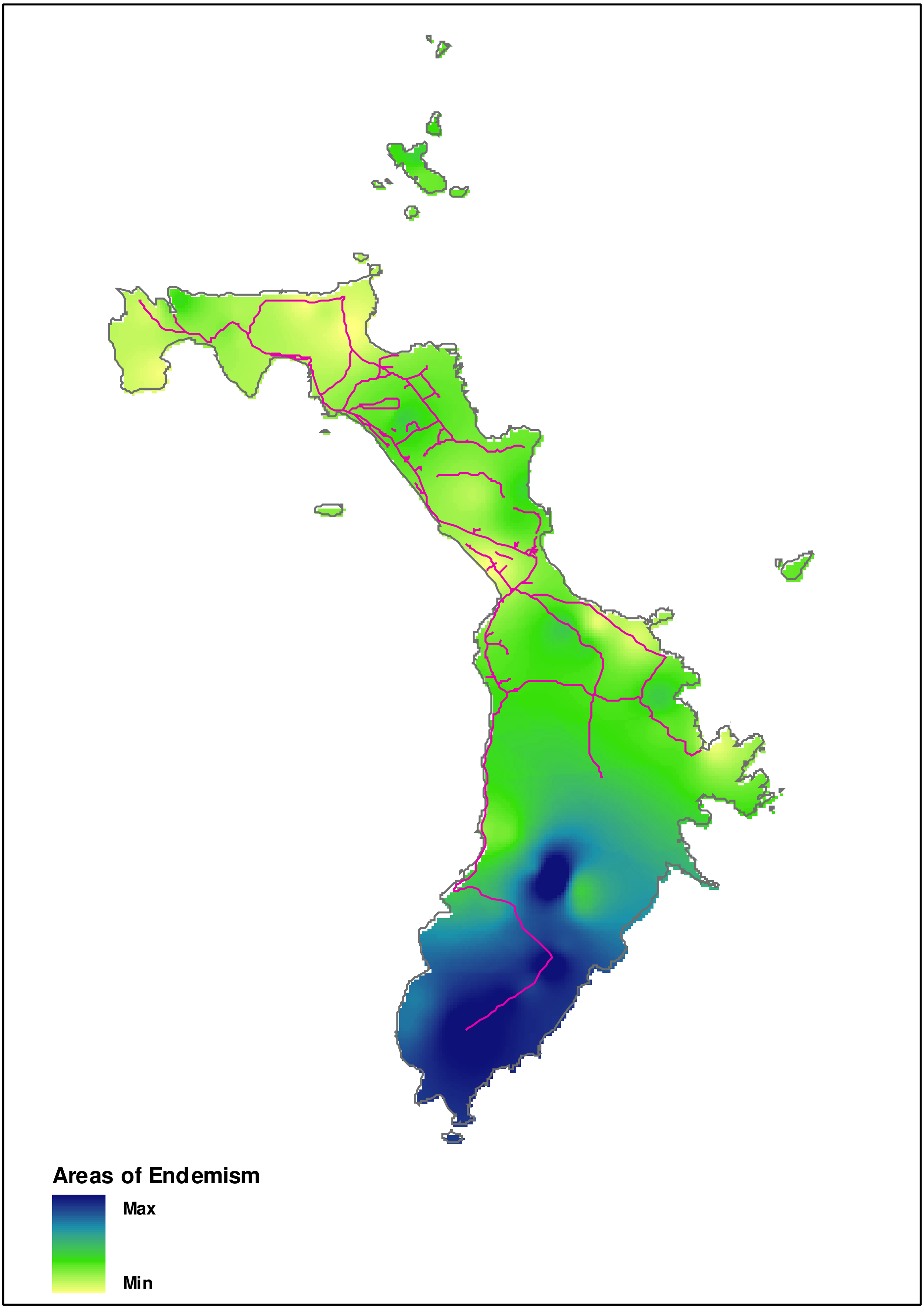


Figure 5. Overall levels of invertebrate endemism for the Lord Howe Island Group. Combined analysis of snails, spiders, beetles and ants (from Cassis *et al.* 2003).

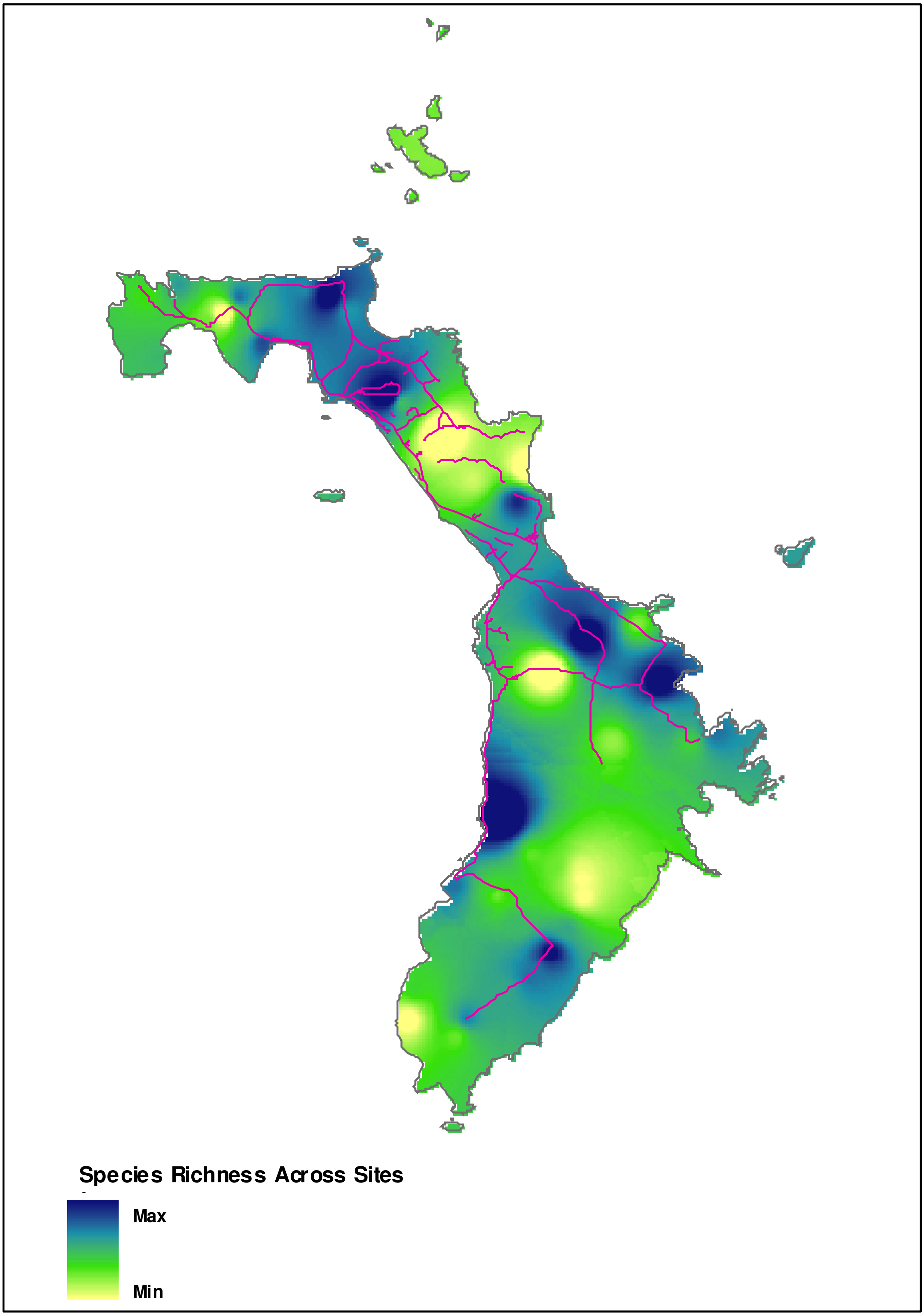


Figure 6. Species richness of snails, spiders, beetles and ants for the Lord Howe Island Group (from Cassis *et al.* 2003).

4 Threats

4.1 Introduction

Like other small oceanic islands, the LHIG has suffered significant species loss due to the impacts of human activities and exotic species introductions. Nine species of land bird and one species of sea bird have disappeared from Lord Howe Island (Hutton 1991), while two species of plants are presumed to be extinct (refer to Appendix 1, appendices document). Two vertebrate species (Lord Howe Island Skink and Lord Howe Island Gecko) are greatly reduced in number on the main island. Several invertebrate species, including two threatened species (Lord Howe Island Wood-feeding Cockroach and Lord Howe Island Phasmid) are locally extinct on the main island and are now confined to offshore islands.

Often, threatening processes on the LHIG are common to several species. Some of these threats occur broadly across the island, such as predation by the Ship Rat (*Rattus rattus*). Others are more geographically identifiable, such as invasion by the introduced weed Climbing Asparagus, which is predominantly a localised problem. Threats are discussed below in more detail and summarised for each species and community in Appendix 3 (appendices document).

Table 6. Key Threatening Processes relevant to Lord Howe Island (August 2007).

TSC Act	EPBC Act
Anthropogenic Climate Change	Loss of Climatic Habitat Caused By Anthropogenic Emissions of Greenhouse Gases
Clearing of Native Vegetation	Land clearance
Competition and habitat degradation by Feral Goats, *Capra hircus*	Competition and Land Degradation by Feral Goats
Infection of Native Plants by *Phytophthora cinnamomi*	Dieback Caused by the Root-rot Fungus *Phytophthora cinnamomi*
Importation of Red Imported Fire Ants *Solenopsis invicta*	The Reduction in the Biodiversity of Australian Native Fauna and Flora due to the Red Imported Fire Ant (*Solenopsis invicta*)
Invasion and establishment of exotic vines and scramblers	
Invasion and establishment of the Cane Toad *Bufo marinus*	The biological effects, including lethal toxic ingestion, caused by Cane Toads (*Bufo marinus)*
Invasion, establishment and spread of Lantana (*Lantana camara*)	
Invasion of the Yellow Crazy Ant	
Invasion of Native Plant Communities by Bitou Bush and Boneseed	
Invasion of Native Plant Communities by Exotic Perennial Grasses	
Predation by the Ship Rat on Lord Howe Island	Predation by exotic rats on Australian offshore islands of less than $100km^2$ (100,000 ha)
Removal of dead wood and dead trees	
	Incidental Catch (or Bycatch) of Sea Birds during Oceanic Longline Fishing Operations
Entanglement in or Ingestion of Anthropogenic Debris in Marine and Estuarine Environments	Injury and Fatality to Vertebrate Marine Life Caused by Ingestion of, or Entanglement in, Harmful Marine Debris

4.2 Key Threatening Processes

The TSC Act and EPBC Act Key Threatening Processes (KTPs) that are relevant to the LHIG are listed in Table 6. There are 15 KTPs listed that are relevant to the LHIG; 14 of these are listed on the TSC Act and nine on the EPBC Act. Some of these KTPs are common to both Acts. These threats are discussed in more detail in Sections 4.3 and 4.4.

4.3 Current and past threats

Habitat clearing and modification

Clearing of Native Vegetation is a Key Threatening Process on the TSC Act, and Land Clearance is a Key Threatening Process on the EPBC Act.

Much of the retention of the biodiversity values of the LHIG can be attributed to the low degree of disturbance to its native vegetation. Less than 13% of the native vegetation of Lord Howe Island is cleared, and less than 24% is disturbed (Hunter 2002; Pickard 1983). Clearing has occurred in the settlement area for both houses and farmland.

While large scale clearing of native vegetation no longer occurs on Lord Howe Island, the impact of vegetation clearing on a smaller scale needs to be assessed. The loss of individual trees in the settlement area through approved felling, natural senescence or as a result of dense weed invasion can have a significant local impact by adding to habitat loss and creating conditions suitable for weed invasion or vegetation dieback.

Although a large proportion of native vegetation remains on Lord Howe Island, certain vegetation types have been cleared more than others. The vegetation types that were dominant in the settlement area have been subject to the greatest amount of clearing (approximately 48% of the settlement area is cleared). For example, the Greybark-Blackbutt (*Drypetes deplanchei* ssp. *affinis-Cryptocarya triplinervis)* closed forest is a dominant vegetation type in the settlement area and, therefore, has had a larger proportion cleared than vegetation types such as Cloud Forest (Hotbark-Fitzgeraldii Closed Forest) which is restricted to the higher parts of the southern mountains and not subject to clearing. If clearing for further development in the settlement area continues, significant vegetation communities and habitats may be threatened. For example, the vegetation community Sallywood Swamp Forest, which has always had a restricted distribution, is listed as an Endangered Ecological Community on the TSC Act due to the ongoing impacts of clearing and grazing in the settlement area.

It is considered that a possible past reduction in the Flesh-footed Shearwater (*Puffinus carneipes*) population may be due to increased residential buildings in the settlement area which has reduced their habitat. Priddel *et al.* (2006) has calculated that the total extent of nesting habitat for this species has been reduced by 35.6% since 1978. This is associated with increased urbanisation and development, especially around Stevens Point and Middle Beach. In addition, low numbers of Flesh-footed Shearwaters are killed by traffic on roads at night (Hutton 2003).

Fragmentation also poses a threat to vegetation on the LHIG. The PPP is split into northern and southern sections, separated by the settlement area. There is no continuous vegetation corridor between these areas (Olsen 2002).

For terrestrial invertebrates, the modification of ecosystems through land clearance and habitat fragmentation is considered to be the most critical threatening process (New 1995 in Cassis *et al.* 2003). A higher proportion of clearing in the settlement area is likely to have had an adverse impact on the Endangered Lord Howe Island Placostylus, whose preferred habitat coincides with this area. Removal of dead wood and trees is also likely to have a negative impact on other invertebrates on the LHIG. This activity is listed as a Key Threatening Process on the TSC Act.

Vegetation windshear

Vegetation windshear and resulting canopy dieback is evident in many parts of the LHIG, particularly in the settlement area, mostly from the impact of salt-laden winds. When protective vegetation on the windward edge is removed, windshear and damage to the canopy often results. Introduced pasture grasses, particularly Kikuyu and Buffalo Grass (*Stenotaphrum secundatum*), can impede or prevent regeneration of native species in these areas, thus exacerbating windshear.

Vegetation windshear and dieback can also occur in areas which are not adjacent to cleared areas or natural edges. Windshear and dieback in these areas often occurs as a result of damage from storm events, which bring strong salt-laden winds.

Certain vegetation communities and flora species are more susceptible to windshear than others. For example, the Greybark-Blackbutt lowland rainforest association is particularly susceptible to dieback. The small remnants of the Endangered Sallywood Swamp Forest community have suffered from windshear due to exposure. In some sites, only remnant trees remain, and these exposed trees continue to decline due to a lack of any protective surrounding vegetation. Two species of trees which are particularly susceptible to wind damage are Scalybark (*Syzygium fullargarii*) and Banyan (*Ficus macrophylla* ssp. *columnaris*) (Olsen 2002).

Trampling, browsing and grazing

Cattle and Horses were introduced to Lord Howe Island soon after settlement. Cattle still provide a source of fresh meat and milk for the islanders and visitors (Havilah & Blackwood 1996).

Pastures maintained for Cattle and Horse grazing are predominantly cleared of native vegetation, and any remaining native vegetation within these areas can be trampled and browsed, preventing or inhibiting regeneration. Where grazing occurs amongst unfenced native vegetation, the understorey is lost, and pasture grasses and other annual weeds may invade. Remnants of Sallywood Swamp Forest and Mangrove Communities (*Aegiceras corniculatum)* show damage from trampling by cattle (Figure 7). The Endangered Lord Howe Island Placostylus is thought to be impacted by trampling of domestic cattle (Ponder & Chapman 1999).

Pigs and Goats were presumably first introduced to the island by sailors as a source of fresh meat (Flora of Australia 1994). Pigs caused a great deal of damage to vegetation, including rooting for rhizomes, eating seeds (Pickard 1983), disturbing soil invertebrates and causing erosion (NSW NPWS 2002). It is also recorded that Pigs ate Lord Howe Woodhens and their nest contents (Miller & Mullette 1985). Feral Pigs were eradicated by the early 1980s.

Competition and land degradation by the Feral Goat is listed as a Key Threatening Process on the EPBC Act and the TSC Act. Goat browsing on vegetation, particularly in the southern mountains, was a cause for concern as early as the late 1800s and prompted a control program in the 1970s. Prior to this, Goats roamed the northern hills and southern mountains and, as well as browsing vegetation, denuded areas in and around cave camps and caused faecal downwash from camps. The control program has reduced the number of Goats to a few non-reproductive animals. Goat damage to vegetation, such as scars on trees from chewed bark, is still visible in some areas.

Predation by the Ship Rat *Rattus rattus*

Predation by the Ship Rat is listed on the TSC Act as a Key Threatening Process. The Ship Rat (or Black Rat) was introduced accidentally to Lord Howe Island after the grounding offshore of the supply ship *Makambo* in 1918. The population of Ship Rats increased dramatically soon after establishment, and the Ship Rat is now distributed widely in terrestrial habitats on the main island.

The Ship Rat has a generalised diet, and is known to take seeds, green plant material, fungi, invertebrates, small vertebrates and eggs as food (NSW Scientific Committee 2000).

On Lord Howe Island, the Ship Rat has been implicated in the decline and extinction of five species of birds, the Island Thrush (*Turdus poliocephalus vinitinctus*), the Robust White-eye (*Zosterops strenuus*), the Lord Howe Island Gerygone (*Gerygone insularis*), the Tasman Starling (Lord Howe Island subspecies, *Aplonis fuscus hullianus*) and the Grey Fantail (Lord Howe Island subspecies, *Rhipidura fuliginosa cervina*).

Figure 7. Degraded Sallywood Swamp Forest showing impacts from grazing. This area has now been fenced off for revegetation.

Two sea bird species, the Kermadec Petrel and the White-bellied Storm Petrel, are now restricted to breeding on Balls Pyramid, where previously they were known to breed on the main island. This loss of breeding habitat is thought to be an impact of Rat predation.

The two species of lizards (the Lord Howe Island Gecko and the Lord Howe Island Skink) are scarce on the main island of Lord Howe, where the Ship Rat occurs. They are both more abundant on small islands where Rats are absent.

Invertebrate species have also been impacted by the introduction of the Ship Rat. The Endangered land snail, the Lord Howe Island Placostylus is at risk from Ship Rat predation (NSW NPWS 2001), as is the large land snail *Gudeoconcha sophiae.* The Ship Rat has been linked with the extinction of two large-sized land snails that lived in the southern mountains of Lord Howe Island, a subspecies of the Lord Howe Island Placostylus and an endemic genus and species *Epiglypta howinsulae.*

The Ship Rat has been implicated in the extinction of the Lord Howe Island Phasmid from the main island. This species was recently rediscovered on Balls Pyramid where Ship Rats are absent. Similarly, the Lord Howe Island Wood-feeding Cockroach and the Darkling Beetle (*Promethis sterrha*) are no longer found on the main island, but are restricted to outlying, rat-free islands.

Ten beetle species, the majority of which were large and often flightless, are thought to be extinct (Cassis *et al.* 2003). Their decline is possibly correlated with the introduction of the Ship Rat. The rarity of some of the larger species of ground-dwelling and bark-dwelling spiders may also be due to predation by introduced rodents (Cassis *et al.* 2003). The Ship Rat is likely to directly compete with invertebrate seed-predators, a common group on Lord Howe Island.

In addition to impacts to fauna, the Ship Rat is known to damage the vegetative parts of several species of plants on Lord Howe Island. It depletes seed yields of the commercially-harvested Kentia

Palm (*Howea forsteriana*), as well as other endemic island palm species e.g. the Big Mountain Palm, the Curly Palm and the Little Mountain Palm (*Lepidorrhachis mooreana*). Species threatened by the Ship Rat are listed in Appendix 3 (appendices document).

Competition and predation from other introduced animals

Two types of introduced species are recognised in this plan. Self-introduced, naturalised species are those that have arrived on the island and have established populations without human intervention. Many of these species are land birds. Some of these species have been able to establish populations due to human habitat modifications, such as the creation of cleared areas which support species such as Buff-banded Rail. Others can be considered part of natural island ecological processes of establishment of new species. Self-introduced species are listed in Section 3 of Appendix 1.3.

Deliberate introductions are those species that have been introduced to the island by humans. These have either established self-perpetuating populations, or are domestic animals such as cattle and horses.

Both self-introduced and deliberately introduced species impact upon native and endemic species to varying degrees. The degree of impact, and interaction with native and endemic species, needs to be assessed in order to determine which introduced species may warrant control programs.

It is thought that the Songthrush (*Turdus philomelos*) and the Blackbird (*Turdus merula*) were brought to the island in 1944 in an attempt to control the weevils that were eating palm flowers and reducing seed yield (Pickard 1983). These birds are still present on the Island and eat a variety of native and endemic insects and snails, including the Endangered Lord Howe Island Placostylus (Hutton 1991).

Masked Owls (*Tyto novaehollandiae*) were introduced to Lord Howe Island to control Ship Rats in the 1920s, without success. Masked Owls persist in most parts of the island but are more common in the southern mountains (NSW NPWS 2002). They are now considered a pest on Lord Howe Island (Hutton 1991) however, are listed as Vulnerable on the TSC Act.

The Masked Owl preys upon House Mice (*Mus domesticus*), Ship Rats and birds (White Terns, Black-winged Petrel, Providence Petrel (*Pterodroma solandri*) chicks and Lord Howe Woodhens), (Hutton 1991) and the Lord Howe Island Skink and Lord Howe Island Gecko (Cogger unpub). They may be preventing Kermadec Petrels (*Pterodroma neglecta*) and White-bellied Storm-Petrels (*Fregetta grallaria*) from recolonising the main island (Hutton 2003).

Barn Owls (*Tyto alba*) were also introduced to Lord Howe Island, but are thought to be no longer present.

Cats were brought to the island probably in the 1840s or 1850s (Hutton 2001b). These had an impact on the birds, reptiles and possibly some invertebrates. Feral Cats were removed from the island in 1979 as part of the Lord Howe Woodhen recovery program. In addition to benefits to the Lord Howe Woodhen, other positive impacts of feral Cat removal have been noted. For example, Wedge-tailed Shearwaters (*Puffinus pacificus*) are increasing on dune areas and Little Shearwaters (*Puffinus assimilis*) have returned to breed on the main island after an absence brought about by Cat predation. In 1982, a local law banned domestic Cats (with a "grandfather" clause to allow current owners to keep pet Cats if they were desexed) (Hutton 2001b). There is now only one pet Cat on Lord Howe Island.

The House Mouse reached the island probably as early as 1860, and most likely has an impact on some plant and invertebrate life (Hutton 2001b). House Mice eat a variety of plant fruits, seeds and invertebrates. House Mice have been reported to have caused a decline of the gecko (*Hoplodactylus maculatus*) and skink (*Cyclodina macgregori*) on Mana Island, New Zealand. Both species recovered when the mice were removed (Cogger unpub).

Two of the most recent introductions to Lord Howe Island are that of the Bleating Tree Frog (*Litoria dentata*) and the Grass Skink (*Lampropholis delicata*). The Bleating Tree Frog can be heard calling in many parts of the settlement area and northern hills, while the Grass Skink can commonly be seen in leaf litter in these places. It is not known what impact these species have, but they are likely to compete with, and prey upon, native invertebrates.

Feral Pigeons (*Columba livia*) nest in the sea cliff areas of the northern hills. They are currently being fed by some community members. Feral Pigeons have the potential to increase their numbers rapidly and compete with native bird species, for nesting, roosting sites and food.

Domestic animals such as Chickens and Ducks have a small but potentially significant impact on native fauna. Chickens are frequently seen foraging in leaf litter amongst native forest in the settlement area, and may feed upon native snails and other invertebrates, including the Endangered Lord Howe Island Placostylus. Ducks that are allowed to forage in such areas would also prey upon native invertebrates.

Introduced invertebrates

Approximately 5% of the almost 2000 species of invertebrates on Lord Howe Island are introduced (Cassis *et al.* 2003). The impact of these on native biota is unknown, however, likely impacts on native plants have been identified. For example, it is thought that the chrysomelid *Arsipoda,* which feeds on the Endangered *Calystegia affinis,* may have been introduced with exotic species of *Ipomoea.* The impact of browsing is not known, however, it may affect the flowering, and thus seed-producing, ability of the plant.

The African Big-headed Ant (*Pheidole megacephala)* was most likely introduced to Lord Howe Island about ten years ago and a survey into its distribution was conducted. In 2005 it was found that the ant's distribution was located in the settlement area, generally in disturbed sites, but significantly including Stevens Reserve, which is known for its high level of endemic and restricted invertebrate fauna. The African Big-headed Ant is recognised as a major threat to biodiversity and ecosystem integrity by its ability to out-compete and displace native invertebrates, particularly native ant species and has had major impacts on the biota of other islands where it has colonised. On Lord Howe Island, field assessments of known African Big-headed Ant infestations on the island have indicated that they are displacing native ant species and other native invertebrate fauna.

A large, introduced slug has established in the lowland forests and is a carnivorous species that preys upon smaller endemic snails and slugs (Hutton 2001b). It could have an impact on the Endangered Lord Howe Island Placostylus, as well as other significant species. An introduced earthworm is thought to have the potential to compete with native soil fauna, and is considered a potential threat to the Endangered Lord Howe Island Earthworm.

The potential impacts of future invertebrate introductions is discussed further in Section 4.4.

Weed invasion

Weed invasion is a major issue for the biodiversity of the LHIG, and affects all vegetation communities to some extent. Weeds threaten native habitats by competing with native species and have the potential to transform habitats to the detriment of native species.

For the purposes of this plan, a weed is defined as a plant that was not present on Lord Howe Island prior to human settlement, and that is naturalised on the island. The focus of this plan in terms of threats is on existing significant weed species, although it must be recognised that many introduced plant species already on the island (e.g. those growing in gardens) have the potential to become weeds in the future. These species are discussed in more detail in Section 4.4.

There are over 670 species of introduced plants on the island, and approximately 40% (271) of these can be defined as weeds. Forty species have established in the PPP while 13 species are classified as very invasive and have colonised extensive areas of the settlement and PPP. They pose a serious threat to LHIG habitats (Smith, 2002; Le Cussan (in prep; 2003b) (Table 7).

About half the weed species present on the island have originated from introduced pasture seeds and fodder, or are weeds of wastelands and disturbed areas. A few weeds have established via ocean currents, for example the American Sea Rocket (*Cakile edentula*), and the Sea Spurge (*Euphorbia paralias*). The other half of the weed species originated as garden plants. As 11 of the 13 major weed species listed in Table 7 originated as garden plants, the settlement area has historically been, and remains, the major source of both new weed species and a seed source for existing weed species. The major weed species currently found in native vegetation on the LHIG produce seeds which are dispersed either by wind, birds, water or gravity. The walking track network may also be an important transport vector for some noxious and significant weeds such as Cherry Guava (when walkers eat fruit and spit out the seeds further along the track), and plants which produce seed that stick to passers by such as Farmer's Friends (*Bidens pilosa*) (Smith 2002).

Table 7. Noxious and significant weeds of the Lord Howe Island Group

Common name (*)	Scientific name	Major Weed
#African Boxthorn (4)	*Lycium ferocissimum*	✓
#Arundinaria Reed (3)	*Arundinaria* sp.	
#Bamboo	*Bambusa* spp.	
#Bitou Bush (2)	*Chrysanthemoides monilifera*	✓
#Bridal Creeper (4)	*Asparagus asparagoides*	✓
Buffalo Grass	*Stenotaphrum secundatum*	
#Castor Oil Plant (3)	*Ricinus communis*	
#Cherry Guava (3)	*Psidium cattleianum*	✓
#Climbing Asparagus (4)	*Asparagus plumosus*	✓
#Cotoneaster	*Cotoneaster glaucophyllus*	✓
#Crofton Weed (4)	*Ageratina adenophora*	✓
#Elephant Grass (3)	*Arundo donax*	
#Glory Lily (3)	*Gloriosa superba*	
#Ground Asparagus (4)	*Asparagus aethiopicus*	✓
Kikuyu Grass	*Pennisetum clandestinum*	
#Lantana (3)	*Lantana camara*	✓
#Madeira Vine (4)	*Anredera cordifolia*	✓
Norfolk Island Pine	*Araucaria heterophylla*	
#Ochna (4)	*Ochna serrulata*	✓
#Palm Grass	*Setaria palmifolia*	
Rhizomatus Bamboo (3)	*Phyllostachys* sp.	
#Rhus Tree (4)	*Toxicodendron succedaneum*	
#Sweet Pittosporum (3)	*Pittosporum undulatum*	✓
#Tiger Lily (4)	*Lilium formosanum*	✓
#Umbrella Tree	*Schefflera actinophylla*	
#White Cedar	*Melia azederach*	

Listed on Schedule 3 (noxious plants) of the Lord Howe Island Regulation 2004. The LHIB may take such measures as it considers necessary to control plants declared to be noxious.

* Noxious weed class (in brackets):

2 = The plant must be eradicated from the land and the land must be kept free of the plant.

3 = The plant must be fully and continuously suppressed and destroyed.

4 = The growth and spread of the plant must be controlled according to the measures specified in a management plan published by the local control authority and the plant may not be sold, propagated or knowingly distributed.

It appears that certain vegetation communities such as *Howea* forest have a fairly low degree of weed invasion (Smith 2002) and, conversely, some vegetation communities, such as grasslands (*Poa)* are significantly affected by weeds across their range. The Greybark-Blackbutt Community also has a high degree of weed invasion, having ten of the 14 major weed species present.

The impact of weeds on terrestrial invertebrates is unknown, but is unlikely to be beneficial (Cassis *et al.* 2003). Weeds usually lack herbivore predators to feed on them, or they support introduced herbivores, which may then attack native plants. Leaf litter of exotic plants may not be palatable to indigenous detritivores.

Three TSC Act Key Threatening Processes concerning weeds are relevant to Lord Howe Island: “Invasion and establishment of exotic vines and scramblers”, “Invasion, establishment and spread of Lantana” and “Invasion of native plant communities by Bitou Bush and Boneseed”.

Following are brief descriptions of the location and impacts of the major weeds of the LHIG. Much of this information has been sourced from Le Cussan (in prep; 2002a; 2002b; 2003a & 2003b), Hutton and Le Cussan (2001) and Smith (2002).

African Boxthorn (Lycium ferocissimum)

A dense infestation of African Boxthorn occurs on the Middle Beach cliffs to Ned’s Beach, with one occurrence on Malabar. This plant is dispersed by birds.

African Boxthorn is a declared Noxious plant in all states of Australia.

Climbing Asparagus (Asparagus plumosus)

A very large infestation of Climbing Asparagus is located on Transit Hill but it is also reasonably widespread throughout the settlement area. In addition it occurs on Malabar.

This species is a vigorous climber and can cause significant forest canopy damage.

Climbing Asparagus is not known to occur in the southern mountains at present.

Climbing Asparagus is present in three vegetation associations, namely Greybark-Blackbutt, Kentia Palm, and Lowland Mixed Forest.

Crofton Weed and Tiger Lily

Crofton Weed and Tiger Lily are widespread on Lord Howe Island, and often occur together. Crofton Weed generally requires moist sites whereas Tiger Lily appears to have a wider environmental tolerance. They pose a particularly severe threat in the southern mountains and Intermediate Hill. They are also present in the settlement area, on Transit Hill and the Malabar Range. They have wind-dispersed seed. Tiger Lily can also reproduce from subterranean bulbs.

Crofton Weed and Tiger Lily are both weeds of disturbed areas. Landslips are a significant feature of the southern mountains and represent a large-scale natural disturbance, where weeds such as Crofton Weed and Tiger Lily are often the primary colonisers. In this situation, once Crofton Weed and Tiger Lily have established, it is very difficult for native species to reestablish. In the southern mountains, native fern, herb and moss areas that would have naturally recolonised landslip areas are being replaced by Crofton Weed and Tiger Lily. There are several threatened and significant plant species e.g. the Endangered *Carmichaelia exsul* that are under risk from invasion by these species.

Tiger Lily, while being a weed of disturbed areas, does not require disturbance for colonisation. It is widely established throughout most plant communities on Lord Howe Island, from the mountain tops to the coastal sand dunes.

Crofton Weed and Tiger Lily occur in Greybark-Blackbutt, Kentia Palm, Lowland Mixed Forest, Scalybark-Blue Plum (*Syzygium fullargarii-Chionanthus quadristamineus*), Bully Bush (*Cassinia tenuifolia*), Big Mountain Palm, and Cliff Communities. Invasion by Crofton Weed poses a major threat to the Mixed Fern and Herbfield Community, which is one of the most significant vegetation communities for invertebrates.

One of the major issues for control of these species is the inaccessibility of the terrain they often inhabit, namely, remote parts of the southern mountains including cliffs and rocky slopes. In addition, it appears that very little work has been done on control of bulbous weeds such as Tiger Lily in Australia. Even in accessible areas, no treatment is undertaken as effective techniques are not known.

Ground Asparagus (Asparagus aethiopicus)

Ground Asparagus is a major weed in the Transit Hill area, with the notable exceptions being the fig and palm forests of Middle Beach/Valley of the Shadows area and part of the south facing slope of Transit Hill. This species is the most abundant and widespread weed species on Transit Hill.

On the north-west slopes of Mount Lidgbird and East Point in the southern mountains, Ground Asparagus occurs in relatively low densities, suggesting that it is in the initial stages of establishment in these areas.

In the northern hills, Ground Asparagus is reasonably widespread, although not in great numbers. It is also present in the settlement area and Intermediate Hill.

Ground Asparagus has the ability to completely dominate understorey vegetation, and thus prevent native regeneration. In such a situation, when damage to the canopy occurs, native seedlings are unlikely to be able to regenerate to replace lost or damaged canopy species, thus leading to a progressive decline and dieback of the forest.

As this species has the ability to dominate, and has been recorded in undisturbed areas of forest via bird-dispersed seed, it is considered a serious problem.

Ground Asparagus has been recorded in a range of vegetation types including Greybark-Blackbutt, Bully Bush, Kentia Palm, Scalybark-Blue Plum, Cliff and Lowland Mixed Forest.

Bridal Creeper (Asparagus asparagoides)

Bridal Creeper is classified as a weed of national significance. It is widespread across a range of habitats. It can invade undisturbed vegetation and has the potential to eliminate most understorey species in the long term (Walton *et al.* 1991).

On the LHIG, Bridal Creeper is known from the north of the main island, particularly in the Curio Point-Kims Lookout-Malabar area of the northern hills, but also Transit Hill, Middle Beach and in the settlement area. Studies indicate that Bridal

Creeper is actively spreading in this area, and is likely to be bird-dispersed (Le Cussan 2002b).

Bridal Creeper has been recorded in Greybark-Blackbutt, Bully Bush, Kentia Palm, Scalybark-Blue Plum, Cliff, and Lowland Mixed Closed Forest Communities.

Bitou Bush (Chrysanthemoides monilifera)

"Invasion of native plant communities by Bitou Bush" is listed as a Key Threatening Process under the TSC Act. Bitou Bush is also classified as a weed of national significance.

Bitou Bush occurs on cliffs in the northern hills (Malabar area), parts of the settlement area, Transit Hill, and the southern mountains. It occurs in a variety of vegetation types, from rainforest and palm forest to more open vegetation types such as those dominated by Bully Bush.

Bitou Bush occurs mostly as scattered plants, but in some locations it grows in larger clumps consisting of many plants (e.g. cliffs in the northern hills, parts of the coastline, and Grey Face).

Bitou Bush is classified as a W1 noxious weed on the LHIG, which means the LHIB must be notified of the presence of the weed within three days and the weed must be fully and continuously suppressed and destroyed. The location of this species in remote areas, however, makes this action difficult to implement.

Cotoneaster (Cotoneaster glaucophyllus)

Cotoneaster is a garden escape and mostly occurs in highly disturbed areas in paddocks of the southern settlement area. Several plants have also been found on Intermediate Hill and the Grey Face. It is found in Greybark-Blackbutt and Kentia Palm Communities. As it has a bird-dispersed seed, it must be considered a serious weed threat.

Lantana (Lantana camara)

Lantana is a weed of national significance, and has devastating impacts on mainland Australia. Invasion, establishment and spread of Lantana is listed as a Key Threatening Process under the TSC Act. It is classified as a class 3 weed by the LHIB, meaning that the weed must be fully and continually suppressed and destroyed.

Currently, Lantana exists on the LHIG as relatively isolated patches in the northern half of the island, mostly around the settlement area and Transit Hill. It is not known why Lantana has not proliferated on the LHIG. The Island's basalt soil, rainfall and climate appear to be ideal conditions for Lantana to thrive. Lantana, therefore, has the potential to significantly impact upon the biota of the LHIG.

Madeira Vine (Anredera cordifolia)

Madeira vine is a significant problem weed species in many parts of Australia, where it can modify native vegetation, particularly rainforest. It is thought that it may be spread by rats in (Parsons & Cuthbertson 2001).

Madeira Vine was introduced to Lord Howe Island as an ornamental. At present it is confined to several leases in the settlement area.

Norfolk Island Pine (Araucaria heterophylla)

The mature Norfolk Island Pines in the settlement area have significant cultural associations and are now an integral part of the landscape there. The pines are restricted to the settlement area, except for an outlier population at North Bay. The species, however, is spreading rapidly in some areas, to the detriment of native species. Norfolk Island Pines have the ability to change the soil chemistry, making soil conditions unsuitable for germination of many native species.

Ochna (Ochna serrulata)

The major distribution of Ochna is in the central parts of Lord Howe Island, on the north-west slopes of Mount Lidgbird, Intermediate Hill and in the Transit Hill area. It is often recorded in disturbed areas, principally previously cleared, but also in isolated patches in intact forest. Generally, hundreds of juveniles are recorded beneath one or two mature plants.

Ochna has the potential to spread at an exponential rate once wildlings become reproductively mature (Brown 1998). Being a bird-dispersed species, this may have significant consequences for as-yet uncolonised parts of the LHIG.

This species is known from Greybark-Blackbutt, Kentia Palm, Lowland Mixed Closed Forest, and Scalybark-Blue Plum Communities.

Figure 8. Buffalo grass invasion on Lord Howe Island

Sweet Pittosporum (Pittosporum undulatum)

Sweet Pittosporum is a relatively long-lived species. Its bird-dispersed seed is capable of germination in low-light and relatively undisturbed situations, and has the potential to form virtual monocultures. It must therefore be considered a serious risk to the habitats of the LHIG.

This species is predominantly a problem in the Transit Hill area, although individual shrubs have been recorded on Intermediate Hill and the Malabar Range. The main infestations of Pittosporum are in the vicinity of cleared areas or paddocks. The presence of many seedlings and young plants spreading out from main areas of infestation is evidence of active recruitment.

Sweet Pittosporum has been recorded in Greybark-Blackbutt, Kentia Palm, and Lowland Mixed Closed Forest Communities.

Cherry Guava (Psidium cattleianum)

The International Union for the Conservation of Nature and Natural Resources (IUCN) consider Cherry Guava to be the worst woody weed of subtropical island ecosystems in the world (Auld & Hutton 2004). It is the major woody weed on the Galapagos Islands, Mauritius, Seychelles, Hawaii and Norfolk Island.

Cherry Guava is recorded in most forest types on Lord Howe Island. With an edible, fleshy fruit, its seed is dispersed primarily by birds and, to a lesser extent, by water, gravity and humans.

The main infestations of Cherry Guava on the LHIG are in the Transit Hill area, Intermediate Hill and disturbed areas and abandoned paddocks on the forest edge of the north-west slopes of Mount Lidgbird. The worst infestations are often linked to the vicinity of cleared areas or paddocks or old landslip areas. From these dense infestations, Cherry Guava penetrates into intact forest. Its spread is then assured by means of suckering, prolific fruiting and allelopathic properties of the leaf litter, inhibiting growth of native species.

There are significant concerns that Cherry Guava will penetrate further into the southern mountains, particularly as this species has been recorded on the slopes around Mt Gower. This infestation has since been treated, however, ongoing monitoring will be required.

Exotic grasses

Invasion of exotic grasses, particularly Kikuyu (*Pennisetum clandestinum)* and Buffalo Grass pose a significant threat to habitats of Lord Howe Island. "Invasion of native plant communities by exotic perennial grasses" is listed as a Key Threatening Process on the TSC Act.

Kikuyu has been deliberately planted in many parts of the island for pasture and also to prevent erosion (e.g. the Get Up place on the Mount Gower track). Kikuyu now covers virtually the entire summit of Muttonbird Point, having spread rapidly from 1970 to 1980. This has reduced the number of Wedge-tailed Shearwaters breeding here, and at Signal Point, as the grass chokes the burrows and has been reported to strangle birds (Hutton 2003).

Both Kikuyu and Buffalo Grass severely restricts regeneration of native species, as they form a thick barrier which is virtually impossible for seedlings to penetrate. Buffalo Grass is a particular problem in the settlement area and forest edges on Transit Hill, inhibiting the regeneration of these areas.

At least two threatened plant species are at risk from exotic grass invasion, namely *Calystegia affinis* and Knicker Nut (*Caesalpinia bonduc*).

Vasey Grass (*Paspalum urvilleana)* and Panic Veldtgrass (*Erhata erecta)* are two additional potentially serious exotic grasses, which establish in moist shaded areas. Both are present in the southern mountains (Le Cussan pers. comm.).

Other weed species

Several other species present on the LHIG have the potential to become major weeds. These are discussed in Section 4.4. Some of these have already established wild populations on the LHIG. All weed species recorded for the LHIG are listed in Appendix 1 (appendices document).

Domestic dogs

Domestic Dogs on the main island have been reported on occasion to attack sea birds such as Flesh-footed Shearwaters. This is thought to be a minor threat to sea bird populations. Under the *Companion Animals Act* 1998, domestic Dogs are required to be on a leash when in public areas, which, if complied with, minimises the risk of wildlife attack. As the settlement area is major seabird nesting habitat some level of attack may occur unnoticed and unreported on individual leasehold properties.

Tourism

The impacts of tourism on the LHIG are generally considered to be low, being mostly erosion and trampling of small areas on and beside tracks and lookouts. This has the associated impact of weed invasion along track edges. Some greater cause for concern is the impact of tourists to Mount Gower. Although the overall number of visitors is relatively low, visitation to the summit may have a negative impact on the Cloud Forest vegetation, primarily through trampling and pollution.

Groundwater pollution

Two of the four groundwater catchments of the island currently show levels of contamination which restrict their use for domestic purposes.

Current effluent disposal arrangements have been shown to impact upon groundwater quality. Limits are required on calcarenite soil types to minimise impacts. Biodiversity implications include potential nutrification of low-lying vegetation communities and streams, and introduction of pathogens.

Hunting and collecting

At least three species of birds are believed to have been hunted to extinction soon after settlement of Lord Howe Island, both for food and because of their predation on crops.

Both the White Gallinule (*Porphyrio albus)* and the White-throated Pigeon (*Columba vitiensis godmanae)* were large, quiet birds and were hunted in large numbers for food in the early years of settlement (Hutton 1991). The White Gallinule was thought to have become extinct around the time of settlement in 1834, while the White-throated Pigeon was not able to be found by 1853 (Hutton 1991). The Red-crowned Parakeet (*Cyanoramphus novaezelandiae subflavescens*) was shot and trapped because it damaged gardens on Lord Howe Island (Garnett 1992). It was last seen in 1869.

Sea bird eggs were collected as a traditional food source for islanders and sailors visiting the island (Etheridge 1889). This is likely to have historically impacted upon population numbers. It is reported that some island residents continue to remove a small number of sea bird eggs for food which would constitute a minor threat to sea bird populations. Native fauna are protected under the NSW *National Parks and Wildlife Act* 1974

(NP&W Act) and any collecting activity requires licensing.

Hunting is not considered to constitute a significant threat for LHIG species any longer.

Over-collection, or illegal collection, of rare invertebrate species may pose a significant threat to some species. In 2002, two collectors were arrested in the possession of over 1000 individuals of two endemic species of stag beetle. Associated with the direct impacts from the loss of the individuals is damage to habitat, such as damage to rotting logs, that can be sustained during collection.

Collection of native plants

Several traditional activities are, or have been, undertaken on the LHIG which may impact upon native flora and fauna. These include collecting native palm seed from within native vegetation, cutting Pandanus *(Pandanus forsteri)* foliage and fern and orchid collection. Palm seeding and Pandanus cutting are not considered to constitute a significant threat to biodiversity, however, collection of rare orchids and ferns may have a detrimental effect on population numbers. Collection of any native plant species requires licensing under the NP&W Act.

Human interactions

In the settlement area, people provide Lord Howe Woodhens with food and water. Woodhens have also been observed eating food provided for domestic poultry (NSW NPWS 2002). A recent study suggests that inappropriate feeding may impact on the health of some birds (Hiscox & Crane 2005). Woodhens are observed in the vicinity of the waste facility and may ingest items deleterious to their health.

It is reported that Woodhens and Flesh-footed Shearwaters are occasionally killed by vehicles, although this is considered a rare occurrence.

Long-line fishing and ingestion of plastic

"Injury and fatality to vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris" is listed as a Key Threatening Processes under the EPBC Act. "Entanglement in or ingestion of anthropogenic debris in marine and estuarine environments", a Key Threatening Process under the TSC Act, also threatens LHIB fauna. The long-line fishing industry operating in waters off eastern Australia is responsible for the drowning deaths of many thousands of sea birds annually, including Flesh-footed Shearwaters (Baker & Wise 2005). Plastic ingested by adult birds is subsequently regurgitated and fed to chicks (Hutton 2003). The impact of such ingestion is unknown and warrants investigation. Sizeable quantities of plastic have been found within skeletal remains of Flesh-footed Shearwaters on the Island. Ingested plastics may also be a threat to Black-winged Petrel, Sooty Tern (*Sterna fuscata*), Masked Booby (*Sula dactylatra*) and White Terns.

Both the above threats are likely to have a negative impact on the populations of these species in the LHIG.

Interaction between species

The Vulnerable Lord Howe Currawong (*Strepera graculina crissalis*) preys on the chicks of the Vulnerable White Tern. While the White Tern has a secure global population and is a relatively recent coloniser of the LHIG, its charismatic status amongst locals and visitors can engender negative sentiment towards the conservation of the Lord Howe Currawong. The Lord Howe Currawong is also a disperser of the seeds of fleshy-fruited weeds.

The popularity of the White Tern has an influence on weed control actions, as one of its favoured nesting sites are the semi-horizontal branches of the Norfolk Island Pine, a weed of the LHIG. This may impact upon the prioritisation of weed control programs.

Lord Howe Woodhens occasionally take Providence Petrel chicks, however, this constitutes a minor threat for the Providence Petrel (Bester 2004).

4.4 Potential threats

Climate change

"Anthropogenic climate change" is listed as a Key Threatening Process under the TSC Act and "Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases" is listed under the EPBC Act.

At highest risk from climate change are those unique communities and species restricted to the southern mountains, in particular, those associated with Cloud Forest vegetation, which is the most extensive vegetation community on the summit of Mount Gower.

The micro-climate of Mount Gower is produced when moist air is forced to rise over the summit, the resulting condensation forming cloud cover over the mountains, particularly during summer. The resulting high humidity provides conditions for many unique species to exist.

Climate change predictions indicate both an upward altitudinal shift in the relative humidity surface (Still *et al.* 1999) and an increase in temperature for Australia of between 0.4°C and 2.0°C by 2030 (Hughes 2003). If cloud cover is reduced and temperatures (thus evapo-transpiration) increase, severe impacts could result on vegetation types such as Cloud Forest that rely on high moisture levels.

Climate change is also likely to alter sea-surface temperatures around Lord Howe Island. The associated changes in the marine ecosystem are likely to have severe consequences for the seabirds breeding within the LHIG, similar to those already observed in the northern hemisphere. Many of the seabirds that breed within the LHIG are at the extremity of their breeding range and breeding birds can travel long distances to forage. A shift in the distribution of prey species can greatly affect breeding success and fledgling survival.

Climate change may alter the frequency and severity of storm events, or lead to an increase in drought events which could have a significant impact on the flora and fauna. Lowland parts of the LHIG are at risk from sea level rise as a result of global warming. A summary of species and communities at risk from climate change is provided in Appendix 3 (appendices document).

Climate change is considered to be a significant threat for LHIG terrestrial invertebrates (Cassis *et al.* 2003).

Introduction of pests, weeds and disease

Introduction of new exotic fauna and flora constitutes a major ongoing threat to the biodiversity of the LHIG. There is a continual risk of the introduction of new pathogens, weeds, invertebrates and vertebrates with the arrival of every ship or aircraft.

The impact of introduced invertebrates is potentially one of the most critical threatening processes affecting the survival of native species and ecosystems of the LHIG (Cassis *et al* 2003). Alien invertebrate species have the potential to have severe impacts on the native biota. Invasion by the Red Imported Fire Ant is listed as a Key Threatening Process on both the TSC Act and the EPBC Act and would have severe impacts on the biota of the LHIG if introduced.

Aside from the Red Imported Fire Ant, other exotic ant species have had dramatic impacts on the ecosystems of other islands. For example, Yellow Crazy Ants *(Anoplolepsis graciliopes)* have invaded Christmas Island and have killed 20-25% of the entire population of land crabs in seven years (www.wilderness.org.au/campaign/marine/christmas_island/ants_ci). If introduced to the LHIG, this species could significantly affect native fauna as they prey heavily on ground invertebrates and attack any slow moving vertebrates such as bird nestlings. They damage plants by eating fruit, seeds, tunnelling into stems and girdling seedlings. This species was recently detected at a Lord Howe Island cargo loading wharf in Iluka, highlighting the high risk of potential invasion by this, and other, exotic invertebrate species. Invasion of the Yellow Crazy Ant is listed as a Key Threatening Process on the TSC Act.

Cane Toads (*Bufo marinus*) represent a significant potential risk of being introduced to the LHIG. If introduced, Cane Toads are likely to have dramatic impacts on the fauna of the LHIG. Vertebrates that may prey upon Cane Toads are likely to be poisoned, and invertebrates would be prey for the Cane Toad. Cane Toad populations are located in the vicinity of wharf areas where Lord Howe Island cargo boats are loaded in Yamba and Iluka.

The invasion, establishment and impacts of Cane Toads are listed as Key Threatening Processes on the TSC and EPBC Acts.

The impact of weeds has already been discussed in some detail (section 4.2). It is important to note the potential threat from the introduction of new weed species, as well as the threat of exotic species already present on Lord Howe Island that have not yet naturalised. There are approximately 271 species that have escaped from cultivation on Lord Howe Island, and around 400 species present in gardens on Lord Howe Island with unknown weed potential. In addition to these species, many garden plants present on Lord Howe Island are environmental weeds in similar habitats on mainland Australia, thus are potential weed problems for the LHIG (Le Cussan 2003b).

"Infection of native plants by *Phytophthora cinnamomi*" is listed as a Key Threatening Process under the TSC Act, and 'Dieback caused by the root-rot fungus *Phytophthora cinnamomi*' is listed as a Key Threatening Process under the EPBC Act.

Introduction of pathogens such as *P. cinnamomi* to forest areas could have a significant negative impact on native vegetation. *P. cinnamomi* has been detected from one lease in the southern settlement area of Lord Howe Island and could potentially be spread via footwear. There are a number of plant taxa in the LHIG that are closely related to taxa in other parts of the world that have been severely impacted by *P. cinnamomi* (Auld & Hutton 2004). These are listed in Table 8.

Herbicide use

There is some concern that herbicide use to control weeds may have a negative impact on non-target species, particularly invertebrates. Studies indicate that large arthropods such as ground predators (spiders and beetles) and fish are not at risk, or at a very low risk, from glyphosate formulations, however, several foliar dwelling species are potentially affected (Gomez & Sagardoy 1985). Reproduction and development of aquatic snails may be impacted by glyphosate use (Tate *et al.* 1997).

Habitat modification is the most likely impact from herbicide use. Methods of weed control or eradication may impact heavily on fauna. For example, modification of vegetation in treated areas can affect invertebrates (Cassis *et al.* 2003) and other fauna through loss of protective habitat or nest sites. Broad scale sprays of infested areas, depending on the spray used, could be toxic to foliage and stem boring species.

Stochastic events

Stochastic (chance) events such as severe storms, cyclones, drought and disease outbreaks constitute a significant threat to the biodiversity of the LHIG. Many species, especially endemic species, are particularly at risk due to limited population size and distribution.

Research projects

Some forms of research may represent a minor threat to species or biodiversity of the LHIG. For example, the only location of an Endangered plant on Lord Howe Island occurs on a narrow ridgeline which is used by researchers to access a remote part of the island. Although visitation to such areas is low, it is important to recognise the potential impacts to threatened or restricted species and communities.

Table 8. Species from the Lord Howe Island Group with conspecifics elsewhere in the world that have been impacted by *Phytophthora cinnamomi* (from Auld & Hutton 2004)

Lord Howe Island species	Conspecific affected elsewhere
Cassinia tenuifolia	*C. aculeata* (eastern Australia)
Coprosma huttoniana; *C. inopinata*; *C. lanceolaris*; *C. prisca*; *C. putida*	*C. australis* (New Zealand)
Drypetes deplanchei; Cryptocarya triplinervis	*C. cinnamomifolia*, *C. corrugata, C. glaucescens* (Tropical Queensland)
Dodonaea viscosa	*D. viscosa* (eastern Australia)
Drachophyllum fitzgeraldii	A range of Epacridaceae
Exocarpus homalocladus	*E. cupressiformis* (eastern Australia)
Gahnia howeana	*G. xanthocarpa* (New Zealand)
Gonocarpus sp.	*Gonocarpus teucrioides* (eastern Australia)
Leptospermum polygalifolium ssp. *howense*	*Leptospermum* spp. (eastern Australia)
Leucopogon parviflorus	*Leucopogon* spp. (eastern Australia)
Metrosideros nervulosa; M. sclerocarpa	*Metrosideros* spp. (Hawaii)
Olearia ballii; *O. elliptica* ssp. *praetermissa; O. mooneyi*	*O. oppositifolia* (eastern Australia)
Syzygium fullagarii	*S. erythrodoxa, S. wesa* (tropical Queensland)
Symplocos candelabrum	*S. stawellii* (tropical Queensland)

5 Current Management and Documents

The LHIB, other government agencies and individuals have been responsible for the preparation and implementation of several management and biodiversity inventory documents for the LHIG.

One of the aims of the LHI BMP is to synthesise biodiversity management documents and management practices to enable prioritisation of management actions to maximise biodiversity outcomes and cost efficiencies. The synthesis of documents may also indicate areas of conflicting management actions.

Documents relevant to the management of biodiversity in the LHIG, including a brief description of their contents and purpose, are listed below.

5.1 Plans of management

Permanent Park Preserve Plan of Management (DECC in prep)

The Plan of Management currently in preparation updates the 1986 Plan. It details management of natural and cultural values of the PPP. The draft plan is due to be exhibited in the near future.

Regional Environment Plan (DIPNR 2005)

A Regional Environment Plan (REP) was adopted in October 2005 to update the 1986 REP. The new REP updates the current planning framework for development for the LHIG.

The REP includes a mapped layer of 'significant vegetation'. Under the REP no development can result in any damage or removal of significant vegetation.

Lord Howe Island World Heritage Property Strategic Plan for Management 2000-2005 (Manidis Roberts 2000)

This document provides a framework for the protection of the world heritage values of the LHIG consistent with the requirements of the World Heritage Convention.

The major goals in the plan are to protect, conserve, rehabilitate, present and transmit the World Heritage values of the property to future generations. A further goal is to integrate the island community in decision making and management of the LHIG World Heritage values.

Lord Howe Island Board Corporate Plan (2004)

The LHIB Corporate Plan identifies key objectives, strategies and performance indicators for the natural environment. The overall objective is to protect, enhance and promote the LHIGs natural environment and cultural heritage. This is to be achieved through weed and pest control, improvements to ground water quality, protection and conservation of threatened species, identification of gaps in scientific knowledge, and promotion of public awareness of conservation.

5.2 Recovery Plans and unpublished reports

There are currently two approved single species Recovery Plans and one draft multi species Recovery Plan relevant to the LHIG.

Lord Howe Island Placostylus Recovery Plan (NSW NPWS 2001)

The Lord Howe Island Placostylus is listed on the TSC Act as Endangered and the EPBC Act as Critically Endangered. The Recovery Plan describes the current understanding of the species and the research and management actions necessary to maximise the likelihood of the species' ongoing viability in the wild. Major actions include survey and monitoring, Ship Rat control at key sites, captive breeding and community awareness. A summary of the actions contained in the plan and their status are provided in Table 9. Refer to the Recovery Plan for a more detailed description of actions.

Table 9. Recovery actions from the *Lord Howe Island Placostylus Recovery Plan*

Action (priority in brackets)	Status
Survey and research	
Survey areas of high potential habitat in the southern mountains (1)	commenced
Establish long-term monitoring at selected *Lord Howe Island Placostylus* sites (1)	commenced
Study the impact of the Blackbird and Songthrush on the *Lord Howe Island Placostylus* and the feasibility of eradicating these bird species from Lord Howe Island (1)	
Support research on threats to the *Lord Howe Island Placostylus* and actions to control these agents, including predation by introduced species, habitat degradation by weeds, and impacts of herbicide and pesticide usage (1)	
Conduct research into the ecology and lifecycle of the *Lord Howe Island Placostylus* (2)	commenced
Support research into genetics (3)	
Ensure that licence applications for any research and field survey projects observe the guidelines provided in Appendix 3 of the Recovery Plan (2)	ongoing
Protection of extant populations and habitat	
Continue Rat baiting program at the eleven high priority areas. Support additional baiting areas relevant to the *Lord Howe Island Placostylus* (1)	underway
Enter locational data onto Wildlife Atlas database and provide to LHIB (1)	complete
Prepare maps of high potential habitat and provide to the LHIB to assist with environmental assessment (1)	complete
Approval authorities to include consideration of potential impacts on the *Lord Howe Island Placostylus* and its habitat for proposed developments and activities (S5A EP&A Act) as per the impact assessment guidelines in Appendix 2 of the Recovery Plan (1)	ongoing
Commonwealth listing	
Prepare nomination for the *Lord Howe Island Placostylus* to be listed as threatened under the Commonwealth EPBC Act (1)	complete
Community awareness and involvement	
Prepare and distribute a brochure on the *Lord Howe Island Placostylus* for residents and tourists (1)	
Prepare a permanent display for the Lord Howe Island Museum to promote awareness of the Lord Howe Island Placostylus (2)	
Undertake media publicity of the status of the Lord Howe Island Placostylus (2)	ongoing
Ensure up to date information is provided for the Australian Museum's invertebrate web site (2)	complete
***Ex-situ* conservation measures**	
Establish a captive breeding program for the Lord Howe Island Placostylus (2)	commenced
Regenerate an area of Greybark-Blackbutt forest on Blackburn Island (3)	commenced
Recovery team	
Form a Lord Howe Island recovery team (1)	complete
Conduct an annual review of the Recovery Plan priorities (1)	ongoing

Lord Howe Woodhen Recovery Plan (NSW NPWS 2002)

The Lord Howe Woodhen is listed on the TSC Act as Endangered and on the EPBC Act as Vulnerable. A number of recovery actions have already been implemented since the approval of the plan. Recovery actions in the Recovery Plan are summarised in Table 10.

Norfolk Island and Lord Howe Island Threatened Lizards Draft Recovery Plan (Cogger, unpub.)

This draft recovery plan addresses two lizard species native to both Norfolk and Lord Howe Islands: the Lord Howe Island Gecko and the Lord Howe Island Skink. Actions relevant to the LHIG are incorporated into this plan.

5.3 Weed and vegetation management

Weed management activities have been a primary long-term focus of the LHIB. To this end, several strategic weed and vegetation management reports have been prepared. These are outlined below.

Weed management strategy for Lord Howe Island (Le Cussan in prep)

The draft weed management strategy updates the 2002 Lord Howe Island Strategic Plan for Weed Management described below. Following a review of weed management on Lord Howe Island and overseas, the LHIB has changed the focus of weed management from control of highest priority environmental weeds to eradication. This has been made possible by a grant from the NSW Environmental Trust. The program is based on one that was developed by the New Zealand Department of Conservation which is currently in use for their island ecosystem management programs. Methods include dividing Lord Howe Island into 414 work units or blocks and systematically treating and recording weed infestations. Blocks and known infestations are permanently marked and details of treatments and infestations recorded in a database. It is intended to treat every block at least once every two years while infestations remain high.

Lord Howe Island Strategic Plan for Weed Management (Smith 2002)

This document is the precursor to the draft plan described above. It includes broad scale distribution and abundance maps for noxious weeds.

This document is in two parts. Part A provides a suggested framework for the development of a strategic and comprehensive program of management of the LHIG's most significant environmental weed problems. Part B is a checklist of all the known environmental weeds for the LHIG. Table 11 lists the key components from this plan.

Density Distribution of Major Weeds of Lord Howe Island (Le Cussan 2002a, 2002b, 2003a, 2003b)

The densities and distributions of key weed species in three areas of the LHIG are mapped in these three reports. The reports document surveys for Bridal Creeper, Cherry Guava, Climbing Asparagus, Coastal Morning Glory, Cotoneaster, Crofton Weed, Ground Asparagus, Ochna, Tiger Lily and Sweet Pittosporum. The three areas mapped are the north-west slopes of Mount Lidgbird and Intermediate Hill (in the southern mountains), Transit Hill and the Malabar Range in the north of the island.

Lord Howe Island Revegetation Plan (Olsen 2002)

This revegetation plan provides strategic directions for revegetation projects. The focus is on restoration or reconstruction of vegetation most under threat from past vegetation clearing. It identifies ways to manage threats to minimise their degrading effects on core areas of native vegetation.

The plan covers the main island and Blackburn Island only and is intended to be active between 2002 and 2007. Key components from this plan are listed in Table 12.

Table 10. Task summary from the *Lord Howe Woodhen Recovery Plan*

Management	
Action (priority in brackets)	**Status**
Continue to implement strict procedures for managing the PPP. Ensure that a full assessment of proposals that may impact upon the Lord Howe Woodhen is undertaken as required by the EP&A Act (1)	ongoing
Ensure that the revised REP considers protection of the Woodhen and continue implementing planning controls to ensure protection of habitat for the Woodhen (1)	ongoing
Enforce current Dog controls and, if required, review current Dog controls, to ensure protection of the Woodhen (2)	ongoing
Eradicate feral Goats on Lord Howe Island and manage domestic Goats to prevent reintroduction to the wild. Ensure that any potential impacts of eradication upon the Woodhen population are assessed (3)	ongoing
Liaise with the Rodent Eradication Taskforce regarding potential impacts and mitigation measures relating to Woodhens (1)	ongoing
Assess the impacts of the introduced Masked Owl on Woodhen population levels and develop an appropriate management response (2)	
Ensure that weed control programs protect Woodhen habitat (3)	ongoing
Ensure that the quarantine plan addresses issues of avian disease and the introduction of plants or animals that may impact on the Woodhen (2)	complete
Establish a recovery team to coordinate the implementation of recovery plans (1)	complete
Research	
Assess the impact on the Woodhen of food competition from Buff-banded Rails, Purple Swamphens, Blackbirds and Songthrushes and, if necessary, formulate and implement a control strategy (2)	
Continue the Woodhen monitoring program. Ensure that LHIB staff are trained in the management of the Woodhen database (1)	ongoing
Determine the carrying capacity of Lord Howe Island for Woodhens and the critical number of Woodhens to trigger an on-island captive breeding program (1)	ongoing
Formulate and implement guidelines for the protection, management and enhancement of Woodhen habitat on leasehold land. Undertake a study to determine the most appropriate supplementary food types (2)	complete
Establish and manage captive populations of the Woodhen in appropriate off-island institutions, consistent with the protocols of the Australian Species Management Program (2)	ongoing
Develop a plan for establishing and resourcing an on-island captive breeding facility, for implementation in the event of a substantial reduction in Woodhen numbers or if the rodent eradication program is approved (1)	
Community awareness	
Prepare a community information brochure on Lord Howe Woodhen monitoring and management (2)	ongoing

Table 11. Key priority components of the *Lord Howe Island Strategic Plan for Weed Management*

Action	Status
Continue noxious weed inspection program	ongoing
Review and update the noxious weeds list	complete/ongoing
Investigate options for providing funding for cooperative programs with special leaseholders, for undertaking noxious weed control, particularly those adjacent to the PPP	ongoing
Seek funding for new projects and undertake review and reporting on projects	ongoing
Develop and review monitoring outcomes and update strategy accordingly	ongoing
Provide bush regeneration training to relevant LHIB staff and interested Island residents	ongoing
Treat all W1 weed incursions on LHIB land and control all new incursions of W1 species	ongoing

Treat incursions of invasive species on PPP boundaries. Provide for long-term planning for eradication of key invasive species from Island	ongoing
Seek and implement new weed control tasks where appropriate	ongoing
Maintain treatment of existing sites	ongoing

Table 12. Key priority components of the Lord Howe Island Vegetation Rehabilitation Plan 2002-2007

Action	Status
Fence, weed and replant selected riparian areas (Sallywood Swamp Forest, Mangrove and significant watercourses in the settlement area, namely; Old Settlement, Cobby's Creek, Soldiers Creek and tributaries)	underway
Restore native grassland on Muttonbird Point	
Continue revegetation of Greybark-Blackbutt forest on Blackburn Island	underway
Undertake gradual weed control along the forest edge at Old Settlement at the Endangered *Calystegia affinis* site	underway
Undertake weed control and encourage natural regeneration in Flesh-footed Shearwater habitat between Neds Beach and Middle Beach	underway
Maintain current revegetation sites	ongoing
Landslips on special leases to be fenced off from cattle and planted out if necessary until vegetation stabilises the slope	commenced
Support prevention of the use of barbed wire fencing within Flesh-footed Shearwater habitat areas	
Support the addition of conditions for special leases relating to removal of noxious weeds and fencing riparian areas off from cattle	underway

5.4 On-ground management programs

Many management activities have been undertaken as part of implementation of existing management documents. Other actions have been implemented on a more *ad hoc* basis due to perceived need or opportunistic funding. Significant biodiversity management actions that have been undertaken, or are still current, are described below.

Weed and revegetation programs

Weed control programs have been undertaken both by the LHIB and by the Friends of Lord Howe Island in conjunction with the LHIB. Revegetation programs have been developed with direction from the revegetation strategy, but also opportunistically when grants for specific projects were received.

The LHIB received large grants during the 2004-2005 and 2005-2006 financial years which enabled the focus of weed control programs to switch from control to eradication of all noxious weeds on Lord Howe Island, with the exception of Crofton Weed and Tiger Lily, with the initial aim to eradicate Category 1, 2 and 3 weeds. Table 13 lists target weed species and their category.

Over the past 20 months, a total of 64 of the 414 blocks have been treated (40% of the known infested areas of the island), and over 1,000,000 weeds removed. It is estimated that a high level of investment will be required until 2009. The current work is funded until 2007. The localities of any particularly dense infestations of weeds are recorded by GPS to alert weeders to look out for infestations in these areas in future weed treatment.

Additional funding from the NSW Environmental Trust has enabled the Board to commence a Bitou Bush eradication program. Over winter 2005, the LHIB contracted DECC to undertake herbicide spraying on the sea cliffs below the northern hills using a helicopter equipped with a specifically-designed spray unit. Over 100 mature plants were treated in this area and further south on the east coast and on the flanks of Mt Lidgbird. Follow up work involving abseiling was undertaken in 2006.

Rat baiting

Rat baiting has been done primarily as a protection measure for the palm industry, seeds of which are preyed upon heavily by Rats (see section 4). Some low level baiting has also been done for biodiversity reasons, for example, for the Lord Howe Island Placostylus.

Table 13. Invasive plants targeted for eradication on the LHIG (from Le Cussan (in prep))

Common Name	Scientific Name
Category 1 weeds	
Cherry Guava	*Psidium cattleianum*
Crofton Weed	*Ageratina adenophora*
Tiger Lily	*Lilium formosanum*
Ground Asparagus	*Asparagus aethiopicus*
Bitou Bush	*Chrysanthemoides monilifera*
Pittosporum	*Pittosporum undulatum*
Bridal Creeper	*Asparagus asparagoides*
Climbing Asparagus	*Asparagus plumosus*
Ochna	*Ochna serrulata*
African Boxthorn	*Lycium ferocissimum*
Lantana	*Lantana camara*
Madeira Vine	*Anredera cordifolia*
Cotoneaster	*Cotoneaster glaucophyllus*
Category 2 weeds	
Glory Lily	*Gloriosa superba*
Simon's Bamboo	*Arundinaria simonii*
Elephant Grass	*Arundo donax*
Tipuana	*Tipuana tipu*
South African Iris	*Dietes biflora*
Flame Tree	*Brachychiton acerifolius*
Umbrella Tree	*Schefflera actinosa*
Coffee	*Coffea arabica*
Loquat	*Eriobotrya japonica*
Ginger	*Hedychium roxburghii*
Castor Oil Plant	*Ricinis communis*
Rhus Tree	*Toxicodendron succedaneum*
Category 3 Weeds	
Singapore Daisy	*Sphagneticola trilobata*
Salvinia	*Salvinia molesta*
Water Hyacinth	*Eichornia crassipes*
Mauritian Hemp	*Furcraea foetida*
Category 4 Weeds	
Kikuyu	*Pennisetum clandestinum*
Everlasting Pea	*Lathyrus latifolius*
New Zealand Christmas Tree	*Metrosideros kermadecensis*
Small-leaved Privet	*Ligustrum sinense*
White Cedar	*Melia azederach*
Zebrina	*Tradescantia zebrina*
Ricepaper Plant	*Tetrapanax papyrifer*
Norfolk Island Pine	*Araucaria heterophylla*
Palm Grass	*Setaria palmifolia*
Buffalo Grass	*Stenotaphrum secundatum*
Purple Groundsel	*Senecio elegans*
Agapanthus	*Agapanthis praecox*
Kaffir Plum	*Harpephyllum caffrum*
Roldana	*Roldana petasitis*

Woodhen recovery program

The Woodhen recovery program has been conducted over many years. Major actions that have been implemented from the approved Recovery Plan are summarised below.

The LHIB maintains strict procedures for managing the PPP to minimise impacts on the Woodhen, including prohibition of Dogs and limited access to Mount Gower. In addition, the LHIB can implement its Dog Control Policy to minimise impacts to Woodhen.

Annual surveys are conducted to monitor Woodhen numbers around the main island. Information to date indicates that the Woodhen population is relatively stable. Data from previous and current surveys are being synthesised to map Woodhen distribution and to estimate the carrying capacity of the Island for Woodhens. Work is currently underway to formulate and implement guidelines for the protection, management and enhancement of Woodhen habitat on leasehold land. This is in conjunction with the consultation of the Lord Howe Island community on feeding practices of Woodhens in the settlement area. Recommendations will be made with regard to best practice feeding regimes and on habitat enhancement within the settlement area.

Options for establishing an *ex-situ* population are being investigated.

Culling of Masked Owls has been undertaken sporadically since 1985. However, evidence suggests that Masked Owls favour Rats and sea birds as prey rather than Woodhen. Culling is not considered a priority until evidence suggests that Masked Owls are adversely impacting upon Woodhens.

Lord Howe Island Placostylus recovery program

Potential habitat mapping for the species has been completed for the Lord Howe Island Placostylus. Habitat mapping can also assist with assessment of impacts of development on this species. In addition, the draft Lord Howe Island REP provides measures for the protection of some areas of Placostylus habitat.

Ongoing Rat control is undertaken at a number of preferred Placostylus habitat locations around the island, such as North Bay and the settlement area.

A research project into the species' life history and investigation into appropriate conditions for captive breeding, including humidity and food requirements, has commenced on the main island. Investigations indicate that high levels of humidity are required for breeding success. Preferred food sources have also been identified.

Surveys in 2006-2007 were undertaken at previously-known Placostylus locations. The survey effort focussed on warm, wet nights when Placostylus are most active. These surveys have resulted in improved knowledge of the population numbers and behaviour of Placostylus, and sites that can be used for ongoing monitoring.

Regeneration of suitable habitat on a small area on Blackburn Island has commenced, with limited success due to difficult environmental conditions. The aim of this ongoing project is to recreate habitat suitable for the Placostylus in a Rat-free environment as a potential site for translocation and as augmentation to the population on the main island.

Phytosanitary procedures

The LHIB is in the process of developing phytosanitary procedures for minimising the spread of soil-borne diseases such as *Phytophthora cinnamomi*. This program will primarily involve instructions and boot-cleaning stations at the heads of all walking tracks.

African Big-headed Ant Survey and Control

The LHIB conducted a number of surveys to accurately map infestations of the introduced African Big-headed Ant. Detailed population mapping was undertaken in 2005 and 2006. This survey found that the Ant was largely confined to disturbed areas of the island.

A trial control program using two types of granular agents was undertaken on the island during 2006. The two products were a juvenile hormone mimic and an insecticidal poison. This program targeted the Lord Howe Island Waste Management Facility being an area where infestations and supercolonies are located, and also due to the high risk of colonies spreading from this site.

Results from the program were very promising and indicated that both the hormone mimic and the insecticidal poison were highly effective in destroying colonies. The hormone mimic is only approved for research trials at this time so the Board has opted to undertake more widespread eradication of African Big-headed ants using a registered insecticidal poison product. The insecticide is ant specific with a protein base which is highly attractive to Big-headed ants. Given that this species exclude all other native ant species from their infestation areas, mortality of native ants is not anticipated.

Goat control program

A Goat control program was commenced on the LHIG in the 1970s. However, the feral Goat population was reduced to a few individuals as a result of a control program in 2002. Two Goats were released to lure in feral Goats and are still present in the southern mountains. These Goats are both desexed females and are being monitored.

5.5 Policies and strategies

Plant Importation policy

This policy was approved by the LHIB in 2003. The aim of the policy is to provide a list of bush friendly plants which can be used for garden plantings by island residents. Under this policy, any proposed plant imports will be dealt with in one of three ways:

1. If it is known to be benign (i.e. has not escaped gardens on Lord Howe Island or elsewhere) importation should be allowed subject to a Declaration of Intent to Import.
2. If it is known to be a threat (i.e. has escaped gardens on Lord Howe Island or in similar climatic regimes) importation is prohibited.
3. If it is unknown, and has never previously been imported to Lord Howe Island, importation is permitted only with an assessment of weed risk.

Quarantine Strategy for Lord Howe Island (Landos 2003)

The quarantine strategy aims to minimise the risk of serious unwanted incursions of pests, weeds or disease. The strategy makes a range of recommendations involving upgrading a number of key components but, wherever possible, either using existing resources or drawing on the resources of existing organisations where this is deemed appropriate. Major recommendations are summarised in Table 14.

The Quarantine strategy was adopted in 2003.

Significant advances to quarantine have been undertaken since the strategy was adopted. These include quarantine awareness training of staff, stevedores and all major mainland suppliers. This has resulted in improved standards in storage. Training has been undertaken twice, and will probably be continued annually. In addition, a new hard stand area is being constructed on the Lord Howe wharf to assist with early detection of pest species.

Dog Control Policy

The Dog Control Policy was adopted by the LHIB in 1998, and was drafted to reflect the provisions of the *Companion Animals Act* (CAA) 1998. The policy aims to outline Dog owners' responsibilities for effective Dog control on both leasehold and public land. The policy designates Dog exercise areas and where Dogs are prohibited. Penalties for impounding wandering Dogs and for other offences under the CAA are also identified.

Animal importation

Regulations under the LHI Act prohibit the importation of any animal without Board approval. Currently, the LHIB assesses each request for importation on a case by case basis. The LHIB is looking to establish a risk assessment process for animal importation. Risks to be assessed will include the likelihood of disease, weed and pest introduction. A risk assessment process is likely to include a list of proscribed species.

Domestic Animal Control Policy

Prior to the adoption of the *Lord Howe Island Regulation* 2004, the LHIB had limited capacity to enforce or obligate domestic animal control. There are now clauses that regulate the control of certain domestic animals such as poultry and goats.

5.6 Inventory reports

Several inventory reports of flora and fauna of the LHIG have been compiled since early settlement. These are listed in Table 15. Full references are provided at the end of this document.

5.7 Research and survey

A broad range of research projects relevant to the biodiversity of the LHIG has been undertaken. Areas of investigation include rare plant surveys, breeding ecology of seabirds, invertebrate survey and research and investigations into the feasibility of rodent eradication. This Plan will assist with prioritising research and ensure that existing knowledge gaps are addressed.

Australian Museum invertebrate research

The Australian Museum has been collecting systematic terrestrial invertebrate data since 1977. Results of these surveys, and systematic surveys done since that time, have been collated in Cassis *et al.* (2003). This information allows changes in invertebrate biodiversity to be assessed, including species distributions, introductions and extinctions.

Nine exclosure plots were established in 2003/2004 to monitor the impact of rodents on invertebrates. Funding for this project is currently not available.

Research by the Australian Museum in collaboration with Macquarie University is underway to assess altitudinal patterns in invertebrate communities on Mounts Gower and Lidgbird to provide a baseline for future impact assessments and to identify whether any changes in communities have already occurred.

Rare plant surveys

Several surveys for rare plants have been undertaken by the DECC to determine the distribution, population size and threats to a number of species (Hutton 2005 and Hutton 2001b). Outcomes of these surveys have resulted in the listing of several plant species on the TSC Act.

Table 14. Key priority components of the *Lord Howe Island Quarantine Strategy*

Management/training/administrative
Establish a high priority list of pests and diseases for the Island
Lobby for legislative changes which strengthen the powers of the LHIB with regards to inspections, permit systems, cost recovery, and offence provisions
Future contractual arrangements for the movement of goods to the Island to include quarantine related standards for both the vessel and the departing (and arriving) wharf, appropriate surveillance, fumigation and baiting/trapping provisions, and the power for goods to be refused boarding at the ports of departure and arrival in the event that an infestation is found.
Training to be provided to LHIB staff in the areas of threat identification, assessment and management, rat inspection, baiting and cargo inspection techniques
Suitable surveillance training be developed and delivered to all relevant LHIB staff and contractors
Suitable training be developed and delivered to all participants in Lord Howe Island tourist and transport industries
No unloading of cargo to take place after dark
Establish a digital database to facilitate review and storage of key information
Baseline surveys to be undertaken for priority pests and diseases
Use the NSW Agriculture Regulatory Officer for inspection at the Goodwood Island wharf
Encourage LHIB staff to conduct regular random inspections of cargo arriving at the LHI wharf
Develop the capacity of the existing Island Trader crew and wharf staff and labourers at Goodwood Island wharf to undertake inspection of goods as they are loaded
A senior person at Goodwood Island wharf be provided with the power to refuse to load any goods that show evidence of unwanted pests or diseases
Ask the Island Trader to advise in advance of any high quarantine cargo observed during loading. Appropriate personnel to inspect this cargo on arrival
Seek specialist advice regarding the safety and practicality of in-transit fumigation of the cargo hold of the Island Trader
Make Goodwood Island and LHI wharves, the airport and associated buildings and surrounds as inhospitable as is practical for pests
Provide sealed "Amnesty" bins at the airport and seaport and label accordingly
Develop disposal procedures for any seized or confiscated goods
Broadcast a brief quarantine message on all flight arrivals
Animals/livestock
Conduct regular baiting and trapping at key areas such as on board all vessels and planes, around the wharf and airport and around accommodation houses and residences
Introduce measures for moored vessels that minimise the chances of rats getting ashore
All vessels visiting LHI to have current de-ratting certificates
All wharf and airport areas including buildings be maintained in a clean state
Undertake a risk analysis where any new plant or animal is proposed for introduction to LHI
No straw, hay or green feed be imported to LHI
Ask NSW Agriculture (and Fisheries as appropriate) to examine any controls that should be applied to imported animal feedstuffs
All animal importations to be in containers using clean sawdust and all waste to be appropriately destroyed on arrival
Ask NSW Agriculture for a set of livestock importation health conditions
Plants
All plants to be imported bare rooted or in soil-less medium or from an accredited supplier
All plants to have identification labels

Build a holding compound at the airport and wharf and hold all plants in this area until cleared by LHIB staff
All plant imports be subject to permit
Building materials/consumables
All second-hand and untreated timber be prohibited unless accompanied by a current fumigation certificate
No bark on timber to be imported to LHI
Regularly inspect hardwood pallets and other dunnage at Goodwood Island and Lord Howe wharves
All pavers and similar materials to be subject to inspection prior to boarding at Goodwood Island
Contracts for the importation of road base to include quarantine considerations such as the exclusion of soil and extraneous matter
Gas depots be requested to only supply gas bottles with clean undersides to LHI

Tiger Lily research

A PhD research project is being undertaken into the ecology of the major weed Tiger Lily. Results from this study will provide data to assist with selection of control or eradication options for this species.

Ecological studies of threatened seabirds

Several ecological studies of the threatened seabirds on Lord Howe Island have been completed. These studies have focussed on breeding productivity and foraging ecology as a means of evaluating conservation status and threats. References to some of these studies are included at the end of this report.

Lord Howe Island Currawong

Initial research on the population size, distribution, breeding and foraging ecology of the Lord Howe Currawong has been completed. The population is estimated at just over 200 individuals, including 48 juveniles.

The study indicated that preying on White Terns by Currawong has not been sufficient to halt the expansion of the White Tern population on Lord Howe Island.

This research could be used when undertaking environmental assessment associated with any rodent eradication program.

Lord Howe Island Phasmid

Previously thought to be extinct, the Lord Howe Island Phasmid was rediscovered on Balls Pyramid in 2001. Two pairs of Phasmids have formed the basis of a captive-breeding program (Priddel *et al.* 2003; Priddel *et al.* 2001). This program, involving both Melbourne Zoo and the company Insektus, has been successful to date. Several new generations have been produced and the population, consisting of several dozen breeding adults in 2005, continues to increase. Development of best-practice techniques for maintaining the captive population is ongoing, along with other interim recovery actions.

Rodent eradication proposal

An assessment of the feasibility of eradicating rodents from the LHIG was conducted in 2001 (Saunders & Brown 2001). The report found that eradication is feasible but recommended that the risks inherent in such a program would need to be managed and the costs and benefits of engaging in such a program would need to be evaluated.

Subsequently, a cost/benefit analysis was prepared (Parkes *et al.* 2004). This review also considered eradication to be feasible and calculated that the costs of eradication would be recouped, in the form of higher yields of palm seed, within five years. Biodiversity values were not modelled in this study due to the difficulties of equating a dollar value to biodiversity, however, there are significant benefits to biodiversity of rodent eradication.

The LHIB in conjunction with DECC is currently working towards rodent eradication planning. This planning incorporates identification of environmental assessment requirements (including necessary environmental approvals), logistical planning and identification of research into potential impacts on non-target species essential for environmental assessment.

Environmental assessment of the potential impact on threatened species of any Rat eradication pilot or program is required under the EP&A Act. If it is assessed that a significant impact to threatened species, populations or communities is likely, then a Species Impact Statement (SIS) under the TSC Act must be prepared. A SIS will investigate the types of impact on threatened species and proposed mitigation measures prior to approval being provided for the project to proceed.

A non-toxic bait trial to assess bait uptake by both rodents and non-target species is being conducted in 2007 in the settlement area.

Table 15. List of inventory reports of flora and fauna of the LHIG

Title	Author	Date	Description
The General Zoology of Lord Howe Island	Etheridge	1889	Anecdotal accounts of fauna sightings and collections made by the Australian Museum collecting party in 1887
Environmental Survey of Lord Howe Island	Recher & Clark	1974	Results and recommendations of a scientific survey undertaken in the early 1970s. The aim of the survey was to determine the current status of the flora and fauna and to recommend ways in which the long-term survival of the indigenous species could be assured.
Vegetation of Lord Howe Island	Pickard	1983	A description and map of the vegetation of the LHIG
Mosses of Lord Howe Island	Ramsay	1984	A checklist of the mosses of Lord Howe Island based on literature and collections in Australian herbaria together with a summary of their distribution patterns on the island
Birds of Lord Howe Island - Past and Present	Hutton	1991	Descriptions of sea birds and land birds, both extant and extinct
Flora of Australia Volume 49 Oceanic Islands 1 - Flora of Lord Howe Island	ABRS	1994	Lists the vascular plants of the LHIG, both exotic and native, that have been recorded on the LHIG
Vegetation and Habitat of Significance Within the Settlement Area of Lord Howe Island	Hunter	2002	An update of vegetation mapping within the settlement area. Mapping of the distribution of high conservation value vegetation within the settlement area and information on the distribution of habitat for threatened flora and fauna species.
Lord Howe Island: Terrestrial Invertebrate Biodiversity and Conservation Report	Australian Museum	2003	A synopsis of collated existing information on the terrestrial invertebrates of Lord Howe Island. It includes a statistical analysis of invertebrate biodiversity patterns across the LHIG, focussing on endemism and species richness, an assessment of the conservation status of selected terrestrial invertebrate taxa, and identifies threatening processes and conservation recommendations. This report was commissioned by DECC and the LHIB in 2003.
The Birds of the Lord Howe Island Group: A Review of Records	McAllen *et al.*	2004	A recent inventory of all known bird records from the LHIG. Management issues are discussed where relevant to the species concerned.

6 Proposed Recovery Actions

Recovery actions and sites selected for management have been prioritised using a combination of information and data sources. These involve expert knowledge, community consultation, existing management documents and analysis of outputs from a GIS decision support tool, the Biodiversity Forecasting Tool (BFT). Management actions in some instances have been refined using outputs from the BFT, either to define a specific locality where a high biodiversity benefit of an action has been indicated, or identify a particularly significant threat. A description of the BFT methods, data inputs and derived outputs is contained in Appendix 4 (appendices document). Where existing management documents are used, key relevant actions are listed in section 5 of this Plan.

This section is divided into four parts: priority areas for management; priority species and communities for management; priority threats; and a comprehensive set of management actions.

The description of priority threats and priority management areas in this section helps to set the scene for the comprehensive list of management actions later in the section.

6.1 Priority areas for management

The following priority areas for management actions were identified using a compilation of expert and community information, published and unpublished reports, and outputs from the BFT.

Areas highlighted as priorities by the BFT are primarily driven by a combination of a high priority ranking given to habitats by experts and the level of threat operating on a particular area. For example, if an area is habitat for an Endangered species it was given a high priority ranking. If this is combined with an area that has been defined as being affected by one or more priority threats, then these areas are highlighted as priority areas for management action.

Areas have been ranked from one to four to provide a level of prioritisation, however, these should be considered a guide and priorities may vary depending on resource availability and other factors.

Number 1 Priority

Sallywood Swamp Forest Community

The Sallywood Swamp Forest vegetation community receives a high priority ranking, primarily due to its listing as an Endangered Ecological Community under the TSC Act, but also due to its limited geographical extent and the level of threat acting upon this community. This resulted in these areas being highlighted as priority sites for management action by the BFT outputs.

Expert opinion agrees that these areas are a significant priority for management action, but consider priority needs to be balanced against competing resource requirements and the overall benefit to biodiversity of the LHIG.

Mangrove sites

The Mangrove community has a very limited extent on the LHIG and is subject to a number of threatening processes. Expert opinion classifies the Mangrove community as a community of conservation concern and thus it receives a high priority ranking. The BFT also identified these areas as a priority.

Watercourses and adjacent habitat in the settlement area

Lowland Freshwater communities are classified as communities of conservation concern, and thus receive a high priority ranking. Watercourses of particular priority are identified in the vicinity of Soldiers Creek, Cobby's Creek and Old Settlement Creek.

Habitat of the Endangered plant Calystegia affinis

Small areas that are habitat for the Endangered plant *Calystegia affinis* are identified as areas of high priority for management by the BFT. This habitat is located in two separate locations; at the Max Nicholls track in the north of the island, and in the southern mountains.

Southern Mountains

Expert opinion regards the southern mountains as being areas of significant conservation priority due to the high level of endemicity and significance of threatening processes such as climate change and human impacts operating in these areas.

The BFT also identifies these areas as a high priority for management.

Balls Pyramid

Balls Pyramid is a high priority management area particularly as it is the only location of the Lord Howe Phasmid. Management to protect this area from threatening processes is critical to the survival of this species in the wild. It is also significant for a number of threatened seabirds, especially as it is a breeding locality for the threatened Kermadec Petrel and the White-bellied Storm Petrel.

Mixed Fern and Herb Community

The Mixed Fern and Herb community is a vegetation community restricted to the southern mountains. It has been identified by both expert opinion and the BFT as being particularly under threat from weed invasion by Crofton Weed and Tiger Lily. As it is a community of limited extent, and contains threatened and significant plant species, it has been highlighted as a priority area for management.

Number 2 Priority

Eastern settlement area and shoreline between Neds Beach and Clear Place

This area is identified as a significant location for management due to its importance for seabirds and for the threats that are active in this area.

Selected threatened plant habitat

The habitat of three threatened plant species is highlighted as priority areas for management. These are: *Chamaesyce psammogeton* habitat at Blinky Beach, Knicker Nut habitat at Neds Beach and *Polystichum moorei* habitat at Kings Beach.

The *P. moorei* habitat indicated is the habitat that is likely to be affected by climate change.

Blackburn Island

Blackburn Island is a priority area for management due to its significance for fauna and the potential for threatening processes to significantly impact upon the biodiversity of this area.

Remnant vegetation in the settlement area

Remnant vegetation in the settlement area has a number of active threatening processes impacting upon it such as weed invasion, the potential for loss of habitat from clearing, and edge effects. These factors result in this habitat receiving management priority.

Number 3 Priority

Coral Sand and Beach Dune Community

This community received a moderate priority due to its restricted extent and its potential to be impacted by threatening processes such as climate change and weed invasion.

Muttonbird Point

A combination of active threatening processes and significant habitat areas has resulted in Muttonbird Point being highlighted as a moderate priority area for management action.

Intermediate Hill

Intermediate Hill has a range of active threatening processes, particularly weed invasion. It is also an important area for invertebrates.

Signal Point to Old Settlement

This area has been highlighted primarily due to it being habitat for the Endangered plant Knicker Nut. This area is also subject to a number of threatening processes such as climate change and weed invasion.

Far Flats

The Far Flats area is highlighted as a significant area for invertebrates. It is also indicated as being an area where threats may substantially reduce the invertebrate biodiversity.

Shorelines of settlement area

The shorelines of the settlement area are highlighted due to their significance for sea birds and wading birds as well as the level of threat operating in these areas.

Greybark-Blackbutt Community

This community is classified as a community of conservation concern primarily as it is subject to a number of threats, including weed invasion and clearing.

Cliffs of the northern hills

The cliffs of the northern hills are important habitat areas for seabirds. They are also subject to a number of threatening processes that may adversely impact the quality of the habitat in this area.

Malabar and northern hills

The combination of threatening processes such as weed invasion and significant vegetation types results in this area being highlighted as a moderate priority area for management actions.

Number 4 Priority

Transit Hill

There are a number of active threats operating in this area including significant weed invasion, canopy windshear and dieback, and the impacts of trampling and grazing on native vegetation. The significance of Transit Hill includes the valuable weed control work that has been undertaken over a number of years in this area by the Friends of Lord Howe Island and the LHIB.

Lower slopes of north and south PPP

Threatening processes such as weed invasion, and a high level of endemicity have resulted in the identification of this area as a moderate management priority.

Muttonbird Island and Admiralty Islands

These islands are identified due to their significance for seabirds and invertebrates as well as the potential for threatening processes to have significant adverse impacts.

Lowland Mixed Forest

Lowland Mixed Forest is a vegetation community of conservation concern and is under threat primarily from clearing and weed invasion.

Locations of restricted vegetation communities

A number of vegetation communities that are restricted in extent are highlighted for management action and include the following: Saltbush (*Atriplex*), Poa (*Poa poiformis*), Bully Bush-Poa (*Cassinia-Poa poiformis*), Leafy Flat Sedge (*Cyperus lucidus*) and *Boehmeria calophleba*-Kava (*Macropiper hooglandii*).

Kentia Palm Communities

As Kentia Palm communities are subject to a range of threatening processes, they are identified as benefiting from a range of management actions.

6.2 Priority threatening processes

A number of threats have been identified as the most significant threatening processes influencing the biodiversity of the LHIG by a combination of expert opinion, existing information sources, the BFT and community opinion.

The four most significant threats to the biodiversity of the LHIG are considered to be the introduction of new pests, weeds and diseases, the impact of weeds that are currently present on the LHIG, the impact of rodents on flora and fauna and climate change.

Other significant threats include: habitat clearing and trampling, browsing and grazing and introduced invertebrates.

6.3 Priority species and communities for management

Flora

Flora species identified as a management priority are those that are either threatened or restricted endemics, with threatened flora receiving the highest priority. Four threatened flora species are indicated as being a particularly high priority for management action due to their restricted habitat and the threatening processes that are acting upon them. These are Knicker Nut, *Chamaesyce psammogeton Calystegia affinis,* and *Polystichum moorei.* In addition, the habitat of the critically endangered grass *Elymus multiflorus* var *kingianus* is a high priority for investigation as no specific current information is available.

Restricted endemic species not currently listed as threatened that have been identified by expert opinion as being a priority for management are *Passiflora herbertiana* ssp. *insulae-howei, Coprosma* sp. nov. and *Senecio pauciradiatus*.

Vegetation communities

Five vegetation communities are identified as high priorities for management. Sallywood Swamp Forest, Mangrove, Lowland Freshwater and Upland Freshwater were previously identified in section 6.1 as priority areas for management. Cloud Forest (Hotbark-Fitzgeraldii) community is also identified as a high priority given its high degree of endemic species and susceptibility to threats such as climate change.

Vertebrate fauna

Vertebrate fauna identified as being of particular significance for management action include threatened species and species with particularly limited habitat areas or those species that are subject to a range of threatening processes. These species are listed below.

Lord Howe Island Gecko and Lord Howe Island Skink

The habitat of these threatened species is subject to a range of threatening processes such as weed invasion, clearing, trampling and rat predation.

Flesh-footed Shearwater

This threatened species has been identified primarily due to much of its habitat being within the settlement area and thus subject to a range of threats associated with this area.

Lord Howe Woodhen

The Lord Howe Woodhen is an iconic species and is subject to a range of active threatening processes on Lord Howe Island warranting ongoing management priority.

Long-finned Eel, Short-finned Eel and the Common Jollytail

These freshwater aquatic vertebrates are identified as priority species for management due to the threatening processes operating on their habitat in the settlement area.

Invertebrate fauna

Threatened invertebrate fauna are identified as being priority species for management. Three of the threatened invertebrates are identified by the BFT and expert opinion as most warranting management action. Non-threatened invertebrates have not been included due to lack of specific information.

Lord Howe Island Phasmid

This species is identified due to its very limited distribution, active threats on the main island and small population size.

Lord Howe Island Wood-feeding Cockroach

Given limited habitat and potential impacts from threatening processes, this threatened species is identified as a high management priority.

Lord Howe Island Placostylus

The Lord Howe Island Placostylus is identified as a high management priority species due to the range of threatening processes affecting this species and its restricted distribution.

6.4 Management actions

A comprehensive list of management actions follows, including the location to which each action is relevant and specific tasks associated with each action. Table 16 provides a summary of recovery actions and the priority species they address, while Table 17 lists all recovery actions, including priority, estimated cost, and potential responsible partners.

The list of management actions has been derived primarily from expert opinion, existing reports and data and input from the LHI community. Where relevant and justified, some of the actions listed below have been refined using outputs from the BFT. These refinements include highlighting particular localities or species of conservation significance.

The actions listed below are both landscape level management actions based on threats and affected areas and management actions for specific threatened species where these species are not adequately covered by broad landscape-based actions.

Objective 1: To prevent the introduction of exotic fauna, flora and pathogens to the LHIG

Introduction of new exotic fauna and flora constitutes one of the major ongoing threats to the biodiversity of the LHIG. There is a continual risk of the introduction of new pathogens, weeds, invertebrates and vertebrates with the arrival of every ship or aircraft (section 4.4).

Keeping further exotics from entering the LHIG will require enforcement of strict quarantine, a high level of surveillance and a rapid response to new introductions.

Action 1.1: Review the LHIB Quarantine Strategy

Location: LHIG

Tasks:

1.1.1 Review the current LHIB Quarantine Strategy to ensure that it reflects the most up-to-date information regarding quarantine and new species introductions. Amend or add tasks as required. The strategy should be reviewed at least every five years.

1.1.2 Ensure that an invasive ant risk assessment and control strategy is included in the LHIB Quarantine Strategy.

1.1.3 Ensure that an offshore island quarantine strategy is included in the LHIB Quarantine Strategy to prevent rodents and other introduced pests and diseases from establishing on these islands. This strategy is to include regular surveillance of significant offshore islands for invasion by exotic fauna and weed species. The potential to include prior approvals to act immediately if introductions occur needs to be investigated.

1.1.4 Develop a public awareness program that highlights the significance of Blackburn Island for biodiversity, specifically targeting Lord Howe Island residents.

1.1.5 Develop a protocol to minimise the risk of rodent introduction for operators that hire watercraft that visit Blackburn Island.

Action 1.2: Implement the LHIB Quarantine Strategy

Location: LHIG and mainland departure points.

Task:

Implement the LHIB Quarantine Strategy as a matter of priority (section 5 summarises the main actions from the current LHIB Quarantine Strategy).

Action 1.3: Review the Lord Howe Island Plant Importation Policy

Location: LHIG

Task:

Review the current Lord Howe Island Plant Importation Policy to ensure that it reflects the most up-to-date information and amend or add tasks as required. The policy should be reviewed at least every five years.

Action 1.4: Implement the Lord Howe Island Plant Importation Policy

Location: LHIG

Task:

Implement the LHI Plant Importation Policy (section 5 summarises the main actions from the current LHI Plant Importation Policy) in conjunction with relevant actions from the LHIB Quarantine Strategy.

Action 1.5: Increase local native plant production and use

Location: settlement area

Task:

1.5.1 Expand the LHIG nursery facilities to allow for increased local native plant production for residents, while making local native plants available to residents at low cost.

Action 1.6: Prepare a rapid response and detection protocol for new introductions of weeds and exotic fauna

Location: LHIG.

Tasks:

1.6.1 Develop an early detection protocols and procedures document to deal with new introductions as soon as possible after incursion. This would include information on how to identify high priority invasive species (e.g. Cane Toad, Yellow Crazy Ant), relevant contact personnel and treatment procedures.

1.6.2 Ensure relevant LHIB staff are trained and equipped to be able to implement early detection protocols and procedures.

Objective 2: To retain native vegetation

Past and any potential future clearing and habitat modification of native vegetation are a significant threat to biodiversity on the LHIG.

Action 2.1 Ensure appropriate environmental assessment is undertaken when assessing development proposals

Location: LHIG

Task:

Ensure that the appropriate level of environmental assessment is undertaken under the EP&A Act and the TSC Act, particularly when development proposals require clearing of native vegetation. The potential impact of proposed clearing and development on flora and fauna should be considered. This includes development proposals both in the settlement area and within the PPP.

Action 2.2: Liaise with leaseholders regarding protection and management of remnant and significant vegetation

Location: Settlement area, particularly any leases where Sallywood Swamp Forest or Mangrove is mapped. Also leases in the vicinity of the Soldiers Creek and Cobbys Creek basins, in the watercourses around Old Settlement, and any identified threatened fauna habitat for species such as the Flesh-footed Shearwater, Lord Howe Island Gecko, Lord Howe Island Placostylus, Lord Howe Island Skink and Lord Howe Woodhen.

Task:

Leaseholders to be informed of the value of remnant vegetation on leases, provided with information on methods of protection and enhancement and encouraged to undertake protection and rehabilitation of native vegetation on their leases.

Action 2.3: Provide assistance for leaseholders to protect native vegetation

Location: LHIG

Task:

Provide financial assistance where funding is available for leaseholders to fence and rehabilitate native vegetation, particularly significant remnant vegetation. Significant remnant vegetation includes Sallywood Swamp Forest, Mangrove, Lowland Mixed Forest, Greybark-Blackbutt on calcarenite/coral sand and threatened species habitat.

Action 2.4: Encourage protection of vegetation and habitat features that constitutes invertebrate habitat

Location: LHIG

Task:

Monitor and discourage the removal and use of native dead wood and trees by visitors and residents where it may offer habitat to invertebrate fauna.

Objective 3: To control the impacts of introduced pathogens on native species

A primary threatening process for the LHIG is posed by introduced pathogens impacting on native species and their habitats (section 4.3).

Action 3.1: Develop and implement measures to minimise the impacts of introduced flora and fauna pathogens

Location: LHIG

Tasks:

3.1.1 Develop and implement a set of phytosanitary guidelines for walkers and palm seeders to minimise the risk of introducing and spreading pests, weeds and disease within the LHIG.

3.1.2 Conduct a detailed survey for the presence of *Phytophthora cinnamomi*.

3.1.3 Develop and implement a strategy for the control of the spread of *Phytophthora cinnamomi*.

3.1.4 Test native species that may be susceptible to *Phytophthora cinnamomi*.

3.1.5 Investigate the potential for poultry pathogens to adversely impact LHI fauna, particularly the LH Woodhen, and implement quarantine measures where appropriate.

Objective 4: To eradicate (where feasible) and control existing weeds to reduce their impact on the biodiversity of the LHIG

Weeds present a major threat to the biodiversity of the LHIG. Many weed species are widespread, some are location specific and there are many species that have the potential to become threats (sections 4.3 and 4.4).

Action 4.1: Review the Weed Management Strategy for Lord Howe Island

Location: LHIG

Task:

Review the Weed Management Strategy for Lord Howe Island on a regular basis to ensure that it reflects the most up-to-date information regarding quarantine and new species introductions and amend or add tasks as required. The strategy should be reviewed at least every five years.

Action 4.2: Implement the Weed Management Strategy for Lord Howe Island

Location: LHIG

Tasks:

4.2.1 Eradicate Category 1, 2 and 3 weeds (except Tiger Lily and Crofton Weed) (refer to Section 5.4) as a priority.

4.2.2 Eradicate Category 4 weeds (refer to Section 5.4) when Category 1, 2 and 3 weeds have been eradicated.

4.2.3 Continue searching for new recruits and missed plants, and new invaders.

4.2.4 Prevent new threats arising through removal of latent invasive alien plants from settlement gardens and removal of non-native vectors.

Action 4.3: Extend current weed inventory, mapping and monitoring work

Location: LHIG

Tasks:

4.3.1 Extend current weed mapping programs to include problem species that have not been mapped such as exotic grasses on offshore islands.

4.3.2 Develop a comprehensive weed monitoring program which identifies parameters to be monitored and includes feedback loops, e.g. mapping outcomes to provide data for future analysis.

4.3.3 Continue current inventory and mapping of weed distribution and spread.

Action 4.4: Continue regular weed inspections of leases

Location: settlement area

Tasks:

4.4.1 The staff of the LHIB to continue to conduct regular inspection of leases for weeds that are at risk of spreading into native vegetation, in addition to those species listed as noxious.

4.4.2 Investigate the potential to include weed control conditions on all vacant crown land leases. This may be appropriate via a Property Management Plan for each lease.

Action 4.5: Investigate and implement funding incentive schemes for weed management on leases

Location: settlement area

Task: Investigate the availability and source of funding for leaseholders to undertake weed control on their leases.

Action 4.6: Develop and implement a community awareness and control program on the impacts of weeds and prevention of spread

Location: LHIG

Tasks:

4.6.1 Increase weed awareness by developing and implementing a community awareness program on the impacts of weeds for both islanders and visitors. The preparation of promotional and educational material is to be included. Educational material should cover weed identification, how visitors and residents can be involved in preventing their spread and encouraging the use of LHIG native plant species in gardens and landscaping (see action 1.5).

4.6.2 Encourage the establishment of a leaseholders' weed control group. Encourage leaseholders to undertake a coordinated approach to weed control. Conduct weed control in conjunction with the LHIB's control programs and using assistance of the LHIB where appropriate.

Action 4.7: Develop a strategy for remote area weed control

Many weed infestations are located in difficult access situations. Development of appropriate techniques and training for staff is necessary to treat weeds in such locations. It is important to continue treatment of previously treated areas, particularly those treated for Bitou Bush, to prevent reinfestation.

Location: PPP, specifically cliffs and remote terrain in southern mountains and northern hills.

Tasks:

4.7.1 Identify training needs and implement training in safe techniques for weed control in remote and dangerous terrain, targeting weed species such as Bitou Bush, Crofton Weed and Tiger Lily.

4.7.2 Monitor remote area weed spread and distribution on a regular basis to provide information on weed status.

4.7.3 Establish a rapid response protocol to control any outbreaks of significant weed species in the southern mountains.

Action 4.8: Manage herbicide use to minimise any adverse impacts

Location: LHIG

Tasks:

4.8.1 Ensure careful use of herbicide, particularly in invertebrate hotspot areas (Figures 5 and 6) and threatened flora and fauna habitat.

4.8.2 Use a gradual approach to weed control in important invertebrate habitats (Figures 5 and 6), so invertebrates have an opportunity to move or recover in untreated or previously treated areas.

4.8.3 Ensure staff and volunteers are adequately trained in herbicide use and are using the most effective and target-specific chemical and application methods.

Action 4.9: Conduct research into weed control and biology

Location: LHIG

Tasks:

4.9.1 Support research into the control techniques and biology of major weed species of the LHIG.

4.9.2 Monitor current research into the biological control of weed species in inaccessible areas, particularly Crofton Weed and Tiger Lily. Initiate and support any funding proposals for research in this area.

Action 4.10: Control exotic grasses

Location: Lagoon Foreshores, Lovers Bay, Muttonbird Point, Dawsons Point, Admiralty Islands, Muttonbird Island

Task:

4.10.1 Exotic grasses to be gradually controlled and replaced by native grass species. Areas to be targeted are those vegetation communities mapped by Pickard (1983) as *Poa poiformis*.

Location: Old Settlement

Task:

4.10.2 Kikuyu to be controlled where it is threatening the population of the Endangered plant C*alystegia affinis*. Due to the twining nature of C. *affinis*, a great deal of care is needed to minimise any adverse impacts of Kikuyu control on the species.

Location: Neds Beach

Task:

4.10.3 The two sites of the Endangered Knicker Nut to be treated to reduce the impacts of Buffalo Grass and Kikuyu. Care is needed to minimise any adverse impacts of grass control on the Endangered species.

Location: Blinky Beach and Lagoon Foreshores

Task:

4.10.4 Exotic grasses such as Buffalo Grass and Kikuyu to be replaced with native grass species in the habitat of the Endangered plant *Chamaesyce psammogeton*. Other problematic exotic species, e.g. Five-leaf Morning Glory *(Ipomoea cairica)* and *Euphorbia paralias*, to be controlled where necessary.

Action 4.11: Support current LHIB Norfolk Island Pine control procedure

Location: Settlement area, particularly Lagoon Foreshores

Task:

Continue the current procedure by the LHIB to remove Norfolk Island Pines that are less than 6m tall. Encourage the removal of larger Norfolk Island Pines outside areas that are culturally significant for the Lord Howe Island community.

Action 4.12: Control weeds in selected priority sites

Location: Blackburn Island, Muttonbird Island

Task:

4.12.1 Monitor for any new weed species on offshore islands, particularly of exotic grasses. Any new weed species to be treated as a priority.

Location: Little Island

Task:

4.12.2 Undertake weed control and encourage regeneration of native species.

Objective 5: To undertake revegetation/ rehabilitation works in high conservation priority areas

Clearing has had a significant impact on the biodiversity of the LHIG. This objective identifies key high conservation priority areas that have been cleared or substantially modified where a significant biodiversity benefit would result from revegetation and rehabilitation. High priority areas are identified in Figure 9.

Action 5.1 Regularly review the Lord Howe Island Vegetation Rehabilitation Plan

Location: LHIG

Task:

Review the current Lord Howe Island Vegetation Rehabilitation Plan to ensure that it reflects the most up-to-date information regarding vegetation rehabilitation and amend or add tasks as required. The plan to be reviewed at least every five years.

5.2 Implement the Lord Howe Island Vegetation Rehabilitation Plan

Location: LHIG

Task:

Implement the Lord Howe Island Vegetation Rehabilitation Plan tasks listed in Section 5 of this plan.

Action 5.3 Revegetate and rehabilitate degraded high conservation priority sites

Location: LHIG

Tasks:

5.3.1 Sallywood Swamp Forest sites 1, 2 and 5 (see Figure 9) to be revegetated and rehabilitated using appropriate native species. Site 3 is at the end of the airport runway and is unable to be revegetated for safety reasons. Site 4 is in fair condition, but would benefit from expansion and regeneration of the edges.

5.3.2 Mangrove Communities in the settlement area are a high priority for revegetation. Staff of the LHIB to work with leaseholders to revegetate these areas.

5.3.3 Where possible, revegetate selected high conservation priority watercourses, specifically, those in the vicinity of Old Settlement, Cobby's Creek and in the Soldiers Creek basin using appropriate native species (Figure 9).

5.3.4 Encourage revegetation of cleared parts in the settlement area, e.g. Flesh-footed Shearwater habitat between Stevens Point and Middle Beach. This includes enlarging patches of isolated vegetation and regenerating gaps in remnant vegetation.

5.3.5 Establish a restoration program for *Poa poiformis* Communities. Locate *Poa poiformis* Communities as mapped by Pickard (1983) that have not already been targeted in previous actions. Identify any weed problems and undertake a restoration program to encourage the reestablishment of the native *Poa poiformis* Community.

5.3.6 Revegetate old clearing and garden sites, particularly those within or adjacent to the PPP, and those that pose a weed risk to the southern mountains.

Action 5.4: Use best-practice regeneration and rehabilitation principles

Location: LHIG

Tasks:

5.4.1 Use local provenance plant stock.

5.4.2 Restore vegetation communities as near as possible to their original composition and condition.

5.4.3 Use appropriate herbicide applications.

5.4.4 Investigate training opportunities to maintain up to date skills for LHIB staff undertaking bush regeneration works.

Action 5.5: Establish a monitoring program for revegetation projects

Monitoring is essential to determine the effectiveness or otherwise of revegetation programs.

Location: LHIG

Tasks:

5.5.1 Establish revegetation monitoring programs to measure their success.

5.5.2 Establish a set of marked photo points in a range of sites to assist with the monitoring of revegetation projects.

5.5.3 Undertake quadrat or transect sampling to measure changes to vegetation, including species composition, height and canopy cover.

5.5.4 Undertake mapping of implementation of management actions suitable for inclusion in GIS biodiversity forecasting analyses.

Action 5.6 Control the impacts of trampling, browsing and grazing by domestic stock on native vegetation communities

Location: Settlement area

Tasks:

5.6.1 Staff of the LHIB to work with leaseholders to fence high conservation priority vegetation communities from domestic stock (Sallywood Swamp Forest, Mangrove and significant watercourse areas at Old Settlement, Cobbys Creek and Soldiers Creek) (refer to Figure 9). Fences to be constructed outside existing habitat areas (i.e. in already cleared areas).

5.6.2 The LHIB to encourage fencing of vegetation remnants other than those listed above from domestic stock.

5.6.3 Erosion control measures to be put in place in fenced-off vegetation wherever necessary.

Action 5.7: Buffer vegetation of high conservation value

Location: LHIG

Tasks:

5.7.1 Plant a buffer of hardy species on the edges of significant remnant vegetation patches, particularly those patches suffering from windshear and exposure due to loss of canopy. Use hardy native species include Bully Bush and Hop Bush (*Dodonaea viscosa)*. Natural regeneration of native species to be encouraged on the edges of remnant vegetation patches.

5.7.2 Monitor the success of herbicide treatments for regeneration at vegetation edges.

Objective 6: To eradicate (where feasible and where there is a worthwhile biodiversity outcome) or control introduced fauna and reduce their impact on biodiversity

Action 6.1: Control introduced rodents

The Ship Rat has been well documented as causing a number of extinctions on the LHIG and being a major threat to extant native species, particularly terrestrial invertebrates (Section 4.3). The impact of the House Mouse on the LHIG biodiversity has not been documented.

Location: Targeted sites on the main Island. These targeted sites were chosen to both continue the existing baiting program, and to increase baiting in areas where there is the potential for a significant biodiversity benefit. These areas, listed below, include high biodiversity areas for seabirds and other vertebrates, invertebrates and selected vegetation communities.

- Existing rodent baiting grids;
- Muttonbird Point and to a lesser extent in the northern hills and cliffs, Lagoon Foreshores and Neds Beach to Clear Place for sea birds;
- Native vegetation in the settlement area;
- Far Flats, Boat Harbour, Malabar and Stevens Reserve;
- Cloud Forest on Mount Lidgbird and Mount Gower;
- Accessible areas in southern mountains, and North Bay;
- Kentia Palm areas in the settlement area; and
- Kentia Palm-Curly Palm communities and Kentia Palm-Blue Plum Communities in the southern mountains.
- Seasonal baiting of sea bird breeding areas for affected sea birds.

Tasks:

6.1.1 Continue current rodent baiting program.

6.1.2 Expand existing rodent baiting program to include additional baiting sites for biodiversity-based outcomes, such as those listed under Objective 6.

6.1.3 Design and implement a monitoring program to evaluate the effectiveness of the program on reducing the threat of rodent predation on target species and locations.

6.1.4 Investigate any impacts from the current rodent control program and use of rodent poisons by residents on the LHIG Currawong population.

Action 6.2 Eradicate introduced rodents

The ongoing existence of the Ship Rat on the main Island continues to place significant pressure on extant vertebrate and invertebrate fauna. Their presence also precludes the potential reintroduction of threatened species now restricted to offshore islands.

Location: Main Island

Tasks:

6.2.1 Convene a Rodent Eradication Taskforce to oversee the planning and implementation of a rodent eradication program for the LHIG.

6.2.2 Assess, and where appropriate, undertake the recommendations contained in the Feasibility and Cost-benefit studies.

6.2.3 Evaluate the potential use of toxins other than brodifacoum that have less potential impact on non-target species.

6.2.4 Prepare a Logistics Plan for the eradication of rodents from the LHIG.

6.2.5 Continue studies where necessary to minimise the potential impacts on non-target species such as the Lord Howe Woodhen and the Lord Howe Currawong.

6.2.6 Undertake environmental assessment for the proposal to eradicate introduced rodents. If the proposal is assessed as likely to have a significant impact to threatened species, prepare a SIS under the TSC Act.

Action 6.3 Eradicate Mallard-Black Duck hybrids from LHIG

Hybrids of Mallard and Black Ducks on Lord Howe Island provide a stepping stone for the continued hybridisation of the Black Duck across the Pacific. These ducks also provide a potential reservoir for avian influenza.

Task:

Eradicate Mallard-Black Duck hybrids from LHIG.

Action 6.4 Conduct research into the impacts of introduced vertebrate fauna on the biodiversity of the LHIG and investigate techniques for control or eradication

The impact of non-rodent introduced vertebrates on the biodiversity of the LHIG is not well documented or understood. Research is necessary to gain a better understanding of the impacts of these exotic species.

Location: Main Island

Tasks:

6.4.1 Investigate the degree of threat through competition and predation posed by introduced faunal species, particularly the Blackbird, Bleating Tree Frog, Feral Pigeon, Grass Skink, Masked Owl, Snake-necked Tortoise and the Songthrush, and self-introduced species, particularly the Australian Kestrel, Purple Swamphen and the Buff-Banded Rail.

6.4.2 Investigate techniques and feasibility for control or eradication of introduced faunal species based on the level of threat each species poses to native species of the LHIG.

6.4.3 Implement control or eradication techniques where available, feasible and where there is a significant biodiversity benefit.

Action 6.5 Conduct research into the impacts of introduced invertebrate fauna on the biodiversity of the LHIG and investigate techniques for control or eradication

Location: Main Island

Tasks:

6.5.1 Investigate the threat posed by established introduced invertebrates through targeted monitoring sites and research.

6.5.2 Investigate techniques and feasibility for control or eradication based on the level of threat each species poses to the native species of the LHIG.

6.5.3 Implement control or eradication techniques where available, feasible and effective.

Action 6.6 Control introduced invertebrates in targeted locations.

Location: *Calystegia affinis* site at Max Nicholls track.

Tasks:

6.6.1 Investigate control methods for the *Arsipoda* beetle on *Calystegia affinis* site on Max Nicholls track.

6.6.2 If control methods are found that are effective and that do not pose a risk to *Calystegia affinis*, undertake a control program.

Objective 7: To reduce impacts of groundwater pollution

Septic systems in parts of the settlement area have the potential to adversely impact on the biodiversity of the watercourses in this area.

Action 7.1 Protect water quality in freshwater creeks

Location: Settlement area

Tasks:

7.1.1 Develop a ground water management strategy to prevent adverse impacts of groundwater pollution to biodiversity in the settlement area. Strategy to include investigation into waste water treatment.

7.1.2 Undertake water quality monitoring in streams, including monitoring of macroinvertebrates.

Objective 8: To enhance positive interactions and reduce negative interactions between humans and wildlife

Action 8.1 Enhance positive interactions between Humans and wildlife through development of guidelines and a public awareness campaign

Tasks:

8.1.1 Ensure any artificial feeding of native fauna is undertaken in accordance with guidelines provided by the LHIB.

8.1.2 Develop wildlife interaction guidelines for all tour operators and include as a condition on licences.

8.1.3 Regularly review and revise Dog importation and management policies, and vehicle and traffic management policies to ensure they contain measures to reduce the impacts of dogs and vehicular traffic on native fauna.

8.1.4 Develop and implement a strategy for the control of non-native fauna which is, or has been, kept as a pet, companion animal, agricultural animal or for some other human use, and which has an ongoing impact on, or poses a threat to native fauna, for example feral pigeons, uncontrolled poultry, non-sterile goats and cats.

8.1.5 Produce and distribute to residents and visitors a plain-language booklet detailing ethics, practices, techniques and behaviours which will minimise negative human impacts on, and encourage positive interaction with, native fauna.

Objective 9: To reduce the impact of commercial, cultural and illegal collecting

There are three main forms of collecting on Lord Howe Island; collecting of the natural materials such as Kentia palm seed and Pandanus, collecting for scientific research purposes and the illegal collection of fauna (such as sea bird eggs or invertebrates) and flora (e.g. orchids, ferns).

Action 9.1 Minimise impacts on biodiversity of commercial Kentia Palm seed collecting

Location: LHIG

Task:

Monitor the impacts of palm seed collection in non-plantation areas. If monitoring indicates negative impacts, encourage collection from less-significant areas.

Action 9.2 Control the illegal collection of fauna

Location: LHIG

Tasks:

9.2.1 Conduct a review of the LHI Act Regulations 2004 to ensure all appropriate taxa that may be subject to illegal collection are addressed.

9.2.2 Raise awareness of the issue of illegal collection by enhancing relationships with customs and the federal police.

9.2.3 Ensure the LHIB has issued appropriate licences for persons undertaking invertebrate collections for research purposes.

9.2.4 Restrict access to all offshore islands outside the lagoon that have significant biodiversity value.

9.2.5 Establish protocols to keep significant invertebrate localities secure.

9.2.6 Ensure the Lord Howe Island community is aware of the impacts and licensing requirements of seabird egg collection.

Objective 10: To reduce human impacts

Action 10.1: Protect vegetation in the vicinity of walking tracks and in areas where research and management activities require walking off-track

Location: LHIG

Tasks:

10.1.1 Promote awareness of the importance of staying on walking tracks.

10.1.2 Establish and implement an appropriate hygiene protocol for access to the PPP, including investigating options for placement of composting toilet at the entrance to the Mount Gower walking track and development of a strategy to protect significant habitats from adverse impacts of visitation.

10.1.3 Ensure field workers accessing the PPP are aware of sensitive areas prior to field work commencing.

10.1.4 Encourage tourists, residents, seed collectors, researchers and management staff to adopt minimal impact bushwalking practices.

Objective 11: To monitor consequences of climate change and develop contingency plans for 'at risk' species

Action 11.1 Monitor areas identified at risk from climate change

Location: LHIG, particularly areas identified most at risk from climate change impacts.

Tasks:

11.1.1 Establish biodiversity monitoring sites in as many 'at risk' areas as possible, including Mangroves, Sallywood Swamp Forest, Cloud Forest, high parts of the northern hills.

11.1.2 Establish long-term monitoring sites of flora and fauna along an altitudinal gradient in the southern mountains.

11.1.3 Undertake research to monitor the impact of climate change on seabird populations, particularly those species breeding within the LHIG that are at the extremity of their breeding range.

11.1.4 Develop and implement a monitoring program to assess the impacts of climate change on invertebrate lifecycles and 'at risk' flora (e.g. Knicker Nut, *Chamaesyce psammogeton*, *Geniostoma huttonii*, *Polystichum moorei*, and *Xylosma parvifolium*).

11.1.5 Establish a climate monitoring station on Mt Gower.

Action 11.2 Investigate options for securing species identified as most at risk from climate change

Location: LHIG

Task:

Investigate propagation and *ex-situ* storage techniques for species restricted to Cloud Forests, including both seed banking and living collections.

Objective 12: To encourage the conservation and protection of significant species, populations and ecological communities

Action 12.1 Prepare nominations for species, populations, ecological communities or critical habitat as required

Location: LHIG

Tasks:

12.1.1 Nominate taxa and communities that are assessed as being threatened for listing under State and Commonwealth legislation, particularly any that may not be adequately covered by actions in this plan.

12.1.2 Where appropriate, potential nominations to be endorsed by the recovery team prior to proceeding with a formal nomination.

12.1.3 A list of significant taxa and communities (Appendix 1) (appendices document) to be maintained and regularly updated.

Objective 13: To promote recovery of individual threatened flora taxa

In addition to landscape-level recovery actions that are designed to provide broad biodiversity benefits across the LHIG, there are also species-specific recovery actions for those species that have particular conservation significance, or are particularly under threat where these species are not adequately addressed by broad-scale actions.

The following actions are targeted at individual listed flora threatened species.

Action 13.1 Protect habitat of threatened flora

Threatened flora species that occur within the settlement area (Knicker Nut, *Calystegia affinis*, *Chamaesyce psammogeton* and *Elymus multiflorus* var *kingianus)* may be at risk of clearing, trampling or grazing.

Location: Settlement area

Tasks:

13.1.1 Habitat of Knicker Nut, *Calystegia affinis*, *Chamaesyce psammogeton* and *Elymus multiflorus* var *kingianus* must be protected from clearing.

13.1.2 Habitat of Knicker Nut, *Calystegia affinis*, *Chamaesyce psammogeton* and *Elymus multiflorus* var *kingianus* to be fenced where possible to protect from trampling or grazing, particularly where expansion of the plant's habitat is possible.

Action 13.2 Undertake weed control in the habitat of threatened flora

Location: LHIG

Tasks:

13.2.1 *Calystegia affinis*

Grass invasion, specifically Kikuyu, is impacting the viability of the *Calystegia affinis* population at Old Settlement. Control of introduced grass to be undertaken at this site. Control will need to be done gradually and with extreme care due to potential impacts to *C. affinis* given its twining habit around the Kikuyu.

13.2.2 Knicker Nut

The introduced grasses Buffalo and Kikuyu are threatening the Knicker Nut population at Neds Beach. These exotic species need to be eradicated or controlled.

13.2.3 *Carmichaelia exsul*

Cherry Guava, Crofton Weed and Tiger Lily to be eradicated or controlled in *Carmichaelia exsul* sites.

13.2.4 *Chamaesyce psammogeton*

As this species occurs on the dunes of Blinky Beach, weed control will need to be opportunistically undertaken to protect its habitat from any new weed species incursions.

13.2.5 *Coprosma inopinata*

C. inopinata habitat should be monitored for any weed incursions, and any weeds treated as a priority.

13.2.6 *Elymus multiflorus* var *kingianus*

Investigate weed control needs for *Elymus* var *kingianus* and undertake weed control if necessary.

13.2.7 *Polystichum moorei*

Crofton weed and Tiger Lily are threatening *Polystichum moorei* habitat in the southern mountains. This needs to be eradicated or controlled where sites are accessible and when suitable techniques are available.

Action 13.3 Undertake monitoring of, and targeted research into, threatened and key endemic flora

Location: LHIG

Tasks:

13.3.1 Develop a monitoring and targeted research program for threatened and key endemic flora. The monitoring program to include measures of the area of the population, the population structure, mapping the extent of populations, threats and specify the time period of the monitoring. The research program to investigate autecological requirements of threatened flora that will assist with management.

13.3.2 Implement a threatened and key endemic flora monitoring program to determine any changes that may influence the long-term viability of the species. Include mapping outcomes from implementation suitable for input into GIS biodiversity forecasting analyses. Results from this program may be used to prioritise species for *ex-situ* conservation actions.

Action 13.4 Establish ex-situ *collections of threatened and key endemic flora*

The threatened flora, and some endemic flora, of Lord Howe Island have critically small populations.

Location: LHIG, mainland

Tasks:

13.4.1 Establish *ex-situ* populations or seedbanks for all threatened flora.

13.4.2 Investigate whether any endemic non-threatened species with small populations warrant *ex-situ* conservation.

Action 13.5 Reduce adverse human impacts on threatened flora and communities

Location: Threatened flora species sites

Tasks:

Some threatened species are potentially at risk from the impacts of tourism and site visitation.

13.5.1 *Calystegia affinis*

A walking track dissects the *Calystegia affinis* population in the north of the island. Adverse impacts from tourism at this site to be minimised, and the boardwalk in the area to be maintained.

13.5.2 Knicker Nut

Two Knicker Nut sites are located near popular areas of Neds Beach and could be impacted on by visitors. Impacts of visitation needs to be monitored and any adverse impacts need to be minimised, by either signage or fencing.

13.5.3 *Coprosma inopinata*

Access to the *C. inopinata* site in the south end of the island should be restricted to essential research and management only, and require approval by the LHIB. Any permitted access to be provided with information on the significance of the site, and ways to minimise any adverse impacts.

13.5.4 Implement a strategy that minimises the risk of introduction of *Phytophthora cinnamomi* to threatened flora and community sites.

Action 13.6 Promote public awareness of threatened plants and communities

Location: LHIG

Task:

Prepare appropriate promotional and public awareness material on the threatened flora of the LHIG.

Objective 14: To improve knowledge and management of threatened and significant fauna species

There is a lack of knowledge regarding the ecology of most of the threatened and significant vertebrate and invertebrate fauna of the LHIG and the threatening processes impacting on them. This lack of knowledge has a considerable impact on the LHIB's ability to adequately protect and manage these species.

Action 14.1: Conduct research into priority fauna species

Location: LHIG

Tasks:

14.1.1 Conduct species-specific fauna research based on identified research priorities into the ecology of priority species, particularly with regards to reproductive ecology and habitat requirements, the impact of threatening processes, and population monitoring. Research should aim to identify management actions that will improve the long-term viability of the species.

14.1.2 Map species distributions, including point locality data as well as habitat mapping to allow for future biodiversity forecasting analyses.

14.1.3 Improve species habitat maps produced for this plan for input to GIS-based biodiversity forecasting analyses.

Action 14.2 Design and implement monitoring programs to evaluate effectiveness of recovery actions on threatened fauna

Tasks:

14.2.1 Implement monitoring programs to measure the success or failure of recovery programs for threatened fauna.

14.2.2 Map any changes to distribution or abundance in a form suitable for input into GIS-based biodiversity forecasting analyses.

Objective 15: To protect and enhance threatened fauna habitat

Action 15.1 Protect and enhance Flesh-footed Shearwater habitat

Location: Eastern settlement area

Tasks:

15.1.1 Zone all mapped Flesh-footed Shearwater nesting habitat (Priddel *et al.* 2006) as Environmental Protection or Significant Vegetation.

15.1.2 Rehabilitate areas within grazing leases where Flesh-footed Shearwaters are continuing to nest, as well as additional areas within the 1978 mapped distribution (Priddel *et al.* 2006).

Action 15.2 Protect and enhance habitat for the Lord Howe Island Silvereye

Location: Main Island

Task:

Encourage planting of native trees and understorey plants in cleared parts of the settlement area.

Action 15.3 Enhance and protect habitat for the Lord Howe Island Wood-feeding Cockroach

Location: Blackburn Island, Admiralty Islands

Tasks:

15.3.1 Control Rhodes Grass on Blackburn Island and revegetate with native grasses and species from the Greybark-Blackbutt Closed Forest Community.

15.3.2 Monitor Admiralty Islands for arrival of introduced grasses.

Action 15.4 Protect habitat of the White-bellied Storm-Petrel and Kermadec Petrel

Location: Balls Pyramid and Roach Island

Task:

Continue to restrict access to Balls Pyramid and control access to Roach Island.

Action 15.5 Protect and enhance Red-tailed Tropicbird habitat

Location: LHIG

Task:

Eradicate Bitou Bush in breeding areas on seacliffs from North Head to Malabar and cliffs of Mounts Lidgbird and Gower.

Action 15.6 Protect and enhance Little Shearwater habitat

Location: Muttonbird Point

Task:

Control Kikuyu and reestablish the *Poa poiformis* Grassland Community on Muttonbird Point.

Action 15.7 Protect and enhance the habitat of Blackburn Island

Location: Blackburn Island

Task:

Develop a strategy for the management of Blackburn Island. This strategy is to aim to protect Blackburn Island from the introduction of rodents and other pests and diseases as well as habitat enhancement activities (e.g. revegetation, weed control).

Objective 16: To reduce impacts of fishing and marine debris on threatened sea birds

Action 16.1: Reduce the amount of plastic bags in use on the LHIG and encourage their responsible disposal

Location: LHIG and surrounding waters

Tasks:

16.1.1 Encourage the use of reusable and biodegradable bags.

16.1.2 Conduct an investigation to consider Lord Howe Island becoming a plastic bag-free island.

16.1.3 Develop guidelines with all fishing boat and tourist boat operators on the LHIG to prevent plastic bait bags and other plastics being deliberately or accidentally disposed of into the ocean.

16.1.4 Undertake research to determine the impact of plastic ingestion by sea birds on survival, breeding success and fledgling condition.

Objective 17: To undertake recovery actions for threatened fauna species identified in existing documents

Action 17.1 Implement the Lord Howe Island Phasmid interim recovery actions

Location: Balls Pyramid, ex-situ.

Recovery actions for the Lord Howe Island Phasmid are based on Interim Recovery Actions by Priddel *et al.* (2001), and Priddel *et al.* (2003b).

Tasks:

17.1.1 Continue to restrict access to Balls Pyramid.

17.1.2 Control Morning Glory *Ipomoea cairica* plants on Balls Pyramid that threatened to encroach upon the habitat of the Phasmid or the *Melaleuca* plants on which these insects feed.

17.1.3 Monitor population numbers on Balls Pyramid annually.

17.1.4 Maintain the captive colonies at Melbourne Zoo and Insektus. The aim of these populations is to secure the immediate survival of the species and to produce the animals needed for its subsequent re-introduction back onto Lord Howe Island.

17.1.5 Investigate availability of institutions with a capability of housing Phasmids.

17.1.6 Undertake research to improve husbandry techniques and maximise egg production, hatch rates and the survival of individuals.

17.1.7 Establish a display of live Phasmids on Lord Howe Island to inform the local community and visitors about the Phasmid, the threats posed by rats and actions being taken to conserve the species.

17.1.8 Develop techniques to reintroduce the Phasmid back onto Lord Howe Island.

Action 17.2: Implement the Lord Howe Island Placostylus recovery actions

Location: LHIG, off-island

Tasks:

Implement recovery actions for the Lord Howe Island Placostylus from the approved Recovery Plan (NSW NPWS 2001). These are summarised and prioritised in Section 5.

Action 17.3: Implement recovery actions for the Lord Howe Island Gecko and Lord Howe Island Skink

The tasks listed below have been derived from Cogger (unpub).

Location: LHIG

Tasks:

17.3.1 Survey for the Lord Howe Island Gecko and Lord Howe Island Skink where the two species are likely but not known to occur (Admiralty Islands, Gower Island and Muttonbird Island).

17.3.2 Study the biology and ecology of at least one population of each species.

17.3.3 Investigate the impact of the Grass Skink and the Bleating Tree Frog on the main island on the Lord Howe Island Skink and Lord Howe Island Gecko.

Action 17.4: Implement the Lord Howe Island Woodhen Recovery Plan

Location: Main Island, ex-situ.

Task:

Implement actions from the Lord Howe Woodhen Recovery Plan. These are listed and prioritised in Section 5.

Objective 18: To investigate the appropriateness of the reintroduction of locally extinct fauna after rodents have been eradicated

The proposed eradication of rodents from Lord Howe Island and the mitigation of other threats provide the opportunity to reestablish populations of locally extinct species.

Action 18.1: Adapt existing guidelines and protocols on translocation and reintroductions to be specific for the LHIG

Task:

Review existing International, National and State guidelines on translocation and reintroductions to determine whether any adaptation is necessary to enable assessment of any reintroduction or translocation proposals.

Action 18.2: Reestablish populations of species on the main island that still exist within the LHIG

Tasks:

18.2.1 Promote the reestablishment of White-bellied Storm-Petrel and Kermadec Petrel breeding populations on the main Island.

18.2.2 Reintroduce the Lord Howe Island Phasmid onto the main Island by the translocation of captive-bred individuals and eggs.

Action 18.3: Reestablish populations of species lost from the LHIG

Tasks:

18.3.1 Investigate the appropriateness of reintroducing the Endangered Red-crowned Parakeet (*Cyanoramphus novaezelandiae subflavescens*) to Lord Howe Island from Norfolk Island.

18.3.2 Investigate the appropriateness of reintroducing closely allied subspecies of other birds that were previously extirpated from Lord Howe Island by rats.

Objective 19: To coordinate implementation of the LHI BMP and regularly evaluate the biodiversity benefits of implementation

The recovery actions from the LHI BMP will be implemented over a ten-year period, and for the Commonwealth, over a five year period. Ongoing evaluation of the effectiveness of actions will assess optimal biodiversity outcomes and the efficient use of resources.

Coordination of the implementation of the Plan will play an important role in ensuring priorities and timelines are met, given the comprehensive and extensive nature of the actions in the plan. In addition, ongoing evaluation of the effectiveness of actions will assess optimal biodiversity outcomes and the efficient use of resources.

Action 19. 1 Coordinate implementation of BMP

Location: LHIG, off-island

Tasks:

19.1.1 Establish a BMP Implementation Group, chaired by a Plan coordinator.

19.1.2 Review progress of all implementation programs on an annual basis, provide guidance on priorities and communicate results to relevant parties.

19.1.3 Update any mapping undertaken for the LHI BMP on an annual basis for all implementation programs.

19.1.4 Evaluate the effectiveness of the implementation program and amend the program as required on an annual basis.

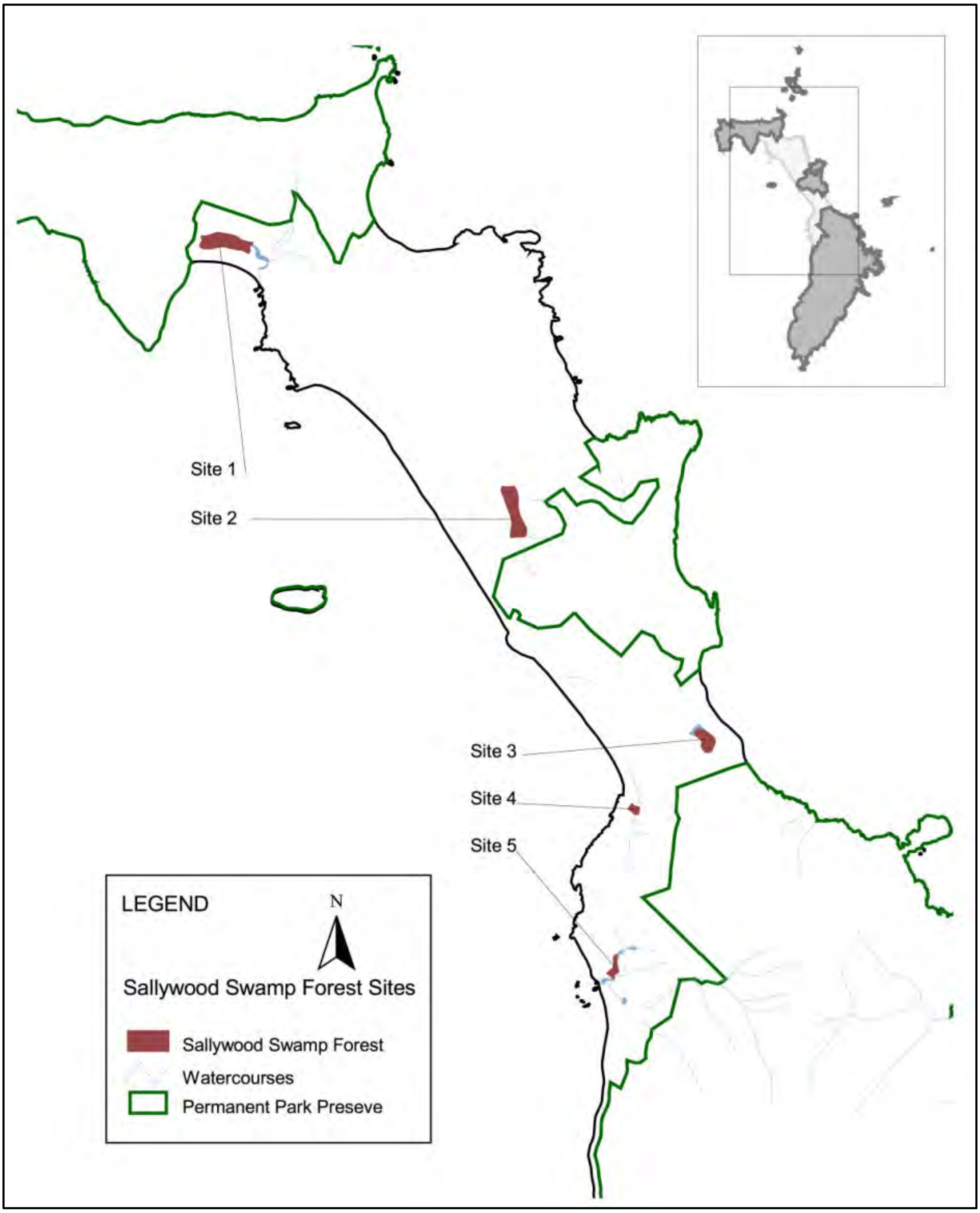


Figure 9. Sallywood Swamp Forest sites

Table 16. Summary of recovery actions and threatened species addressed

Threatened Species	1.Quarantine	2. Retain native vegetation	3. Control impacts of introduced pathogens	4. Weed eradication and control	5. Revegetation/rehabilitation	6. Introduced fauna eradication and control	7. Reduce impacts of groundwater pollution	8.Encourage positive appreciation of biodiversity	9. Reduce the impact of illegal collection	10. Reduce human impacts.	11. Monitor consequences of climate	12. Encourage conservation & protection of significant species	13. Promote recovery of threatened flora	14. Improve knowledge & management of fauna	15. Protect & enhance threatened fauna habitat	16. Reduce impacts of fishing & marine debris on sea birds.	17. Undertake recovery of threatened fauna	18. Investigate fauna reintroductions	19. Evaluate implementation of LHI BMP
Fauna																			
LHI Phasmid	□		□	□		□		□	□	□	□			□	□		□	□	□
LHI Cockroach	□	□	□	□	□	□		□	□	□	□			□	□			□	□
LHI Earthworm	□	□	□	□		□		□	□	□	□			□	□				□
LH Placostylus	□	□	□	□	□	□	□	□	□	□	□			□	□		□		□
LHI Gecko	□	□	□	□	□	□	□	□	□	□	□			□	□		□		□
LHI Skink	□	□	□	□	□	□	□	□	□	□	□			□	□		□		□
LHI Currawong	□	□	□	□	□	□		□		□	□			□	□				□
LHI Silvereye	□	□	□	□	□	□		□		□	□			□	□				□
LHI Golden Whistler	□	□	□	□	□	□		□		□	□			□	□				□
LHI Woodhen	□	□	□	□	□	□		□		□	□			□	□		□		□
Flesh-footed Shearwater	□	□	□	□	□	□		□		□	□			□	□	□			□
Grey Ternlet	□		□	□		□		□		□	□			□	□	□			□
Kermadec Petrel	□		□			□		□		□	□			□	□	□			□
Little Shearwater	□	□	□	□	□	□		□		□	□			□	□	□			□
Masked Booby	□		□	□	□	□		□		□	□			□	□	□			□
Providence Petrel	□	□	□	□		□		□		□	□			□	□	□			□
Red-tailed Tropicbird	□		□	□		□		□		□	□			□	□	□			□
Sooty Tern	□		□			□		□		□	□			□	□	□			□
White Tern	□	□	□	□	□	□		□		□	□			□	□	□			□
White-bellied Storm Petrel	□		□	□	□	□		□		□	□			□	□	□			□
Black-winged Petrel	□		□	□	□	□		□		□	□			□	□	□			□
Flora																			
Caesalpinea bonduc	□	□	□	□	□			□		□	□		□						□
Calystegia affinis	□	□	□	□	□	□		□		□	□		□						□
Carmichaelia exsul	□	□	□	□				□		□	□		□						□
Chamaesyce psammogeton	□	□	□	□	□			□		□	□		□						□
Coprosma inopinata	□	□	□	□				□		□	□		□						□
Elymus multiflorus var *kingianus*	□	□	□	□				□		□	□		□						□
Geniostoma huttonii	□	□	□	□				□		□	□		□						□
Polystichum moorei	□	□	□	□				□		□	□		□						□
Xylosma parvifolium	□	□	□	□				□		□	□		□						□
Vegetation communities																			
Sallywood Swamp Forest	□	□	□	□	□	□	□	□		□	□								□

Table 17. Estimated costs of implementing the actions identified in the biodiversity management plan for Lord Howe Island

(note: where priorities are the same for each sub-action, only the priority of the action is listed. Where priorities vary for sub-actions, the priority of the action is not listed. Total costs are listed for each objective and split for actions and sub-actions where relevant. Costings are defined for sub-actions where possible).

Action No.	Action Title	Priority	Location	Total Cost ($) / 10 years	Potential partners
Objective 1: To prevent the introduction of exotic fauna, flora and pathogens to LHIG				**731 000**	
1.1	**Review the LHIB Quarantine Strategy**	1	LHIG, mainland departure points	10 500	LHIB
1.1.1	Review current LHIB Quarantine Strategy				
1.1.2	Ensure invasive ant risk assessment and control strategy is included				
1.1.3	Ensure offshore island quarantine strategy is included				
1.1.4	Develop a public awareness program for Blackburn Island				
1.1.5	Develop a protocol to minimise risk of rodent introduction to Blackburn Island				
1.2	**Implement LHIB Quarantine strategy**	1	LHIG, mainland departure points	600 000	LHIB, Biosecurity Australia, AQIS, Australian Government, DECC, DPI
1.3	**Review the LHI Plant Importation Policy**	1		10 500	LHIB
1.4	**Implement the LHI Plant Importation Policy**	1	LHIG	10 000	LHIB, Biosecurity Australia, AQIS, DPI
1.5	**Increase local native plant production and use**	2	settlement area	70 000	LHIB, LHI residents, nursery
1.6	**Prepare a rapid response and detection protocol for new introductions of weeds and exotic fauna**	1	LHIG, mainland departure points	30 000	LHIB, DECC, DPI, AQIS
1.6.1	Develop an early detection protocol and procedures document to deal with new introductions				
1.6.2	Ensure LHIB staff are trained and equipped to be able to implement the rapid response protocol				

Objective 2: To retain native vegetation				**295 000**	
2.1	**Ensure appropriate environmental assessment is undertaken when assessing development proposals**	1	LHIG	35 000	LHIB, proponents
2.2	**Liaise with leaseholders regarding protection and management of remnant and significant vegetation**	1	settlement area	70 000	LHIB
2.3	**Provide assistance for leaseholders to protect native vegetation**	1	settlement area	170 000	LHIB, NRCMA
2.4	**Encourage protection of vegetation and habitat features that constitutes invertebrate habitat**	1	settlement area	20 000	LHIB
Objective 3: To control the impacts of introduced pathogens on native species				**125 000**	
3.1	**Develop and implement measures to minimise the impacts of introduced flora and fauna pathogens**				
3.1.1	Develop and implement a set of phytosanitary guidelines for walkers and palm seeders to minimise the risk of introducing pests, weeds and disease to LHIG	1	LHIG	5 000	LHIB, DPI, DECC
3.1.2	Conduct a detailed survey for the presence of *Phytophthora cinnamomi*	3	LHI	10 000	LHIB, DPI, DECC
3.1.3	Develop and implement a strategy to control spread of *P. cinnamomi*	1	Settlement area	50 000	LHIB, DPI, DECC
3.1.4	Test native species that have the potential to be susceptible to *P. cinnamomi*	4	LHIG	10 000	LHIB, DPI, DECC
3.1.5	Investigate the potential for poultry pathogens to adversely impact LHI fauna	2	LHIG	50 000	LHIB, tertiary institution, AQIS, DPI
Objective 4: To eradicate (where feasible) and control existing weeds to reduce their impact on the biodiversity of the LHIG				**4 173 000**	
4.1	**Review Weed Management Strategy for Lord Howe Island**	1	LHIG	10 500	
4.2	**Implement Weed Management Strategy for LHI**			3 807 500	
4.2.1	Eradicate Category 1, 2 & 3 weeds	1	LHIG		LHIB, Environmental Trust, NRCMA, FOLHI

4.2.2	Eradicate Category 4 weeds	2	LHIG		LHIB, Environmental Trust, NRCMA, FOLHI
4.2.3	Continue searching for new recruits, missed plants and new invaders	2	LHIG		LHIB, Environmental Trust, NRCMA, FOLHI
4.2.4	Prevent new weed threats arising	2	LHIG		LHIB, Environmental Trust, NRCMA, DPI
4.3	**Extend current weed inventory, mapping and monitoring work**			10 500	
4.3.1	Extend current weed mapping programs to include problem species that have not been mapped	2	LHIG		LHIB, NRCMA, Environmental Trust
4.3.2	Develop a comprehensive weed monitoring program	3	LHIG		LHIB, NRCMA, Environmental Trust
4.3.3	Continue current inventory and monitoring of weed distribution and spread	3	LHIG		LHIB, NRCMA, Environmental Trust
4.4	**Continue regular weed inspections of leases**	1	settlement area	17 500	
4.4.1	LHIB staff to continue to conduct regular inspections of leases for weeds				LHIB, DPI
4.4.2	Investigate the potential to include weed control conditions on vacant crown land leases				LHIB
4.5	**Investigate and implement funding incentive schemes for weed management on leases**	1	settlement area	170 000	LHIB, Dept Planning, DPI, NRCMA, DECC
4.6	**Develop and implement a community awareness and control program on the impacts of weeds and prevention of spread**			10 000	
4.6.1	Develop and implement a community awareness program	3	LHIG		LHIB, DEWR, NRCMA, FOLHI, DPI, Australian Government, WWF, Environmental Trust, National Parks Foundation
4.6.2	Encourage the establishment of a leaseholders' weed control group	4	LHIG		LHIB, FOLHI, private tour operators

4.7	**Develop a strategy for remote area weed control**	2		20 000	
4.7.1	Identify training needs and implement training techniques for weed control in remote terrain		PPP, specifically cliffs and remote terrain in southern mountains and northern hills		LHIB
4.7.2	Monitor remote area weed spread and distribution on a regular basis		PPP, specifically cliffs and remote terrain in southern mountains and northern hills		LHIB, DECC, NRCMA
4.7.3	Establish a rapid response protocol to control any outbreaks of significant weed species		PPP, specifically cliffs and remote terrain in southern mountains and northern hills		LHIB
4.8	**Manage herbicide use to minimise any adverse impacts**			2 000	
4.8.1	Ensure careful use of herbicide	2	LHIG		LHIB, FOLHI
4.8.2	Use a gradual approach to weed control in important invertebrate habitats	2	LHIG		LHIB, FOLHI
4.8.3	Ensure staff and volunteers are adequately trained in herbicide use	1	LHIG		LHIB, FOLHI
4.9	**Conduct research into weed control and biology**	3	LHIG	100 000	LHIB, DPI, tertiary institutions
4.9.1	Support research into the control techniques and biology of major weed species				
4.9.2	Monitor current research into the biological control of weed species in inaccessible areas				
4.10	**Control exotic grasses**			20 000	
4.10.1	Exotic grasses to be gradually controlled and replaced by native grass species	2	Lagoon foreshores, Lovers Bay, Muttonbird Point, Dawsons Point, Admiralty Islands, Muttonbird Island, Jims Point to Stevens Point.		LHIB, FOLHI, NRCMA, Environmental Trust, Australian government
4.10.2	Kikuyu to be controlled where it is threatening *Calystegia affinis*	1	Old Settlement		LHIB, FOLHI, NRCMA, Environmental Trust, Australian government
4.10.3	Control exotic grass in the habitat of Knicker Nut	2	Neds Beach		LHIB, FOLHI, NRCMA, Environmental Trust, Australian government

4.10.4	Replace exotic grass species with native species in the habitat of *Chamaesyce psammogeton*	3	Blinky Beach		LHIB, FOLHI, NRCMA, Environmental Trust, Australian government
4.11	**Support current LHIB Norfolk Island Pine control procedure**	3	settlement area, particularly Lagoon Foreshores	5 000	LHIB, FOLHI,NRCMA, Australian government
4.12	**Control weeds in selected priority sites**				
4.12.1	Monitor for new weed species on offshore islands	1	Blackburn Island, Muttonbird Island		LHIB, FOLHI, NRCMA, Australian government
4.12.2	Undertake weed control and encourage regeneration of native species	4	Little Island		LHIB, FOLHI, NRCMA, Australian government
Objective 5: To undertake revegetation/rehabilitation works in high conservation priority areas				**710 500**	
5.1	**Regularly review the LHI Vegetation Rehabilitation Plan**	1		10 500	LHIB
5.2	**Implement the LHI Vegetation Rehabilitation Plan**	1	LHIG		LHIB, FOLHI
5.3	**Revegetate and rehabilitate degraded high conservation priority sites**				
5.3.1	Revegetate and rehabilitate selected Sallywood Swamp Forest sites	1	settlement area		LHIB, FOLHI, leaseholders
5.3.2	Revegetate Mangrove Communities	1	settlement area		LHIB, FOLHI, leaseholders
5.3.3	Revegetate selected watercourse areas	1	settlement area		LHIB, FOLHI, leaseholders
5.3.4	Encourage revegetation of cleared areas where appropriate	3	settlement area		LHIB, FOLHI, leaseholders
5.3.5	Establish a restoration program for *Poa poiformis* Communities	2	LHIG		LHIB, FOLHI
5.3.6	Revegetate selected old clearing and garden sites	4	LHI		LHIB, leaseholders
5.4	**Use best-practise regeneration and rehabilitation principles**		LHIG		
5.4.1	Use local provenance plant stock	1			LHIB, FOLHI
5.4.2	Restore vegetation communities as near as possible to their original composition and condition	1			LHIB, FOLHI
5.4.3	Use appropriate herbicide applications	1			LHIB, FOLHI
5.4.4	Investigate training opportunities to maintain up to date skills for LHIB staff undertaking bush regeneration works	3			LHIB

5.5	**Establish a monitoring program for revegetation projects**	2	LHIG		LHIB
5.5.1	Establish revegetation monitoring programs and measure their success				
5.5.2	Establish a set of marked photo points in a range of sites to assist with the monitoring of revegetation projects				
5.5.3	Undertake quadrat or transect sampling to measure changes to vegetation				
5.5.4	Undertake mapping of implementation of management actions suitable for GIS	2			
5.6	**Control trampling, browsing and grazing**				LHIB,FOLHI, NRCMA, leaseholders
5.6.1	Fence high conservation priority vegetation communities from domestic stock	1	settlement area		
5.6.2	Fence other patches of remnant vegetation from domestic stock	2	settlement area		
5.6.3	Implement erosion control measures in fenced areas wherever necessary	2	settlement area		
5.7	**Buffer vegetation of high conservation value**	3	settlement area		LHIB, FOLHI, NRCMA leaseholders
5.7.1	Plant a buffer of hardy species on the edges of significant remnant vegetation patches				
5.7.2	Monitor the success of herbicide treatments for regeneration at vegetation edges				
Objective 6: To eradicate (where feasible and where there is a worthwhile biodiversity outcome) or control introduced fauna and reduce their impact on biodiversity				**1 650 000**	
6.1	**Control introduced rodents**		LHI	200 000	LHIB, DECC, Australian government, Environmental Trust, WWF, NRCMA
6.1.1	Continue current rodent baiting program	1	LHI		LHIB
6.1.2	Expand existing baiting program to include additional baiting sites for biodiversity based outcomes	1	LHI		LHIB
6.1.3	Design and implement a monitoring program to evaluate the effectiveness of the program on reducing the threat of rodent predation on target species and locations	3	LHI		LHIB, Australian Museum, tertiary institutions

6.1.4	Investigate impacts from current rodent control program and baiting by residents on the LHI Currawong	2	LHI		LHIB, Australian government, NRCMA, Environmental Trust
6.2	**Eradicate introduced rodents**	**1**	LHI	1 000 000	
6.2.1	Convene a Rodent Eradication Taskforce				LHIB, LHI Recovery Team, DECC
6.2.2	Assess and, where appropriate, undertake the recommendations contained in the Feasibility and Cost-benefit studies		LHIG	190 000	LHIB, LHI Recovery Team, DECC, WWF, NRCMA, Australian government
6.2.3	Evaluate the potential use of toxins other than brodifacoum		LHIG		LHIB, DECC, tertiary institutions
6.2.4	Prepare a logistics plan for rodent eradication		LHIG		LHIB, DECC, LHI Recovery Team
6.2.5	Continue studies where necessary to investigate non-target impacts		LHI		LHIB, DECC, Australian government, WWF, NRCMA
6.2.6	Undertake environmental assessment for the proposal		LHI		LHIB, DECC
6.3	**Eradicate Mallard-Black Duck hybrids**	3	LHIG	10 000	LHIB
6.4	**Conduct research into the impacts of introduced vertebrate fauna on the biodiversity of the LHIG and investigate control or eradication**	2	LHIG	100 000	LHIB, DECC, tertiary institutions
6.4.1	Investigate the degree of threat through competition and predation posed by introduced faunal species				
6.4.2	Investigate techniques and feasibility for control or eradication of introduced faunal species				
6.4.3	Implement control or eradication techniques where available, feasible and where there is a significant biodiversity benefit				
6.5	**Conduct research into the impacts of introduced invertebrate fauna and investigate techniques for control or eradication**	2	LHIG	100 000	
6.5.1	Investigate the threat posed by established introduced invertebrates through targeted monitoring sites and research				LHIB, Australian Museum
6.5.2	Investigate techniques and feasibility for control or eradication based on the level of threat				LHIB, Australian Museum, DPI

6.5.3	Implement control or eradication techniques where available, feasible and effective				LHIB
6.6	**Control introduced invertebrates in targeted locations**	2	LHI	50 000	
6.6.1	Investigate control methods for the *Arsipoda* beetle on *Calystegia affinis* site		Old Settlement		LHIB, Australian Museum, DPI
6.6.2	If control methods are found that are effective, undertake a control program		Old Settlement		LHIB
Objective 7: To reduce impacts of groundwater pollution				**50 000**	
7.1	**Protect water quality in freshwater creeks**		settlement area		
7.1.1	Develop a ground water management strategy	1	creeklines in Soldiers Creek basin		LHIB
7.1.2	Undertake water quality monitoring in streams, including monitoring of macroinvertebrates	4	settlement area		LHIB
Objective 8: To enhance positive interactions and reduce negative interactions between humans and wildlife				**30 000**	
8.1	**Enhance positive interactions through development of guidelines and public awareness**				
8.1.1	Ensure artificial feeding of fauna is undertaken in accordance with guidelines	1	LHIG		LHIB
8.1.2	Develop wildlife interaction guidelines for tour operators	1	LHIG		LHIB
8.1.3	Regularly review and revise Dog importation and management policies and traffic policies	2	LHIG		LHIB
8.1.4	Develop and implement a strategy for the control of non-native fauna	3	LHIG		LHIB
8.1.5	Produce and distribute a booklet on minimising negative human impacts on native fauna	2	LHIG		LHIB
Objective 9: To reduce the impact of commercial, cultural and illegal collecting				**30 000**	
9.1	**Minimise biodiversity impacts of commercial Kentia Palm seed collecting**	4	LHI		LHIB
9.2	**Control the illegal collection of fauna**				
9.2.1	Conduct a review of the LHI Act Regulations 2004	3	LHIG		LHIB
9.2.2	Raise awareness of the issue of illegal collection	2	LHIG, mainland		LHIB, DECC, Australian government

9.2.3	Ensure the LHIB has issued appropriate licences for persons undertaking invertebrate collections	1	LHIG		LHIB, DECC, AQIS, Biosecurity Australia
9.2.4	Restrict access to offshore islands outside the lagoon	2	LHIG		LHIB
9.2.5	Establish protocols to keep significant invertebrate localities secure	1	LHIG		LHIB
9.2.6	Ensure the LHI community is aware of the impacts and licensing requirements of seabird egg collection	1	LHIB		LHIB
Objective 10: To reduce human impacts				**20 000**	
10.1	**Protect vegetation in the vicinity of walking tracks and other areas**				
10.1.1	Promote awareness of the importance of staying on walking tracks	3	LHIG		LHIB
10.1.2	Establish and implement an appropriate hygiene protocol for access to the PPP	1	LHIG		LHIB, DECC
10.1.3	Ensure people accessing the PPP are aware of sensitive areas prior to field work commencing	1	LHIG		LHIB
10.1.4	Encourage tourists, residents, seed collectors, researchers and management staff to adopt minimal impact bushwalking practices	2	LHIG		LHIB
Objective 11: To monitor consequences of climate change and develop contingency plans for 'at risk' species				**200 000**	
11.1	**Monitor areas identified at risk from climate change**				
11.1.1	Establish biodiversity monitoring sites in as many "at risk" areas as possible	2			LHIB, tertiary institutions, DECC
11.1.2	Establish long-term monitoring sites of flora and fauna along an altitudinal gradient in the southern mountains	2			LHIB, tertiary institutions, DECC
11.1.3	Undertake research to monitor the impact of climate change on sea bird populations	4			LHIB, DECC, tertiary institutions
11.1.4	Develop and implement a monitoring program to assess the impacts of climate change on invertebrate lifecycles and 'at risk' flora	2			LHIB, DECC, Australian Museum, tertiary institutions.
11.1.5	Establish a climate monitoring station on Mt Gower	2			LHIB, DECC, tertiary institutions

11.2	**Investigate options for securing species identified as most at risk from climate change**	3			LHIB, tertiary institutions, zoological and herbarium institutions
Objective 12: To encourage the conservation and protection of species, populations and ecological communities				**10 000**	
12.1	**Prepare nominations for species, populations, ecological communities or critical habitat as required**				LHIB, DECC, tertiary institutions, Australian Museum
12.1.1	Nominate taxa and communities that are assessed as being threatened	4			
12.1.2	Where appropriate, potential nominations to be endorsed by the recovery team	4			
12.1.3	A list of significant taxa and communities to be maintained and regularly updated	3			
Objective 13: To promote recovery of individual threatened flora taxa				**200 000**	
13.1	**Protect habitat of threatened flora**	1			LHIB
13.1.1	Habitat of threatened flora must be protected from clearing		LHIG		
13.1.2	Habitat areas should be fenced where possible		settlement area		
13.2	**Undertake weed control in the habitat of threatened flora**				
13.2.1	*Calystegia affinis*	1	Old Settlement		LHIB, FOLHI
13.2.2	Knicker Nut	1	settlement area		LHIB, FOLHI
13.2.3	*Carmichaelia exsul*	2	southern mountains		LHIB
13.2.4	*Chamaesyce psammogeton*	1	settlement area		LHIB, FOLHI
13.2.5	*Coprosma inopinata*	4	southern mountains		LHIB
13.2.6	*Elymus multiflorus* var *kingianus*	1	Old Settlement		LHIB
13.2.7	*Polystichum moorei*	2	southern mountains		LHIB
13.3	**Undertake monitoring of, and targeted research into threatened and key endemic flora**	2	LHIG		LHIB, DECC
13.3.1	Develop a monitoring and targeted research program for threatened and key endemic flora				

13.3.2	Implement a threatened and key endemic flora monitoring program				
13.4	**Establish *ex-situ* populations of threatened and key endemic flora**	3	LHIG, mainland		LHIB, herbaria
13.4.1	Establish *ex-situ* populations or seedbanks for all threatened flora				
13.4.2	Investigate whether any endemic non-threatened species with small populations warrant *ex-situ* conservation				
13.5	**Reduce adverse human impacts on threatened flora and communities**				LHIB
13.5.1	*Calystegia affinis*	1	Old Settlement		
13.5.2	Knicker Nut	1	settlement area		
13.5.3	*Coprosma inopinata*	1	southern mountains		
13.5.4	Implement a strategy that minimises the risk of introduction of *Phytophthora cinnamomi* to threatened flora and community sites	2	LHIG		
13.6	**Promote public awareness of threatened plants and communities**	4	LHIG		LHIB
Objective 14: To improve knowledge and management of threatened and significant fauna species				**200 000**	
14.1	**Conduct priority fauna species research**	2	LHIG		LHIB, tertiary institutions, DECC
14.1.1	Conduct species-specific fauna research into the ecology of priority species				
14.1.2	Species distributions to be mapped, including point locality data				
14.1.3	Improve species habitat maps produced for this plan for input into GIS-based biodiversity forecasting analyses				
14.2	**Design and implement monitoring programs to evaluate effectiveness of recovery actions on listed threatened fauna**	2	LHIG		LHIB, DECC
14.2.1	Implement monitoring programs to measure the success or failure of recovery programs for threatened fauna				
14.2.2	Map changes to distribution or abundance in a form suitable for GIS analyses				

Objective 15: To protect and enhance threatened fauna habitat				**50 000**	
15.1	**Protect and enhance Flesh-footed Shearwater habitat**		Eastern settlement area		LHIB, DECC
15.1.1	Zone all mapped Flesh-footed Shearwater habitat as Environmental Protection or Significant Vegetation	1			
15.1.2	Rehabilitate Flesh-footed Shearwater nest habitat within grazing leases	2			
15.2	**Protect and enhance LHI Silvereye habitat**	3	settlement area		LHIB, DECC
15.3	**Protect and enhance the Lord Howe Island Wood-feeding Cockroach habitat**	1			
15.3.1	Revegetate and Control Rhodes Grass on Blackburn Island		Blackburn Island		LHIB, DECC
15.3.2	Monitor Admiralty Islands for introduced grasses		Admiralty Islands		LHIB, DECC
15.4	**Protect habitat of the White-bellied Storm-Petrel and Kermadec Petrel**	1	Balls Pyramid, Roach Island		LHIB, DECC
15.5	**Protect and enhance Red-tailed Tropicbird habitat**	4	Northern clifflines between North Head and Malabar and clifflines in southern mountains		LHIB, DECC
15.6	**Protect and enhance Little Shearwater habitat**	3	Muttonbird Point		LHIB, DECC
15.6.1	Control Kikuyu and reestablish the *Poa poiformis* Grassland Community on Muttonbird Point				
15.7	**Protect and enhance the habitat of Blackburn Island**	1	Blackburn Island		
Objective 16: To reduce impacts of fishing and marine debris on threatened sea birds				**30 000**	
16.1	**Reduce the amount of plastic bags in use on the LHIG**		LHIG and surrounding waters		
16.1.1	Encourage use of reusable and biodegradable bags	2			LHIB, tourism operators, island residents
16.1.2	Investigate LHI becoming plastic bag-free	4			LHIB
16.1.3	Develop guidelines with boat operators on the LHIG to prevent plastic bags being disposed in the ocean	3			LHIB, tourism operators
16.1.4	Undertake research to determine the impact of plastic ingestion by sea birds	4			LHIB, DECC, tertiary institutions

Objective 17: To undertake recovery actions for threatened fauna species identified in existing documents				**737 000**	
17.1	**Implement the Lord Howe Island Phasmid Interim recovery actions**			100 000	
17.1.1	Continue to restrict access to Balls Pyramid	1	Balls Pyramid		LHIB
17.1.2	Control Morning Glory	1	Balls Pyramid		LHIB, NRCMA
17.1.3	Monitor Balls Pyramid population	1	Balls Pyramid		LHIB, DECC
17.1.4	Maintain captive colonies	3	Off-island		Zoos, Insektus, DECC
17.1.5	Investigate availability of institutions with a capability of housing Phasmids	3	Off-island		Zoos, Insektus, DECC
17.1.6	Undertake research to improve husbandry	2	Off-island		Zoos, Insektus, DECC
17.1.7	Establish a live Phasmid display on LHI	4	LHI		DECC, LHIB
17.1.8	Develop techniques to reintroduce the Phasmid to LHI	4	LHI		DECC, LHIB, tertiary institutions
17.2	**Implement the Lord Howe Island Placostylus recovery actions**	**1, 2, 3**	LHI, Blackburn Island	158 000	LHIB, DECC, Australian government, NRCMA
17.3	**Implement recommended actions from the draft Gecko and Skink draft National Recovery Plan**		LHIG	199 000	
17.3.1	Survey for the LHI Gecko and LHI Skink	3	LHIG	5 000	LHIB, DECC, Australian government, NRCMA
17.3.2	Study the biology and ecology of at least one population	2	LHIG	190 000	LHIB, DECC, Australian government, tertiary institutions
17.3.3	Investigate the impact of the Grass Skink and Bleating Tree Frog on the LHI Skink and LHI Gecko	4		4 000	LHIB, Australian government, tertiary institutions
17.4	**Implement the LHI Woodhen Recovery Plan**	**1, 2, 3**	LHI	275 000	LHIB, DECC, Australian government, NRCMA
Objective 18: To investigate the appropriateness of reintroduction of locally extinct taxa				**50 000**	
18.1	**Adapt existing guidelines & protocols to be specific for the LHIG**	4	LHIG		LHIB
18.2	**Reestablish populations of species on the main island that still exist within the LHIG**				

18.2.1	Promote the reestablishment of White-bellied Storm-Petrel & Kermadec Petrel on the main island	3	LHI		LHIB, DECC, Environmental Trust
18.2.2	Reintroduce the LHI Phasmid to the main island	4	LHI		LHIB, DECC, Environmental Trust, tertiary institutions
18.3	**Reestablish populations of species lost from the LHIG**	4			LHIB, DECC, LHI Recovery Team, Environmental Trust, tertiary institutions
18.3.1	Investigate the appropriateness of reintroducing the Red-crowned Parakeet		LHIG		
18.3.2	Investigate the appropriateness of reintroducing closely allied subspecies of other birds		LHIG		
Objective 19: To coordinate implementation of the LHI BMP and regularly evaluate the biodiversity benefits of implementation				**60 000**	
19.1	**Coordinate the implementation of the BMP**	**1**	LHIG	10 000	DECC
19.1.1	Establish a BMP Implementation Group, chaired by a Plan coordinator				DECC
19.1.2	Review progress of all implementation programs on an annual basis and provide guidance on priorities				LHIB
19.1.3	Update mapping for the BMP on an annual basis				LHIB, DECC
19.1.4	Evaluate effectiveness of the implementation program and re-prioritise the program on an annual basis				LHIB
Total	**10 year cost of Recovery Program**			**9 351 500**	

7 Performance Criteria for Recovery Actions

Objective	Performance criteria	Timeframe from plan commencement
1: To prevent the introduction of exotic fauna, flora and pathogens to LHIG	1. The LHIB Quarantine Strategy and Plant Importation Policy is reviewed and fully implemented	Priority 1 actions within one year; Priority 3 actions within three years
	2. No exotic plants are imported that are assessed as posing a weed risk	Life of plan
	3. The LHI nursery is producing a larger range of indigenous plants for use by the LHI community at reasonable cost	Within two years
	4. A rapid response program to deal with new introductions of exotic fauna or flora has been developed and staff adequately trained	Within two years
2: To retain native vegetation	1. No clearing of significant remnant vegetation occurs on LHI	During life of Plan
	2. There is minimal clearing of native vegetation approved by the LHIB as part of development proposals	During life of Plan
	3. Funding has been secured and provided to leaseholders for significant vegetation protection projects	During life of Plan
	4. Leaseholders have fenced and commenced revegetation of native vegetation on their leases, particularly: • in areas of Sallywood Swamp Forest or Mangrove; • in the vicinity of the Soldiers Creek and Cobbys Creek basins, and the watercourses around Old Settlement Creek; • in areas of identified threatened fauna and flora habitat.	During life of Plan
3: To control the impacts of introduced pathogens on native species	1. Phytosanitary guidelines are produced for walkers	Within one year
	2. Strategy to control the spread of *Phytophthora cinnamomi* is implemented	Within two years
	3. A detailed survey of the spread of *P. cinnamomi* and native species 'at risk' is completed	Within five years
4: To eradicate (where feasible) and control existing weeds to reduce their impact on the biodiversity of the LHIG	1. Weed Management Strategy for Lord Howe Island is reviewed	Within six months; then every two years
	2. Weed Management Strategy for Lord Howe Island is implemented	Within six years
	3. Category 1, 2 and 3 weeds eradicated	Within three years
	4. Category 4 weeds eradicated	Within six years
	5. Ongoing searching for weeds undertaken	During life of Plan
	6. Weed inventory, mapping and monitoring work extended	Within five years

	7. Funding of incentive schemes investigated and funding secured	Within two years
	8. Weed community awareness program developed	Within two years
	9. Strategy for remote area weed control developed	Within one year
	10. Herbicide managed to minimise any adverse impacts	During life of Plan
	11. Research into weed control and biology undertaken	Within eight years
	12. Exotic grasses controlled or eradicated	Within five years
	13. Norfolk Island Pine control procedure supported and undertaken	During Life of Plan
	14. Weeds controlled in selected priority sites	Within two years
5: To undertake revegetation/rehabilitation works in high conservation priority areas	1. The LHI Vegetation Rehabilitation Plan is reviewed	Within one year
	2. The LHI Vegetation Rehabilitation Plan is implemented	Life of plan
	3. High conservation priority sites are revegetated and rehabilitated	Commenced within one year, ongoing during life of plan
	4. Best practise regeneration and rehabilitation principles used	Life of plan
	5. Monitoring program established and commenced for revegetation projects	Within one year
	6. Trampling, browsing and grazing controlled in high conservation priority sites	Within two years
	7. Vegetation of high conservation value buffered	Within five years
6: To eradicate or control introduced fauna and reduce their impact on biodiversity	1. Rodent control program continues and is reviewed to include additional biodiversity baiting sites	Within one year
	2. Rodents are eradicated if studies indicate this to be appropriate and feasible	Within five years
	3. Mallard-Black Duck hybrids are eradicated	Within three years
	4. Research is conducted into the impacts of introduced vertebrate fauna	Within ten years
	5. Research is conducted into the impacts of introduced invertebrate fauna	Within ten years
	6. Introduced invertebrates controlled at targeted locations	Within two years
7: To reduce impacts of groundwater pollution	1. Water quality is protected in freshwater creeks	Within two years
8: To enhance positive interactions and reduce negative interactions between humans and wildlife	1. Positive interactions between humans and wildlife are enhanced and negative interactions reduced	Within three years
9: To reduce the impact of commercial, cultural and illegal collecting	1. Impacts of commercial Kentia Palm seed collecting are minimised	Within five years
	2. Illegal collection of fauna is controlled	Within two years
10: To reduce human impacts.	1. Vegetation in the vicinity of walking tracks is protected	During life of plan

11: To monitor consequences of climate change and develop contingency plans for species at risk.	1. Monitoring is commenced for areas at risk from climate change 2. Options for securing species most at risk are identified and implemented	Within three years Within five years
12: To encourage the conservation and protection of significant species, populations and ecological communities.	1. Nominations for listing species, populations and ecological communities or critical habitat are prepared as required	During life of plan
13: To promote recovery of individual threatened flora taxa.	1. Habitat of threatened flora is protected 2. Weed control is undertaken within habitat of identified threatened flora 3. Monitoring programs are commenced for threatened and key endemic flora 4. *Ex-situ* collections of threatened and key endemic flora are established 5. Human impacts on threatened flora and communities are reduced 6. Public awareness of threatened plants and communities is promoted	During life of plan Within two years Within two years Within five years During life of plan Within three years
14: To improve knowledge and management of threatened and significant fauna.	1. Research on priority fauna species is commenced 2. Monitoring programs are designed and implemented to assess effectiveness of recovery actions	Within four years Within three years
15: To protect and enhance threatened fauna habitat.	1. Flesh-footed Shearwater habitat is protected and enhanced 2. LHI Silvereye habitat is protected and enhanced 3. LHI Cockroach habitat is protected and enhanced 4. Habitat of the White-bellied Storm Petrel and Kermadec Petrel is protected 5. Red-tailed Tropicbird habitat is protected and enhanced 6. Little Shearwater habitat is protected and enhanced. 7. Habitat on Blackburn Island is protected and enhanced	During life of plan During life of plan During life of plan During life of plan Within five years Within five years During life of plan
16: To reduce impacts of fishing and marine debris on threatened sea birds.	1. The use of plastic bags is measurably reduced 2. Amount of plastic bags and plastic debris recorded within sea bird carcasses on Lord Howe Island is measurably reduced	Within one year Within five years
17: To undertake recovery actions for threatened fauna species identified in existing documents.	1. The Lord Howe Island Phasmid interim recovery actions have been implemented 2. The Lord Howe Island Placostylus high priority recovery actions are implemented 3. The remaining recovery actions for the Lord Howe Island Placostylus are implemented 4. The Lord Howe Island Gecko and Lord Howe Island Skink high priority recovery actions are implemented	Within three years Within two years Within five years Within two years

	5. The remaining recovery actions for the Lord Howe Island Gecko and Lord Howe Island Skink are implemented	Within five years
	6. The Lord Howe Woodhen high priority recovery actions are implemented	Within two years
	7. The remaining recovery actions for the Lord Howe Woodhen are implemented	Within five years
18: To investigate the appropriateness of reintroduction of locally extinct fauna after rodents have been eradicated.	1. Guidelines for assessing reintroduction or translocation proposals are adapted for the LHIG	Within three years
	2. Populations of species that still exist within the LHIG are reintroduced to the main island	After rodent eradication is complete
	3. Investigations are undertaken and species reintroduced where appropriate	Within ten years
19: To regularly evaluate the biodiversity benefits from implementing the LHI BMP.	1. Mapping of implementation programs is regularly updated	Annually
	2. Mapping is used for input to appropriate biodiversity forecasting tools, and used to assist the review of recovery actions	Annually

8 Social and Economic Consequences

Producing a Biodiversity Management Plan for the LHIG provides an efficient use of resources, both in terms of plan preparation, and by efficient and effective prioritisation of recovery actions.

This plan meets the Recovery Plan requirements for 30 listed threatened species, negating the need to produce multiple individual species Recovery Plans. In addition 190 significant species are specifically addressed by this plan.

Addressing the overall biodiversity of Lord Howe Island, with a focus on significant species, as a holistic approach also enables potential future listings on threatened species schedules to be addressed, with a minimal amount of additional work needed to meet the Recovery Plan requirements of these species.

The total cost of implementing the recovery actions will be $9 351 500 over the ten-year period covered by this plan.

It is anticipated that there will be no significant adverse social or economic costs associated with the implementation of this Biodiversity Management Plan and that the overall benefits to society of implementation of the Biodiversity Management Plan will outweigh any specific costs.

8.1 Responsible parties

Most of the implementation of the actions in this plan are the responsibility of the LHIB, in conjunction with the DECC.

Other potential responsible parties include: the Commonwealth DEWR, the Australian Museum, AQIS, Biosecurity Australia, the Northern Rivers Catchment Management Authority (Lord Howe Island is within the Northern Rivers Catchment), Department of Primary Industries, Friends of Lord Howe Island, Coastcare, Worldwide Fund for Nature, Natural Heritage Trust, Environmental Trust, tertiary institutions, and Lord Howe Island leaseholders.

8.2 Implementation and costs

Table 18 outlines the implementation of recovery actions specified in this biodiversity management plan to relevant government agencies and/or parties for the period of ten years from publication.

8.3 Preparation details

This Recovery Plan has been prepared by Dianne Brown, Lynn Baker, Katrina McKay and Michael Murphy (DECC, North East Branch) in consultation with the Lord Howe Island recovery team and the LHIB. Contributions to species profiles were provided by Ian Hutton, Dean Hiscox, Dianne Brown, Michael Murphy and Sean Thompson.

8.4 Review date

This Recovery Plan will be reviewed within ten years of the date of its publication.

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10 Glossary of Terms

Biodiversity Forecasting Tool	GIS-based tool that allows analysis of multiple sources of biological and threat data to predict biodiversity persistence and outcomes dependant on management actions.
Biodiversity hot spots	Areas where species richness or endemicity is particularly high.
Biodiversity persistence index	Estimate of the probability of persistence of overall biodiversity over time, predicted using active threats.
Dissimilarity	Refers to communities or groups of species that are dissimilar, to each other, i.e. the greatest dissimilarity indicates communities or assemblages of species that are most unique.
Endemic	A species which occurs only on the Lord Howe Island Group.
Exotic species	Species not indigenous to the Lord Howe Island Group.
Extant species	Species that are not extinct.
Extinct species	Species that no longer exist.
Ex-situ	Collection and storage of living animal or plant material off site.
Habitat richness	The number of species habitats that display similar distributions. A high level of habitat richness is where a relatively high number of species habitats overlap.
Indigenous species	Species native to the Lord Howe Island Group prior to settlement.
Introduced species	Species not native to the Lord Howe Island Group prior to settlement.
Naturalised species	Non-indigenous species that are reproducing in the wild.
Species assemblage	A group of species that display similar distributions.
Species richness	The number of species that occur at any one location. Areas of high species richness are those where there are a relatively high number of species.
Vegetation community	A vegetation community refers to vegetation mapping by Pickard (1983), modified for this report by Hunter and Hutton.
Weed	A plant species that has naturalised in the wild.

11 Acronyms Used in this Document

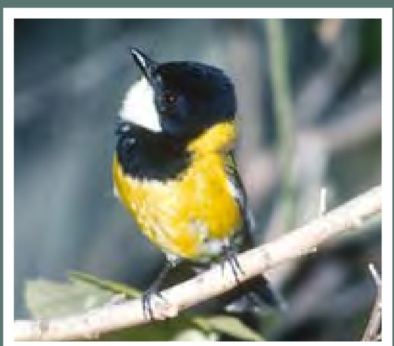
AQIS	Australian Quarantine Inspection Service
BFT	Biodiversity Forecasting Tool
CAA	Companion Animals Act 1998
DECC	NSW Department of Environment and Climate Change
DEWR	Commonwealth Department of Environment and Water Resources
DPI	Department of Primary Industries
EP&A Act	NSW *Environmental Planning and Assessment Act* 1979
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999
FOLHI	Friends of Lord Howe Island
GIS	Geographical Information Systems
GPS	Global Positioning System
KTP	Key Threatening Process (under the TSC Act or the EPBC Act)
LHI	Lord Howe Island
LHIB	Lord Howe Island Board
LHI BMP	Lord Howe Island Biodiversity Management Plan
LHIG	Refers to the Lord Howe Island Group, consisting of Lord Howe Island, Blackburn Island, Muttonbird Island, Gower Island, the Admiralty Islands and Balls Pyramid.
NPW Act	NSW *National Parks and Wildlife Act* 1974
NPWS	NSW National Parks and Wildlife Service
NRCMA	Northern Rivers Catchment Management Authority
PPP	Permanent Park Preserve
REP	Regional Environment Plan
SIS	Species Impact Statement
TSC Act	NSW *Threatened Species Conservation Act* 1995
WWF	Worldwide Fund for Nature

Department of **Environment & Climate Change** NSW

APPENDICES

LORD HOWE ISLAND

BIODIVERSITY MANAGEMENT PLAN



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Cover photography:

Masked Booby (*Sula dactylatra*)
Photo: Ian Hutton

Lord Howe Island Golden Whistler (*Pachycephala pectoralis contempa*) Photo: Ian Hutton

Lord Howe Island Southern Gecko (*Christinus guentheri*) Photo: Ian Hutton

Knicker Nut (*Caesalpinia bonduc*) Photo: Ian Hutton

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Introduction

The Lord Howe Island Biodiversity Management Plan constitutes the formal National and NSW Recovery Plan for threatened species and communities of the Lord Howe Island Group and, as such, considers the conservation requirements of these species within the Group. It also addresses significant species and communities so as to manage the Lord Howe Island Group's biodiversity in a holistic and cost-effective manner. This plan identifies the actions to be taken to ensure the long-term viability of the threatened species and communities of the Lord Howe Island Group in nature and the parties who will undertake these actions.

The Lord Howe Island Biodiversity Management Plan is presented in two documents. The first document consists of the main body of the plan, this document contains the appendices that accompany the main plan.

Contents

Figures

Appendix 1 Species list for Lord Howe Island Group

1.1 Vascular Flora

LHI=LHI endemic; ^= LHI native (occurring on LHI pre-settlement) but not endemic; *=naturalised exotic (reproducing in the wild on LHI); $^{<}$ = possibly extinct, but not listed on either the TS C Act or EPBC Act as extinct; - not covered by Biodiversity Management Plan (non-terrestrial sea grasses). E = Endangered; CE = Critically Endangered. Taxonomy follows Flora of Australia (1994) unless more recent revision available.

Origin	Scientific Name	Common Name	TSC	EPBC	Priority
^	*Achyranthes aspera*				
*	*Acokanthera oblongifolia*	Septic Tree			
*	*Actites megalocarpa*				
^	*Adiantum aethiopicum*	Maidenhair Fern			
^	*Adiantum aldroviride*	A Maidenhair Fern			
^	*Adiantum hispidulum*	Rough Maidenhair Fern			
^	*Adiantum pubescens*	A Maidenhair Fern			
^	*Aegicerus corniculatum*	River Mangrove			
*	*Agapanthus praecox* ssp. *Orientalis*	Agapanthus			
*	*Agave americana*	Century Plant			
*	*Ageratina adenophora*	Croton Weed			
*	*Ageratum conyzoides*	Billy-goat Weed			
^	*Agrostis aemula*				
*	*Agrostis gigantea*	Red-top Bent			
*	*Aloe arborescens*				
*	*Aloe ciliaris*	Aloe			
*	*Aloe maculata*	Aloe			
*	*Alstroemeria pulchella*	Christmas Lily			
*	*Alternanthera bettzichiana*				
LHI	*Alyxia lindii*				✓
^	*Alyxia ruscifolia*	Prickly Alyxia			
LHI	*Alyxia squamulosa*				✓
*	*Amaranthus blitum*	Amaranth			
*	*Anagallis arvensis*	Scarlet Pimpernel			
*	*Andredera cordifolia*	Madeira Vine			
*	*Apium graveolens*	Celery			
LHI	*Apium prostratum* ssp. *howense*	Sea Celery			✓
^	*Arachniodes aristata*				

*	*Araucaria heterophylla*	Norfolk Island Pine			
*	*Araujia hortum*	Moth Vine			
*	*Arenaria serpyllifolia*	Thyme-leaved Sandwort			
^	*Arthropteris tenella*	Climbing Fishbone Fern			
*	*Arundinaria simonii* f. *variegata*	Bamboo			
*	*Arundo donax*	Giant Reed			
*	*Asclepias curassavica*	Swan Plant			
*	*Asparagus aethiopicus*	Ground Asparagus			
*	*Asparagus asparagoides*	Bridal Creeper			
*	*Asparagus plumosus*	Climbing Asparagus			
^	*Asplenium australasicum* f. *australasicum*	Bird's Nest Fern			
LHI	*Asplenium goudeyi*				▯
LHI	*Asplenium milnei*				▯
^	*Asplenium polyodon*	Sickle Spleenwort			
LHI	*Asplenium pteridoides*				▯
LHI	*Asplenium surrogatum*				▯
	Aster subulatus	Wild Aster			
LHI	*Atractocarpus stipularis*	Green Plum			▯
*	*Atriplex australasica*				
^	*Atriplex cinerea*	Grey Saltbush			
*	*Atriplex prostrata*				
*	*Avena barbata*	Bearded Oat			
*	*Avena byzantina*				
^	*Avicennia marina* v. *australasica*	Grey Mangrove			
*	*Axonopus compressus*	Grass			
^	*Baloghia inophylla*	Brush Bloodwood			
^	*Baumea juncea*	Bare Twig-rush			
*	*Bidens pilosa*	Farmer's Friend			
*	*Billbergia pyramidalis*				
LHI	*Blechnum contiguum*				▯
LHI	*Blechnum fullagarii*				▯
LHI	*Blechnum geniculatum*				▯
LHI	*Blechnum howeanum*				▯
^	*Blechnum patersonii*	Strap Water Fern			
LHI	*Boehmeria calophleba*				▯
^	*Boerhavia tetrandra*				
^	*Botrychium australe*	Parsley Fern			
*	*Brachychiton acerifolius*	Flame Tree			
LHI	*Brachyscome segmentosa*				▯
*	*Briza maxima*	Giant Shivery Grass			
*	*Briza minor*	Small Shivery Grass			

*	*Bromus catharticus*	Prairie Grass			
*	*Bromus diandrus*	Great Brome			
*	*Bromus hordeaceus*	A Soft Brome			
*	*Bromus molliformis*	A Soft Brome			
*	*Bryophyllum pinnatum*	Mother of Millions			
*	*Buddleja madagascariensis*	Buddleja			
^	*Bulbophyllum argyropus*				
^	*Bulbostylis densa*				
^	*Caesalpinia bonduc*	Knicker Nut	E		□
*	*Cakile edentula*	American Sea Rocket			
^	*Calanthe triplicata*	Christmas Orchid			
*	*Callisia fragrans*				
LHI	*Calystegia affinis*		E	CE	□
^	*Calystegia soldanella*				
^	*Canavalia rosea*	Coastal Jack Bean			
*	*Canna* x *generalis*	Canna Lily			
*	*Capsella bursa-pastoris*	Shepherd's Purse			
*	*Cardamine hirsuta*				
^	*Carex breviculmis*				
^	*Carex brunnea*				
^	*Carex inversa*				
^	*Carex pumila*				
LHI	*Carmichaelia exsul*		E		□
^	*Carpobrotus glaucescens*				
LHI	*Cassinia tenuifolia*	Bully Bush			□
*	*Casuarina glauca*	Swamp Oak			
*	*Catapodium rigidum*	Rigid Fescue			
*	*Catharanthus roseus*	Madagascar Periwinkle			
LHI	*Celtis conferta* ssp. *amblyphylla*	Cotton Wood			□
*	*Centaurea melitensis*	Maltese Cockspur			
*	*Centaurium tenuiflorum*	Centaury			
*	*Centella asiatica*	Pennywort			
*	*Centranthus ruber*	Red Valerian			
^	*Cephalomanes atrovirens*				
LHI	*Cephalomanes bauerianum*				□
*	*Cerastium fontanum* ssp. *vulgare*	Chickweed			
*	*Cerastium glomeratum*	Chickweed			
*	*Cestrum nocturnum*	Lady of the Night			
*	*Chamaesyce hyssopifolia*				
*	*Chamaesyce prostrata*	Red Caustic Weed			
^	*Chamaesyce psammogeton*		E		□

^	*Cheilanthes distans*	Bristly Cloak Fern			
^	*Cheilanthes sieberi*				
*	*Chenopodium album*	Fat Hen			
*	*Chenopodium murale*	Nettle-leaf Goosfoot			
LHI	*Chionanthus quadristamineus*	Blue Plum			□
LHI	*Chionochloa howensis*				□
*	*Chloris gayana*	Rhodes Grass			
*	*Chloris truncata*	Windmill Grass			
*	*Chlorophytum comosum*	Spider Plant			
^	*Christella dentata*				
*	*Chrysanthemoides monilifera* ssp. *Rotundata*	Bitou Bush			
*	*Ciclospermum leptophyllum*	Carrot Weed			
*	*Cirsium vulgare*	Spear Thistle			
*	*Citrus jambhiri*	Bush Lemon			
^	*Clematis glycinoides*	Headache Vine			
*	*Coffea arabica*	Coffee			
^	*Commelina cyanea*	Blue Wandering Jew			
*	*Conyza bonariensis*	Fleabane			
*	*Conyza parva*				
*	*Conyza sumatrensis*				
LHI	*Coprosma huttoniana*				□
LHI	*Coprosma inopinata*		E		□
LHI	*Coprosma lanceolaris*				□
LHI	*Coprosma prisca*	Goatwood			□
LHI	*Coprosma putida*	Stinkwood			□
LHI	*Coprosma* sp. nov				□
LHI	*Corokia carpodetoides*				□
*	*Coronopus didymus*	Swinecress			
*	*Cortaderia selloana*	Pink Pampass Grass			
^	*Corybas barbarae*	Helmet Orchid			
*	*Cotoneaster glaucophyllus*	Cotoneaster			
^	*Cotula australis*	Carrot Weed			
*	*Crassula aborescens* ssp. *Arborescens*				
^	*Crassula sieberiana*				
^	*Crinum asiaticum* var. *pedunculatum*	Crinum Lily			
*	*Crocosmia* x *crocosmiiflora*	Montbretia			
LHI	*Cryptocarya gregsonii*	Blackbutt			□
^	*Cryptocarya triplinervis*	Blackbutt			
LHI	*Cyathea brevipinna*				□
LHI	*Cyathea howeana*				□
LHI	*Cyathea macarthurii*				□

LHI	*Cyathea robusta*				□
*	*Cynodon dactylon*	Couch Grass			
*	*Cyperus eragrostis*	Umbrella Sedge			
*	*Cyperus involucratus*				
^	*Cyperus lucidus*	Leafy Flat Sedge			
*	*Cyperus rotundus*	Nut Grass			
*	*Dactylis glomerata*	Cocksfoot			
*	*Datura stramonium*	Thornapple			
*	*Delairea odorata*	Cape Ivy			
LHI	*Dendrobium macropus* ssp. *howeanum*				□
LHI	*Dendrobium moorei*				□
^	*Dianella intermedia*				
^	*Dichelachne crinita*				
*	*Dietes grandiflora*				
LHI	*Dietes robinsoniana*	Wedding Lily			□
*	*Digitaria ciliaris*	Summer Grass			
*	*Digitaria sanguinalis*	Crab Grass			
*	*Digitaria violescens*				
LHI	*Diplazium melanochlamys*				□
^	*Dodonaea viscosa* ssp. *burmanniana*	Hop Bush			
^	*Doodia aspera*				
^	*Doodia caudata*	Small Rasp Fern			
^	*Doodia media*				
LHI	*Dracophyllum fitzgeraldii*	Fitzgeraldii			□
LHI	*Drypetes deplanchei* ssp. *affinis*	Greybark			□
*	*Duchesnea indica*	Wild Strawberry			
LHI	*Dysoxylum pachyphyllum*	Island Apple			□
*	*Echinochloa crusgalli*	Barnyard Grass			
*	*Echinopogon caespitosus* var. *caespitosus*				
^	*Echinopogon ovatus*				
*	*Ehrharta erecta*				
LHI	*Elaeocarpus costatus*				□
^	*Elaeodendron curtipendulum*	Tamana			
LHI	*Elatostema grande*				□
*	*Eleusine indica*	Crab Grass			
^	*Elymus multiflorus* var. *kingianus*			CE	
*	*Elymus scaber*	Wheat Grass			
^	*Epilobium billardiereanum* ssp. *cinereum*				
*	*Eragrostis cilianensis*	Stink Grass			
*	*Eragrostis tenuifolia*	Elastic Grass			
*	*Eranthemum pulchellum*	Lilac Flower			

*	*Eriobotrya japonica*	Loquat			
*	*Eucalyptus siderophloia*	Grey Ironbark			
^	*Euchiton involucratus*				
*	*Eugenia uniflora*	Brazilian Cherry			
*	*Euphorbia cyathophora*				
*	*Euphorbia paralias*	Sea Spurge			
*	*Euphorbia peplus*	Petty Spurge			
*	*Euphorbia prostrata*				
^	*Euphorbia psammogeton*				
LHI	*Exocarpus homalocladus*				□
LHI	*Ficus macrophylla* ssp. *columnaris*	Banyan			□
^	*Flagellaria indica*	Whip Vine			
*	*Fumaria bastardii*	Bastard's Fumitory			
*	*Fumaria muralis*	Wall Fumitory			
*	*Furcraea foetida*				
LHI	*Gahnia howeana*				□
^	*Gahnia xanthocarpa*				
*	*Gaillardia x grandiflora*	Daisy			
*	*Galinsoga parviflora*	Potato Weed			
*	*Gamochaeta purpurea*				
^	*Geitonoplesium cymosum*	Scrambling Lily			
LHI	*Geniostoma huttonii*		E		□
LHI	*Geniostoma petiolosum*				□
*	*Geranium molle*	Cranesbill Geranium			
*	*Gladiolus x hortulanus*	Gladioli			
*	*Gloriosa superba*	Glory Lily			
LHI	*Gonocarpus* sp				□
LHI	Gonocarpus teucrioides				
LHI	*Grammitis diminuta*				□
LHI	*Grammitis nudicarpa*				□
LHI	*Grammitis watsii*				□
*	*Grevillea robusta*	Silky Oak			
LHI	*Guoia coriacea*	Island Cedar			□
*	*Gynura aurantiaca*				
^ -	*Halophila ovalis*	Sea Grass			
*	*Harpephyllum caffrum*	Kaffir Plum			
*	*Hedera helix*	English Ivy			
LHI	*Hedyscepe canterburyana*	Big Mountain Palm			□
*	*Hedychium* sp.	Ornamental Ginger			
^	*Hibiscus diversifolius*				
*	*Hibiscus mutabilis*	Hibiscus			

^	*Hibiscus tiliaceous*	Cottonwood Hibiscus			
*	*Hippeastrum puniceum*	Hippeastrum			
^	*Histiopteris incisa*				
^	*Homolanthus populifolius* (syn. *Omalanthus popularifolius*)	Bleeding Heart			
*	*Hordeum murinum* ssp. *glaucum*	Hedgehog Grass			
*	*Hordeum murinum* ssp. *leporinum*	Barley Grass			
LHI	*Howea belmoreana*	Curly Palm			□
LHI	*Howea forsteriana*	Kentia Palm			□
^	*Huperzia varia*				
*	*Hydrocotyle bonariensis*	Beach Pennywort			
^	*Hydrocotyle hirta*	Pennywort			
LHI	*Hymenophyllum howense*				□
LHI	*Hymenophyllum moorei*				□
*	*Hypochaeris radicata*	Flatweed			
^	*Hypolepis elegans*				
^	*Hypolepis tenuifolia*				
*	*Imperata cylindrica* var. *major*	Blady Grass			
*	*Ipomoea alba*	Moonflower			
*	*Ipomoea cairica*	Five-leaf Morning Glory			
*	*Ipomoea indica*	Blue Morning Glory			
^	*Ipomoea pes-caprae* ssp. *brasiliensis*	Beach Bean			
^	*Isolepis nodosa*				
^	*Jasminium didymum* ssp. *didymum*				
^	*Jasminium simplicifolium* ssp. *australiense*				
*	*Juncus aridicola*				
*	*Juncus bufonius*				
*	*Juncus pallidus*				
*	*Justica carnea*	Pink Spider Shrub			
LHI	*Korthalsella emersa*				□
^	*Korthalsella rubra* ssp. *rubra*				
*	*Kyllinga brevifolia*				
*	*Lactuca saligna*	Wild Lettuce			
^	*Lagunaria patersonia* ssp. *patersonia*	Sallywood			
*	*Lagurus ovatus*	Hare's Tail Grass			
*	*Lamium amplexicaule*	Dead Nettle			
*	*Lantana camara*	Lantana			
LHI	*Lastreopsis nephrodioides*				□
*	*Lathyrus latifolius*	Sweet Pea			
*	*Lepidium africanum*				
*	*Lepidium bonariense*	Peppercress			

LHI	*Lepidium howei-insulae*				□
LHI	*Lepidium nesophilum*				□
LHI	*Lepidorrhachis mooreana*	Little Mountain Palm			□
LHI	*Leptopteris moorei*				□
LHI	*Leptospermum polygalifolium* ssp. *howense*	Tea Tree			□
^	*Lepturus repens*				
*	*Leucanthemum* x *superbum*	Shasta Daisy			
^	*Leucopogon parviflorus*				
*	*Ligustrum sinense*	Small-leaved Privet			
*	*Lilium formosanum*	Tiger Lily			
^	*Lobelia alata*				
^	*Lobelia anceps*				
*	*Lobularia maritima*	Sweet Alyssum			
*	*Lolium perenne*	Rye Grass			
*	*Lolium rigidum* var. *rigidum*	Rigid Rye Grass			
*	*Lolium rigidum* var. *rottboelliodes*				
LHI	*Lordhowea insularis*				□
LHI	*Luzula longiflora*				□
*	*Lycium ferocissimum*	African Boxthorn			
*	*Lycopersicum esculentum*	Cherry Tomato			
*	*Lythrum hyssopifolia*				
LHI	*Machaerina insularis*				□
^	*Macropiper excelsum* ssp. *psittacorum* (syn. *Piper excelsum)*	Kava			
LHI	*Macropiper hooglandii*	Kava			□
*	*Macroptilium atropurpureum*	Siratro			
*	*Malva parviflora*	Mallow			
*	*Malvastrum coromandelianum*				
LHI	*Marattia howeana*				□
^	*Marsdenia rostrata*	Common Milk Vine			
LHI	*Marsdenia tubulosa*<				□
*	*Medicago lupulina*	Black Medic			
*	*Medicago polymorpha*	Burr Medic			
LHI	*Melaleuca howeana*	Tea Tree			□
*	*Melia azedarach* var. *australasica*	White Cedar			
LHI	*Melicope contermina*				□
LHI	*Melicope polybotrya*				□
LHI	*Melicytus novae-zelandieae* ssp. *centurionis*				□
*	*Melilotus indicus*	King Island Melilot			
*	*Melinis minutiflora*	Molasses Grass			
*	*Mentha spicata*	Spearmint			

*	*Metrosideros kermadecensis*	Christmas Bush			
LHI	*Metrosideros nervulosa*	Mountain Rose			□
LHI	*Metrosideros sclerocarpa*	Mountain Rose			□
^	*Microlaena stipoides*				
^	*Microtis unifolia*				
*	*Mirabilis jalapa*	Marvel of Peru			
*	*Modiola caroliniana*	Red-flower Mallow			
*	*Morus alba*	Mulberry			
^	*Mucuna gigantea*	Burny Bean			
^	*Muehlenbeckia complexa*				
^	*Myoporum insulare*	Boobialla			
LHI	*Negria rhabdothamnoides*	Pumpkin Tree			□
*	*Nephrolepis biserrata*	Giant Fishbone			
^	*Nephrolepis cordifolia*	Fishbone Fern			
^	*Nicotiana forsteri*				
*	*Nothoscordum borbonicum*	Wild Onion			
*	*Ochna serrulata*	Mickey Mouse Plant			
^	*Ochrosia elliptica*				
*	*Odontonema tubaeforme*	Red Tube Flower Shrub			
*	*Oenothera drummondii*	Evening Primrose			
*	*Oenothera stricta* ssp. *stricta*				
^	*Olea paniculata*	Native Olive			
LHI	*Olearia ballii*	Mountain Daisy			□
LHI	*Olearia elliptica* ssp. *praetermissa*				□
LHI	*Olearia mooneyi*	Pumpkin Bush			□
*	*Onopordum acanthium*				
^	*Ophioglossum coriaceum*				
^	*Ophioglossum pendulum*	Ribbon Fern			
^	*Ophioglossum petiolatum*				
^	*Ophioglossum reticulatum*				
^	*Oplismenus hirtellus* (syn. *O. imbecillus*)	Creeping Beard Grass			
^	*Oxalis corniculata*				
*	*Oxalis debilis*	Large-leaved Wood Sorrel			
LHI	*Pandanus forsteri*	Forked Tree			□
^	*Pandorea pandorana* ssp. *austrocaledonia*				
*	*Papaver rhoeas*	Poppy			
*	*Papaver somniferum*	Opium Poppy			
^	*Parietaria debilis*				
*	*Parietaria judaica*				
LHI	*Parsonsia howeana*				□
*	*Paspalum dilatatum*	Paspalum			

^	*Paspalum distichum*	Water Couch			
*	*Paspalum mandiocanum*				
*	*Paspalum urvillei*				
^	*Paspalum vaginatum*<				
*	*Paspalum wettsteinii*	Broad-leaved Paspalum			
*	*Passiflora edulis*	Black Passionfruit			
LHI	*Passiflora herbertiana* ssp. *insulae-howei*				□
*	*Pelargonium australe*	Pelargonium			
^	*Pellaea falcata*	Sickle Fern			
^	*Pellaea paradoxa*	Sickle Fern			
*	*Pennisetum clandestinum*	Kikuyu			
*	*Pennisetum purpureum*	Elephant Grass			
^	*Peperomia tetraphylla*	Four-leaved Pepper Plant			
^	*Peperomia urvilleana*				
*	*Petunia x hybrida*	Petunia			
*	*Phalaris aquatica*	Phalaris			
*	*Phalaris canariensis*	Canary Grass			
*	*Phanerophlebia falcata*	Holly Fern			
^	*Phragmites australis*	Common Reed			
*	*Phragmites karka*				
*	*Phyllanthus tenellus*	Hen and Chickens			
*	*Phylostachys* spp.	Rhizomatous Bamboo			
LHI	*Phymatosorus pustulatus* ssp. *howensis*				□
^	*Phymatosorus pustulatus* ssp. *pustulatus*				
^	*Phymatosorus scandens* (syn. *Microsorum scandens*)				
*	*Physalis ixocarpa*				
*	*Physalis peruviana*	Cape Gooseberry			
LHI	*Pimelea congesta*				□
^	*Pisonia brunoniana*	Punkwood			
*	*Pistacia chinensis*	Pistacio			
LHI	*Pittosporum erioloma*				□
*	*Pittosporum undulatum*	Sweet Pittosporum			
LHI	*Plantago hedleyi*				□
*	*Plantago lanceolata*	Plantain			
*	*Plantago major*	Large Plantain			
^	*Platycerium bifurcatum*	Elkhorn			
LHI	*Plectorrhiza erecta*				□
^	*Plectranthus graveolens*				
*	*Poa annua*	Winter Grass			
^	*Poa poiformis*				

*	*Polycarpon tetraphyllum*	Four-leaf Allseed			
*	*Polypogon monspeliensis*	Annual Beard Grass			
^	*Polyscias cissodendron*	Island Pine			
LHI	*Polystichum moorei*		E		□
LHI	*Polystichum whiteleggei*				□
*	*Portulaca oleracea*	Portulaca			
^	*Pouteria myrsinoides* ssp. *reticulata*	Axe-handle Wood			□
*	*Pratia purpurascens*	White Root			
*	*Prunella vulgaris*	Self-heal			
*	*Prunus persica*	Peach			
^	*Pseudognaphalium luteoalbum*				
*	*Psidium cattlianum* var. *cattleianum*	Cherry Guava			
*	*Psidium guajava*	Guava			
^	*Psilotum nudum*	Skeleton Fork Fern			
LHI	*Psychotria carronis*	Black Grape			□
LHI	*Pteris microptera*				□
^	*Pteris tremula*	Tender Bracken			
^	*Pterostylis curta*				
^	*Pterostylus obtusa*				
^	*Pterostylus pedunculata*				
*	*Punica granatum*	Pomegranate			
*	*Pycreus polystachyos*				
^	*Pyrrosia confluens*	Horshoe Felt Fern			
^	*Pyrrosia rupestris*	Rock Felt Fern			
*	*Ranunculus parviflorus*	Buttercup			
*	*Ranunculus sessiliflorus*	Buttercup			
LHI	*Rapanea mccomishii*				□
LHI	*Rapanea myrtillina*				□
LHI	*Rapanea platystigma*				□
*	*Richardia stellaris*				
*	*Ricinus communis*	Castor Oil Plant			
*	*Roldana petasitis*				
*	*Romulea rosea* var. *australis*	Onion Grass			
*	*Rostraria cristata*	Annual Catstail			
*	*Rottboellia coelorachis*				
*	*Rumex brownii*	Swamp Dock			
*	*Rumex crispus*	Curled Dock			
^	*Rytidosperma racemosum*				
^	*Rytidosperma unarede*				□
*	*Sagina apetala*	Pearlwort			
*	*Salvia coccinea*	Texas Sage			

*	*Sanseviera trifasciata*	Mother-in-law's Tongue			
^	*Sarcocornia quinqueflora* ssp. *quinqueflora*				
^	*Sarcomelicope simplicifolia* ssp. *simplicifolia*	Bauerella			
^	*Scaevola calendulacea*				
LHI	*Scaevola taccada*				✓
*	*Schefflera actinophylla*	Umbrella Tree			
*	*Senecio elegans*	Purple Groundsel			
LHI	*Senecio hooglandii*				
LHI	*Senecio howeanus*				✓
LHI	*Senecio pauciradiatus*				✓
*	*Senecio vulgaris*	Common Groundsel			
*	*Senna pendula* var. *glabrata*	Winter Senna			
*	*Senna septemtrionalis*	Brazilian Buttercup			
^	*Sesuvium portulacastrum*				
*	*Setaria gracilis*				
*	*Setaria palmifolia*	Palm Grass			
*	*Setaria verticillata*	Whorled Pigeon Grass			
*	*Sherardia avensis*				
^	*Sicyos australis*	Native Cucumber			
*	*Sida rhombifolia*	Paddy's Lucerne			
*	*Silene gallica*	Catchfly			
*	*Silybum marianum*	Variegated Thistle			
*	*Sisymbrium officinale*				
*	*Sisyrinchium micranthum*	Scour Weed			
^	*Smilax australis*	Native Sarsparilla			
*	*Solanum americanum* ssp. *nigrans*				
*	*Solanum americanum* ssp. *nutans*	Blackcurrant			
^	*Solanum aviculare*				
^	*Solanum bauerianum*<				✓
*	*Solanum mauritianum*	Tobacco Bush			
*	*Solanum nigrum*	Nightshade			
*	*Solidago canadensis*				
*	*Sonchus asper* ssp. *glaucescens*	Prickly Sowthistle			
*	*Sonchus megalocarpus*	Dune Thistle			
*	*Sonchus oleraceus*	Milk Thistle			
LHI	*Sophora howinsula*	Lignum Vitae			✓
*	*Sphagneticola trilobata*	Singapore Daisy			
^	*Spinifex sericeus*	Spinifex			
*	*Sporobolus africanus*	Parramatta Grass			
^	*Sporobolus virginicus*	Sonchus			
*	*Stachys arvensis*	Stagger Weed			

*	*Stellaria media*	Chickweed			
*	*Stenotaphrum secundatum*	Buffalo Grass			
LHI	*Stephania japonica* var *timoriensis*				□
^	*Sticherus lobatus*	Spreading Shield Fern			
*	*Stipa ramosissima*	Bamboo Grass			
LHI	*Symplocos candelabrum*				□
LHI	*Syzygium fullargarii* (syn. *Cleistocalyx fullargarii*)	Scalybark			□
*	*Taraxacum officinale*	Dandelion			
LHI	*Tetragonia implexicoma*[<]				□
^	*Tetragonia tetragonioides*	New Zealand Spinach			
*	*Tetrapanax papyrifer*	Rice Paper Plant			
^	*Tmesipteris truncata*				
*	*Torilis nodosa*				
*	*Tradescantia fluminensis*	Wandering Jew			
*	*Tradescantia spathacea*				
*	*Tradescantia zebrina*	Striped Wandering Jew			
*	*Trifolium dubium*	Clover			
*	*Trifolium glomeratum*	Clustered Clover			
*	*Trifolium repens*	Dutch Clover			
*	*Trifolium subterraneum*	Subterranean Clover			
^	*Triglochin striata*				
*	*Tropaeolum majus*	Nasturtium			
LHI	*Trophis scandens* ssp. *megacarpa*				□
^	*Tylophora biglandulosa*				
^	*Typha domingensis*	Cumbungi			
LHI	*Uncinia debilior*				□
*	*Urtica urens*	Stinging Nettle			
*	*Verbascum virgatum*	Mullein			
*	*Verbena bonariensis*	Purple Verbena			
*	*Verbena brasiliensis*	Purple Top			
*	*Veronica arvensis*	Wall Speedwell			
*	*Veronica persica*				
*	*Vicia sativa* ssp. *angustifolia*				
*	*Vicia sativa* ssp. *nigra*	Common Vetch			
^	*Vigna marina*				
*	*Vinca major*	Periwinkle			
*	*Vulpia bromoides*				
*	*Vulpia myuros*				
^	*Wahlenbergia gracilis*				
LHI	*Wahlenbergia insulae-howei*				□

^	*Westringia fruticosa*				
LHI	*Westringia viminalis*				
^	*Wollastonia biflora* (syn. *Melanthera biflora*)				
LHI	*Xylosma maidenii*				
LHI	*Xylosma parvifolium*		E		
*	*Yucca aloifolia*	Yucca			
*	*Zantedeschia aethiopica*	Arum Lily			
^	*Zanthoxylum pinnata*	Yellow Wood			
^ -	*Zostera capricorni*	Sea Grass			
LHI	*Zygogynum howeanum* (syn. *Bubbia howeanum*)	Hotbark			

1.2 Vegetation communities recognised in LHI Biodiversity Management Plan

Terrestrial Communities	Mapping (Pickard 1983 map unit, and any futher derivation)
Closed Forest Communities	
Chionanthus quadristamineus Closed Forest	Cq
Cryptocarya gregsonii Closed Forest	Cg
Drypetes deplanchei-Cryptocarya triplinervis Closed Forest on calcarenite/coral sand	DaCt on calcarenite/coral sand
Drypetes deplanchei-Cryptocarya triplinervis Closed Forest on basalt	DaCt on volcanics
Drypetes deplanchei-Cryptocary triplinervis Low Closed Forest on exposed calcarenite	DaCtC
Drypetes deplanchei-Cryptocarya triplinervis Low Closed Forest on exposed basalt	DaCtX
Hedyscepe canterburyana Closed Sclerophyll Forest	Hc
Howea belmoreana Closed Sclerophyll Forest	Hb
Howea forsteriana Closed Sclerophyll Forest on calcarenite/coral sand	Hf on calcarenite/coral sands
Howea forsteriana Closed Sclerophyll Forest on basalt	Hf on volcanics
Lagunaria patersonia Closed Swamp Forest	Lp
Lowland Mixed Closed Forest	LMF
Pandanus forsteri Closed Sclerophyll Forest	Pf
Syzygium fullagarii Closed Forest	Cf
Zygogynum howeanum-Dracophyllum fitzgeraldii Gnarled Mossy Closed Forest	BhDf
Closed Scrub Communities	
Aegiceras corniculatum Closed Swamp Scrub	Ac
Boehmeria calophleba-Macropiper hooglandii Closed Scrub	BcMep
Cassinia tenuifolia Closed Scrub	Ca
Dodonaea viscosa Closed Scrub	Dv
Dracophyllum fitzgeraldii-Metrosideros nervulosa Closed Scrub	unit DfMn
Melaleuca howeana Closed Scrub	Mh
Dwarf Scrub Communities	
Alyxia squamulosa-Coprosma inopinata Dwarf Scrub	I. Hutton
Atriplex cinera Dwarf Scrub	Ax
Open Scrub Communities	
Avicennia marina v. *australasica* Open Swamp Scrub	Ama
Herb Communities	
Ipomoea cairica-Carpobrotus glaucescens* Herbfield	IcCg
Mixed Fern and Herb	MFH
Grass Communities	
Cyperus lucidus Sedgeland	Cl

Poa poiformis Grassland	Pp
Specialised Landform Communities	
Basalt Boulder Beach	
Calcarenite and Coral Boulder Beach	
Cliff	
Coral Sand Beach and Dune	
Waterfall Cliff	I. Hutton.
Disturbed Areas	
Cleared land/non-native vegetation/buildings	Updated by Hunter (2002)
Aquatic Communities	
Lowland Freshwater Instream Community	Drainage lines 2nd order and below on calcarenite/coral sands. Excluding mapped *Lagunaria patersonia* community
Upland Freshwater Instream Community	Drainage lines 2nd order and below found on volcanics

1.3 Vertebrate fauna and threatened invertebrate fauna.

E = endangered; PEx = Presumed Extinct; V = Vulnerable; M = Migratory species. # = restricted to Lord Howe Island and Norfolk Island, ~ = regular migratory visitor, ^ = feral population subsequently extirpated. [1] Subfossil deposits known but not known to breed on LHIG today.

Common name	Scientific Name	TSC	EPBC	Priority
Section 1: Endemic native species				
Mammals				
Lord Howe Island Long-eared Bat	*Nyctophilus howensis*	Pex	Pex	
Land Birds				
Lord Howe Island Grey Fantail	*Rhipidura fuliginosa cervina*	Pex	Pex	
Lord Howe Currawong	*Strepera graculina crissalis*	V	V	✓
Lord Howe Island Thrush	*Turdus poliocephalus vinitinctus*	Pex	Pex	
Lord Howe Island Gerygone	*Gerygone insularis*	Pex	Pex	
Lord Howe Island Golden Whistler	*Pachycephala pectoralis contempta*	V		✓
Lord Howe Island Silvereye	*Zosterops lateralis tephropleura**	V		✓
Lord Howe Woodhen	*Gallirallus sylvestris*	E	V	✓
Red-crowned Parakeet (Lord Howe Island ssp.)	*Cyanoramphus novaezelandiae subflavescens*	Pex	Pex	
Robust White-eye	*Zosterops strenuus*	Pex	Pex	
Southern Boobook (Lord Howe Island ssp.)	*Ninox novaeseelandiae albaria*	Pex	Pex	
Tasman Starling (Lord Howe Island ssp.)	*Aplonis fusca hullianus*	Pex	Pex	
White Gallinule	*Porphyrio albus*	Pex	Pex	
White-throated Pigeon (Lord Howe Island ssp.)	*Columa vitiensis godmanae*	Pex	Pex	
Invertebrates (TSC Act/EPBC Act-listed species only)				
Lord Howe Island Earthworm	*Pericryptodrilus nanus*	E		✓
Lord Howe Island Ground Weevil	*Hybomorphus melanosomus*	Pex		
Lord Howe Island Phasmid	*Drycocelus australis*	E	CE	✓
Lord Howe Island Wood-eating Cockroach	*Panesthia lata*	E		✓
Lord Howe Placostylus	*Placostylus bivaricosus*	EE	E	✓
Section 2: Non-endemic native species (residents or regular visitors on the LHIG at time of European settlement).				
Mammals				
Large Forest Bat	*Vespedelus darlingtonii*			✓
Land Birds				
Bar-tailed Godwit	*Limosa lapponica ~*		M	✓
Double-banded Plover	*Charadrius bicinctus ~*		M	✓
Eastern Curlew	*Numenius madagascariensis ~*		M	✓

Emerald Ground-dove	*Chalcophaps indica*			□
Grey-tailed Tattler	*Tringa brevipes* ~		M	□
Latham's Snipe	*Gallinago hardwickii* ~		M	□
Pacific Golden Plover	*Pluvialis fulva* ~			□
Red Knot	*Calidris canutus* ~		M	□
Red-necked Stint	*Calidris ruficollis* ~		M	□
Ruddy Turnstone	*Arenaria interpres* ~		M	□
Sharp-tailed Sandpiper	*Calidris acuminata* ~		M	□
Wandering Tattler	*Tringa incana* ~		M	□
Whimbrel	*Numenius phaeopus* ~		M	□
Sea Birds				
Common (Brown) Noddy	*Anous stolidus*		M	□
Flesh-footed Shearwater	*Puffinus carneipes*	V	M	□
Grey Ternlet	*Procelsterna cerulea*	V		□
Kermadec Petrel	*Pterodroma neglecta*	V	V	□
Little Shearwater	*Puffinus assimilis*	V		□
Masked Booby	*Sula dactylatra*	V	M	□
Providence Petrel	*Pterodroma solandri*	V	M	□
Pycroft's Petrel[1]	*Pterodroma pycrofti*			
Red-tailed Tropicbird	*Phaethon rubricauda*	V		□
Sooty Tern	*Sterna fuscata*	V		□
Wedge-tailed Shearwater	*Puffinus assimilis*			□
White-bellied Storm Petrel	*Fregata grallaria*	V	V	□
White-faced Storm Petrel[1]	*Pelagodroma marina*			
Reptiles				
Lord Howe Island Gecko	*Christinus guentheri#*	V	V	□
Lord Howe Island Skink	*Pseudomioa lichenigerum#*	V	V	□
Freshwater Fishes				
Long-finned Eel	*Anguilla reinhardtii*			□
Short-finned Eel	*Anguilla australis*			□
Common Jollytail	*Galaxias maculatus*			□
Section 3: Non-native species (residents or regular visitors on the LHIG, present through either intentional/accidental introduction or by colonisation since European settlement).				
Mammals				
Black Rat	*Rattus rattus*			
Feral Cat ^	*Felis cattus*			
Feral Goat	*Capra hircus*			
Feral Pig ^	*Sus scrofa*			
House Mouse	*Mus musculus*			
Land Birds				

Australasian Gannet	*Morus serrator*			
Nankeen Kestrel	*Falco cenchroides*			
Blackbird	*Turdus merula*			
Buff-banded Rail	*Gallirallus philippensis*			
Cattle Egret	*Ardea ibis* ~		M	
Common Starling	*Sturnus vulgaris*			
Feral Pigeon	*Columba livia*			
Great Cormorant	*Phalacrocorax carbo*			
Magpie Lark	*Grallina cyanoleuca*			
Masked Lapwing	*Vanellus miles*		M	
Masked Owl (Tasmanian subspecies)	*Tyto novaehollandiae* ssp. *castanops*			
Pacific Black Duck	*Anas superciliosa*			
Pacific Black Duck-Mallard hybrids	*Anas superciliosa* x *A. platyrhynchos*			
Purple Swamphen	*Porphyrio phrphyrio*			
Sacred Kingfisher	*Todiramphus sanctus*			
Songthrush	*Turdus philomelos*			
Welcome Swallow	*Hirundo neoxena*			
White-faced Heron	*Ardea novaehollandiae*			
Sea Birds				
Black Noddy	*Anous minutus*			
Black-winged Petrel	*Pterodroma nigripennis*	V		□
Cape Petrel	*Daption capense*			
Great-winged Petrel	*Pterodroma macroptera*			
White Tern	*Gygis alba*	V		□
Reptiles				
Eastern Snake-necked Turtle	*Chelodina longicollis*			
Grass Skink	*Lampropholis delicata*			
Amphibians				
Bleating Tree Frog	*Litoria dentata*			

Section 4: Vagrants or irregular visitors				
Marine Mammals				
Bottlenose Dolphin	*Tursiops truncatus*			
Common Dolphin	*Delphinus delphis*			
Humpback Whale	*Megaptera novaeangliae*	V		
Sperm Whale	*Physeter macrocephalus*	V		
Pilot Whale	*Globicephala* sp.			
Blainville's Beaked-whale	*Mesoplodon densirostris*			
Marine Reptiles				
Green Turtle	*Chelonia mydas*	V		
Loggerhead Turtle	*Caretta caretta*	E		
Yellow-bellied Sea Snake	*Pelamis platurus*			
Land Birds				
Australasian Bittern	*Botaurus poiciloptilus*	V		
Australasian Grebe	*Tachybaptus novaehollandiae*			
Australian Pratincole	*Stiltia isabella*			
Australian Shelduck	*Tadorna tadornoides*			
Australian White Ibis	*Threskiornis spinicollis*			
Australian Wood Duck	*Chenonetta jubata*			
Australian Raven	*Corvus coronoides*			
Baillon's Crake	*Porzana pusilla*			
Banded Lapwing	*Vanellus tricolor*			
Black Swan	*Cygnus atratus*			
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*			
Black-tailed Godwit	*Limosa limosa*	V	M	
Black-winged Stilt	*Himantopus himantopus*			
Brahminy Kite	*Haliastur indus*			
Brown Falcon	*Falco berigora*			
Brush Bronzewing	*Phaps elegans*			
Brush Cuckoo	*Cacomantis variolosus*			
Buff-breasted Sandpiper	*Tryngites subruficollis*		M	
Canada Goose	*Branta canadensis*			
Common Chaffinch	*Fringilla coelebs*			
Chestnut Teal	*Anas castanea*			
Channel-billed Cuckoo	*Scythrops novaehollandiae*			
Common Greenshank	*Tringa nebularia*		M	
Common Koel	*Eudynamys scolopaceus*			
Common Sandpiper	*Tringa hypoleucos*		M	
Curlew Sandpiper	*Calidris ferruginea*		M	
Dollarbird	*Eurystomus orientalis*			
Dusky Moorhen	*Gallinula tenebrosa*			

Eastern Reef Egret	*Egretta sacra*		M	
Eastern Rosella	*Platycercus eximius*			
Eurasian Coot	*Fulicia atra*			
European Goldfinch	Carduelis carduelis			
European Greenfinch	*Carduelis chloris*			
Fairy Martin	*Hirundo ariel*			
Fan-tailed Cuckoo	*Cacomantis pyrrhophanus*			
Fork-tailed Swift	*Apus pacificus*		M	
Glossy Ibis	*Plegadis falcinellus*		M	
Great Egret	*Egretta alba*		M	
Great Knot	*Calidris tenuirostris*	V	M	
Grey Plover	*Pluvialis squatarola*		M	
Grey Teal	*Anas gibberifrons*			
Hoary-headed Grebe	*Poliocephalus poliocephalus*			
Intermediate Egret	*Ardea intermedia*			
Greater Sand Plover	*Charadrius leschenaultii*	V	M	
Leaden Flycatcher	*Myiagra rubecula*			
Lesser Sand Plover	*Charadrius mongolus*	V	M	
Common Redpoll	*Carduelis flammea*			
Little Bittern	*Ixobrychus minutus*			
Little Egret	*Egretta garzetta*			
Little Curlew	*Numenius minutus*		M	
Long-tailed Cuckoo	*Eudymanys taitensis*			
Marsh Sandpiper	*Tringa stagnatilis*		M	
Masked Woodswallow	*Artamus personatus*			
Nankeen Night Heron	*Nycticorax caledonicus*			
Noisy Friarbird	*Philemon corniculatus*			
Olive-backed Oriole	*Oriolus sagittatus*			
Oriental Cuckoo	*Cuculus pallidus*			
Oriental Plover	*Charadrius veredus*		M	
Oriental Pratincole	*Glareola maldivarum*		M	
Painted Snipe	*Rostratula benghalensis*	V	M	
Pallid Cuckoo	*Cuculus pallidus*			
Paradise Shelduck	*Tadorna variegata*			
Pectoral Sandpiper	*Calidris melanotos*		M	
Rainbow Bee-eater	*Merops ornatus*		M	
Richard's Pipit	*Anthus novaeseelandiae*			
Royal Spoonbill	*Platalea regia*			
Shining Bronze-cuckoo	*Chrysococcyx lucidus*			
Skylark	*Alauda arvensis*			
White-throated Needletail	*Hirundapus caudacutus*		M	

Sooty Oystercatcher	*Haematopus fuliginosus*			
South Island Pied Oystercatcher	*Haematopus finschi*			
Spotted Turtledove	*Streptopelia chinensis*			
Straw-necked Ibis	*Threskiornis spinicolis*			
Swamp Harrier	*Circus approximans*			
Swift Parrot	*Lathamus discolor*	E		
Terek Sandpiper	*Xenus cinerus*	V	M	
Tree Martin	*Hirundo nigricans*			
Pied Imperial Pigeon	*Ducula bicolor*			
White-browed Woodswallow	*Artamus superciliosus*			
White-winged Triller	*Lalage sueurii*			
Willie Wagtail	*Rhipidura leucophrys*			
Yellow-billed Spoonbill	*Platalea flavipes*			
Yellowhammer	*Emberiza citrinella*			
Seabirds				
Antarctic Prion	*Pachyptila desolata*			
Arctic Tern	*Sterna paradisaea*			
Black-browed Albatross	*Diomedea melanophris*	V	M	
Black-naped Tern	*Sterna sumatrana*		M	
Brown Booby	*Sula leucogaster*		M	
Buller's Shearwater	*Puffinus bulleri*			
Caspian Tern	*Sterna caspia*		M	
Common Tern	*Sterna hirundo*		M	
Crested Tern	*Sterna bergii*			
Fairy Prion	*Pachyptila turtur*			
Fluttering Shearwater	*Puffinus gavia*			
Southern Giant Petrel	*Macronectes giganteus*		M/E	
Gould's Petrel	*Pterodroma leucoptera*		M/E	
Gull-billed Tern	*Sterna nilotica*			
Hutton's Shearwater	*Puffinus huttoni*			
Kelp Gull	*Larus dominicanus*			
Lesser Frigatebird	*Fregata ariel*		M	
Little Black Cormorant	*Phalacrocorax sulcirostris*			
Little Penguin	*Eudyptula minor*			
Little Pied Cormorant	*Phalacrocorax melanoleucos*			
Little Tern	*Sterna albifrons*	E	M	
Long-tailed Jaeger	*Stercorarius longicauda*		M	
Mottled Petrel	*Pterodroma inexpectata*			
Pied Cormorant	*Phalacrocorax varius*			
Red-footed Booby	*Sula sula*		M	
Short-tailed Shearwater	*Puffinus tenuirostris*		M	

Silver Gull	*Larus novaehollandiae*			
Sooty Shearwater	*Puffinus griseus*		M	
Wandering Albatross	*Diomeda exulans*	E	M/V	
Westland Petrel	*Procellaria westlandica*		M	
Wilson's Storm Petrel	*Oceanites oceanicus*		M	
Whiskered Tern	*Chlidonias leucoptera*		M	
White-fronted Tern	*Sterna striata*			
White-headed Petrel	*Pterodroma lessonii*			
White-necked Petrel	*Pterodroma cervicalis*			
White-tailed Tropicbird	*Phaethon lepturus*		M	
White-winged Black Tern	*Chlidonias leucopterus*		M	

Appendix 2 Invertebrates of the Lord Howe Island Group Considered Threatened*

* This table lists species considered to be eligible for listing as threatened by Cassis *et. al.* 2003, but not currently on the TSC Act or EPBC Act schedules

List of threatened ant (Hymenoptera: Formicidae) species of Lord Howe Island.

'N' refers to the northern end of the island. 'ST' refers to the settlement. 'IH' refers to the Intermediate Hill are. 'S' refers to the southern end of the island.

Status	**Order**	**Family**	**Genus Species**	**Comments**
Presumed Extinct	Hymenoptera - Formicidae	Myrmicinae	*Orectognathus howensis*	1 specimen recorded in 1915, 3 specimens recorded in 1966, 1 specimen in 1979, Not recorded since.

Status	**Order**	**Family**	**Genus Species**	**No. Specimens**	**No. Sites Occurs**	**Abundance**	**Distribution (N, ST, IH, S)**
Threatened Vulnerable	Hymenoptera - Formicidae	Myrmicinae	*Lordomyrma leae*	4	3	Rare	S Only
Threatened Vulnerable	Hymenoptera - Formicidae	Ponerinae	*Amblyopone* sp. nov.	9	4	Rare	S Only
Threatened Vulnerable	Hymenoptera - Formicidae	Ponerinae	*Amblyopone* sp. nov.	2	1	Rare	S Only
Threatened Vulnerable	Hymenoptera - Formicidae	Ponerinae	*Discothyrea* sp. nov.	5	3	Rare	S Only
Threatened Vulnerable	Hymenoptera - Formicidae	Ponerinae	*Proceratium* sp. nov.	1	1	Rare	S Only
Threatened At Risk	Hymenoptera - Formicidae	Ponerinae	*Amblyopone leae*	>100	19	Locally Common	S Only

b) List of threatened beetle (Coleoptera) species of Lord Howe Island.

'N' refers to the northern end of the island. 'ST' refers to the settlement. 'IH' refers to the Intermediate Hill area. 'S' refers to the southern end of the island. 'U' refers to unknown distribution. SAM refers to the South Australian Museum collection.

Status	Order	Family	Genus Species	No. Specimens	No. Sites Occurs	Abundance	Distribution (N, ST, IH, S, U)
Presumed Extinct	Coleoptera	Buprestidae	*Melobasis empyria*	?	?	Rare	not collected since 1880's, distribution U
Presumed Extinct	Coleoptera	Carabidae	*Lacordairea fugax*	?	?	Rare	all records pre 1900, distribution U
Presumed Extinct	Coleoptera	Cerambycidae	*Elasmotena insulana*	1	1	Rare	not collected since 1880's, distribution U
Presumed Extinct	Coleoptera	Cerambycidae	*Somatidia pulchella*	1	1	Rare	not collected since 1910's, distribution U
Presumed Extinct	Coleoptera	Cleridae	*Cormodes darwini*	1	1	Rare	not collected since 1910's, distribution U
Presumed Extinct	Coleoptera	Curculionidae	*Howeotranes insularis*	2	1	Rare	not collected since 1920's, Summit Mt Gower
Presumed Extinct	Coleoptera	Curculionidae	*Hybomorphus melanosomus*	3	1	Rare	not recorded since 1889, distribution U
Presumed Extinct	Coleoptera	Curculionidae	*Leptopius etheridgei*	1	1	Rare	not collected since 1910's, distribution U
Presumed Extinct	Coleoptera	Mordellidae	*Tomoxia howensis*	1	1	Rare	not collected since 1880's, distribution U
Presumed Extinct	Coleoptera	Staphylinidae	*Cafius gigas*	2	1	Rare	not collected since 1910's, distribution U
Threatened Vulnerable	Coleoptera	Staphylinidae	*Scaphisoma glabripenne*	9	1	Locally Common	S
Threatened Vulnerable	Coleoptera	Anobiidae	*Mysticephala elliptica*	10	8	Uncommon	S, IH, ST

Status	Order	Family	Genus Species	No. Specimens	No. Sites Occurs	Abundance	Distribution (N, ST, IH, S, U)
Threatened Vulnerable	Coleoptera	Anobiidae	*Mysticephala punctipennis*	5	5	Uncommon	N, ST,
Threatened Vulnerable	Coleoptera	Anthribidae	*Mecocerinopis balli*	7	4	Uncommon	ST
Threatened Vulnerable	Coleoptera	Cerambycidae	*Somatidia olliffi*	5	2	Uncommon	S
Threatened Vulnerable	Coleoptera	Cerambycidae	*Xyloteles segrex*	8	4	Uncommon	S
Threatened Vulnerable	Coleoptera	Cerylonidae	*Mychocerus peckorum*	8	4	Uncommon	S, IH, ST
Threatened Vulnerable	Coleoptera	Curculionidae	*Aethreus cicatricosus*	7	2	Uncommon	ST
Threatened Vulnerable	Coleoptera	Curculionidae	*Ephrycinus pilistriatus*	4	4	Uncommon	N, S, ST
Threatened Vulnerable	Coleoptera	Curculionidae	*Orthorhinus lateralis*	9	7	Uncommon	S, ST (only 5 recent specimens)
Threatened Vulnerable	Coleoptera	Elateridae	*Ochosternus howensis*	8	7	Uncommon	ST & S
Threatened Vulnerable	Coleoptera	Oedomeridae	*Copidita interocularis*	5	2	Uncommon	S
Threatened Vulnerable	Coleoptera	Staphylinidae	*Heterothops castaneus*	9	4	Uncommon	S
Threatened Vulnerable	Coleoptera	Tenebrionidae	*Trachyscelis howensis*	7	2	Uncommon	ST
Threatened Vulnerable	Coleoptera	Aderidae	*Aderus conspicillatus*	5	3	Rare	S, IH, ST
Threatened Vulnerable	Coleoptera	Aderidae	*Aderus pilosicornis*	1	1	Rare	S
Threatened Vulnerable	Coleoptera	Anthribidae	*Howeanthribus bufo*	4	2	Rare	S

Status	Order	Family	Genus Species	No. Specimens	No. Sites Occurs	Abundance	Distribution (N, ST, IH, S, U)
Threatened Vulnerable	Coleoptera	Buprestidae	*Maoraxia roseocuprea*	1	1	Rare	U
Threatened Vulnerable	Coleoptera	Carabidae	*Mecyclothorax howei*	5	5	Rare	S
Threatened Vulnerable	Coleoptera	Carabidae	*Microferonia howei*	5	5	Rare	S
Threatened Vulnerable	Coleoptera	Carabidae	*Scopodes ovalis*	5	4	Rare	S
Threatened Vulnerable	Coleoptera	Cerambycidae	*Howea angulata*	2	2	Rare	U
Threatened Vulnerable	Coleoptera	Cerambycidae	*Xyloteles wollastoni*	7	2	Rare	ST, only 1 specimen since 1916
Threatened Vulnerable	Coleoptera	Curculionidae	*Leptopius mirabilis*	2	2	Rare	ST
Threatened Vulnerable	Coleoptera	Curculionidae	*Nechyrus cribratus*	1	1	Rare	N
Threatened Vulnerable	Coleoptera	Curculionidae	*Poropterus pictus*	1	1	Rare	ST
Threatened Vulnerable	Coleoptera	Histeridae	*Platylomalus cribratus*	1	1	Rare	U
Threatened Vulnerable	Coleoptera	Laemophloeidae	*Cryptolestes distorticornis*	2	1	Rare	U
Threatened Vulnerable	Coleoptera	Laemophloeidae	*Laemophloeus bimaculiflavus*	1	1	Rare	U
Threatened Vulnerable	Coleoptera	Languriidae	*Hapalips investigatus*	1	1	Rare	S
Threatened Vulnerable	Coleoptera	Melyridae	*Helcogaster litoralis*	6	3	Rare	N, Roach Is
Threatened Vulnerable	Coleoptera	Rhipiphoridae	*Nephrites helenae*	1	1	Rare	ST

Status	Order	Family	Genus Species	No. Specimens	No. Sites Occurs	Abundance	Distribution (N, ST, IH, S, U)
Threatened Vulnerable	Coleoptera	Salpingidae	*Notosalpingus montanus*	1	1	Rare	N
Threatened Vulnerable	Coleoptera	Scarabaeidae	*Platytomus pachypus*	2	2	Rare	ST
Threatened Vulnerable	Coleoptera	Sphindidae	*Aspidiphorus howensis*	4	3	Rare	N, ST,
Threatened Vulnerable	Coleoptera	Staphylinidae	*Pachycorynus megacephalus*	1	1	Rare	S
Threatened Vulnerable	Coleoptera	Tenebrionidae	*Promethis sterrha*	8	2	Rare	Now Blackburn Is. only, pre 1918 found on main island
Threatened At Risk	Coleoptera	Curculionidae	*Hoplocossonus lethargicus*	32	5	Common	ST

c) List of threatened spider (Araneae) species of Lord Howe Island.

'N' refers to the northern end of the island. 'ST' refers to the settlement. 'IH' refers to the Intermediate Hill area. 'S' refers to the southern end of the island. 'U' refers to unknown distribution.

Status	Order	Family	Genus Species	No. Specimens	Abundance	Distribution & Comments
Threatened Vulnerable	Araneae	Clubionidae	*Clubiona* sp. (AM sp. 4)	16	Locally Common	S, Only altitudes over ca 300m
Threatened Vulnerable	Araneae	Micropholcommatidae	*Micropholcomma* sp.	13	Locally Common	Mt Gower summit area only
Threatened Vulnerable	Araneae	Corinnidae	unidentified sp.	6	Uncommon	N and ST
Threatened Vulnerable	Araneae	Cyatholipidae	*Lordhowea nesiota*	4+ types (QM)	Uncommon	Mainly S
Threatened Vulnerable	Araneae	Linyphiidae	*Bathyphantes rainbowi*	7 + types (SAM)	Uncommon	Scattered; recent records only from Roach Island & Ball's Pyramid
Threatened Vulnerable	Araneae	Micropholcommatidae	*Parapua* sp.	5 + unregistered	Uncommon	Mt Gower & Mt Lidgbird only
Threatened Vulnerable	Araneae	Mimetidae	*Australomimetus annulipes*	6	Uncommon	Scattered – All records below 120m
Threatened Vulnerable	Araneae	Pholcidae	*Spermophora* sp.	5	Uncommon	Scattered
Threatened Vulnerable	Araneae	Salticidae	*Pseudomaevia cognata*	6 adult & 6 juv. + type (SAM)	Uncommon	Mainly S
Threatened Vulnerable	Araneae	Theridiidae	*Achaearanea nigrodecorata*	9 + types (SAM)	Uncommon	Mt Gower summit only
Threatened Vulnerable	Araneae	Zodariidae	*Storena colossea*	5 + cotype (SAM)	Uncommon	Scattered
Threatened Vulnerable	Araneae	Zoridae	*Argoctenus vittatus*	6 + cotype (SAM)	Uncommon	Scattered
Threatened Vulnerable	Araneae	Amaurobioidea	unidentified sp. (AM sp. 2)	2	Rare	Mt Gower summit only

Status	Order	Family	Genus Species	No. Specimens	Abundance	Distribution & Comments
Threatened Vulnerable	Araneae	Araneidae	*Cyclosa* sp.(AM sp.12)	5	Rare	No recent records, all from S half of island
Threatened Vulnerable	Araneae	Araneidae	*Archemorus cicatrosus*	6	Rare	only 6 juveniles recorded since 1915
Threatened Vulnerable	Araneae	Araneidae	*Araneus rainbowi*	2?	Rare	No definite record since types (1915)
Threatened Vulnerable	Araneae	Desidae	*Forsterina* sp.gp., (AM sp.4)	1	Rare	Unknown – single recent specimen
Threatened Vulnerable	Araneae	Desidae	*Forsterina* sp.gp (ecribellate) (AM sp.7)	1	Rare	Unknown – single specimen from the 1970's
Threatened Vulnerable	Araneae	Mimetidae	*Australomimetus* spp. (AM sp.1 & ?sp.3)	5	Rare	Rare, all sites below 20m
Threatened Vulnerable	Araneae	Oonopidae	*Oonops leai*	3 + type (SAM)	Rare	Rare (only two adult records, one on Ball's Pyramid)
Threatened Vulnerable	Araneae	Segestriidae	*Ariandna montana*	1 adult, 10 juves + type (SAM)	Rare	Either rare or too difficult to collect
Threatened Vulnerable	Araneae	Sparassidae	*Cheiracanthium pallidum*	3 + type (SAM)	Rare	N & ST, all below 50m
Threatened Vulnerable	Araneae	Sparassidae	*Neosparassus haemorrhoidalis*	4	Rare	Probably lowlands only
Threatened Vulnerable	Araneae	Theridiidae	*Crustulina* sp.	2	Rare	Scattered
Threatened Vulnerable	Araneae	Theridiidae	*Euryopis* sp. (AM sp. 9)	2	Rare	Recorded from Mt Lidgbird only
Threatened Vulnerable	Araneae	Thomisidae	?*Stephanopis* (AM sp. 7)	2	Rare	Mt Gower summit only
Threatened Vulnerable	Araneae	Uloboridae	Unidentified sp.	1 + unregistered	Rare	Unknown

Status	Order	Family	Genus Species	No. Specimens	Abundance	Distribution & Comments
Threatened At Risk	Araneae	Mysmenidae	Unidentified sp. (AM sp. 2)	20	Locally Common	Mt Gower summit area only
Threatened At Risk	Araneae	Salticidae	*Tara gratiosa*	22 + types (SAM)	Locally common	S Only – Mt Gower summit
Threatened At Risk	Araneae	Tetragnathidae	*Nanometa* sp.	22	Locally Common	Mt Gower summit only

Appendix 3 Threat tables for flora, vegetation communities, and vertebrate and invertebrate fauna.

Threats are indicated across the top row, with species or communities on the left hand column. The impact of each threat is estimated with a value between 0 to 100, where 100 means the threat does not impact upon the species, and 0 means the threat completely removes the habitat of the species. Where habitat is divided into two qualities, a value for each particular quality is assigned and the threat value is proportionalised. A legend of the threat codes is provided at the end of this table.

a) Flora threat table

Species	Priority	No threat	Thr_01	Thr_02	Thr_03	Thr_04	Thr_05	Thr_06	Thr_07	Thr_08	Thr_09	Thr_10	Thr_11	Thr_12	Thr_13	Thr_14	Thr_15	Thr_16	Thr_17	Thr_18	Thr_19	Thr_20	Thr_21	Thr_22	Thr_23	Thr_24	Thr_25	Thr_26	Thr_27	Thr_28	Thr_29	Thr_30	Thr_31
Alyxia lindii	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100
Alyxia squamulosa - Class 1	2	100	100	100	100	100	100	100	100	90	100	100	100	100	100	90	100	100	100	100	100	100	100	100	100	80	100	100	90	100	90	20	100
Alyxia squamulosa - Class 2	2	20	20	20	20	20	20	20	20	18	20	20	20	20	20	18	20	100	20	20	20	20	20	20	20	16	20	20	18	20	18	4	20
Apium prostratum ssp. *howense*	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	30	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100
Asplenium goudeyi	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Asplenium milnei	2	100	100	100	100	100	100	0	100	100	100	95	100	100	100	50	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	0
Asplenium pteridoides - Class 1	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	20	100
Asplenium pteridoides - Class 2	2	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	100	50	50	50	50	50	50	50	50	50	50	50	50	50	10	50
Asplenium surrogatum	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Atractocarpus stipularis	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	50	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	80	100

Blechnum contiguum	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	20	100
Blechnum fullagarii	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	20	100
Blechnum geniculatum	2	100	100	100	100	100	100	100	100	80	100	100	100	100	100	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	5	100
Blechum howeanum	2	100	100	100	100	100	100	100	100	40	100	100	100	100	100	40	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100
Boehmeria calophleba - Class 1	2	100	100	100	100	100	60	100	100	60	100	100	100	100	100	60	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Boehmeria calophleba - Class 2	2	30	30	30	30	30	18	30	30	18	30	30	30	30	30	20	30	100	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Brachyscome segmentosa	2	100	100	100	100	100	100	100	100	20	100	100	100	100	100	20	100	100	100	100	100	100	100	100	100	100	100	30	100	100	100	100	100
Caesalpinia bonduc	3	100	100	100	100	100	100	0	100	100	100	100	100	100	100	15	15	100	100	100	100	100	100	100	100	100	100	100	100	100	100	5	0
Calystegia affinis	4	100	100	100	100	100	100	0	100	100	100	80	100	100	70	30	30	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	0
Carmichaelia exsul	4	100	100	100	100	100	30	100	100	20	100	100	100	100	100	20	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100
Cassinia tenuifolia	2	100	100	100	100	100	100	0	100	100	100	100	100	100	100	40	100	100	100	100	100	100	100	100	60	100	100	100	100	100	90	100	0
Cassinia tenuifolia	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Celtis conferta	2	100	100	100	100	100	100	0	100	100	100	90	100	100	100	60	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0
Cephalomanes bauerianum	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100
Chamaesyce psammogeton	3	100	100	100	100	100	100	50	100	100	100	100	100	100	100	10	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	5	50
Chionanthus quadristamineus - Class 1	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	30	100	100	100	100	100	100	100	100	100	20	100	100	100	100	100	100	100
Chionanthus quadristamineus - Class 2	2	30	30	30	30	30	30	30	30	30	30	30	30	30	30	9	30	100	30	30	30	30	30	30	30	6	30	30	30	30	30	30	30
Chionochloa howensis	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	60	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Coprosma huttoniana	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Coprosma inopinata	4	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	5	100
Coprosma lanceolaris	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Coprosma prisca	2	100	100	100	100	100	100	0	100	100	100	100	100	100	100	40	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0

Coprosma putida	2	100	100	100	100	100	100	0	100	100	100	100	100	100	100	40	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0
Coprosma sp. nov	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	60	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Corokia carpodetoides	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	20	100
Cryptocarya gregsonii - Class 1	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	50	100
Cryptocarya gregsonii - Class 2	2	40	40	40	40	40	40	40	40	40	40	40	40	40	40	36	40	100	40	40	40	40	40	40	40	36	40	40	40	40	40	20	40
Cyathea brevipinna	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	50	100
Cyathea howeana	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	50	100
Cyathea macarthurii	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Cyathea robusta	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Dendrobium macropus ssp. *howeanum*	2	100	100	100	100	100	100	0	100	100	100	100	100	100	100	60	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0
Dendrobium moorei - Class 1	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	95	100	90	100
Dendrobium moorei - Class 2	2	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	100	30	30	30	30	30	30	30	30	30	30	30	28.5	30	27	30
Dianella intermedia	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	50	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Dietes robinsoniana	2	100	100	100	100	100	100	100	100	70	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	60	100	100	70	100	100	100	100
Diplazium melanochlamys	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Dracophyllum fitzgeraldii	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0	100	100	100	100	100	100	50	100
Drypetes deplanchei ssp. *affinis* - Class 1	2	100	100	100	100	100	100	0	100	100	100	80	100	100	100	30	100	100	100	100	100	100	100	100	100	80	100	100	100	100	95	100	0
Drypetes deplanchei ssp. *affinis* - Class 2	2	30	30	30	30	30	30	0	30	30	30	24	30	30	30	9	30	100	30	30	30	30	30	30	30	24	30	30	30	30	28.5	30	0
Dysoxylum pachyphyllum	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	60	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100
Elaeocarpus costatus	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100	100	10	80	100	100	100	100	100	50	100
Elatostema grande	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	50	100

Exocarpus homalocladus	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	10	80	100	100	100	100	100	100	100
Ficus macrophylla ssp. *columnaris* - Class 1	2	100	100	100	100	100	100	0	100	100	100	0	100	100	100	90	100	100	100	100	100	100	100	100	100	95	100	100	100	100	95	100	0
Ficus macrophylla ssp. columnaris - Class 2	2	30	30	30	30	30	30	0	30	30	30	0	30	30	30	27	30	100	30	30	30	30	30	30	30	28.5	30	30	30	30	28.5	30	0
Gahnia howeana syn. *G. xanthocarpa*	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	0	100	100	100	100	100	100	80	100
Geniostoma huttonii	4	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	20	100
Geniostoma petiolosum	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100
Gonocarpus sp	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	100	100	100	100	100	95	100	100
Grammitis diminuta	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	50	100
Grammitis nudicarpa	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	20	100
Grammitis watsii	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	20	100
Guoia coriacea	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100
Hedescepe canterburyana - Class 1	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	20	100	100	100	95	100	50	100
Hedescepe canterburyana - Class 2	2	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	100	40	40	40	40	40	40	40	8	40	40	40	38	40	20	40
Howea belmoreana - Class 1	2	100	100	100	100	100	100	0	100	100	100	90	100	100	100	60	100	100	100	100	100	100	100	100	100	40	100	100	100	85	20	100	0
Howea belmoreana - Class 2	2	40	40	40	40	40	40	0	40	40	40	36	40	40	40	24	40	100	40	40	40	40	40	40	40	16	40	40	40	34	8	40	0
Howea forsteriana - Class 1	2	100	100	100	100	100	100	0	100	100	100	90	100	100	100	60	100	100	100	100	100	100	100	100	100	40	100	100	100	80	20	100	0
Howea forsteriana - Class 2	2	40	40	40	40	40	40	0	40	40	40	36	40	40	40	24	40	100	40	40	40	40	40	40	40	16	40	40	40	32	8	40	0
Hymenophyllum howense	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	10	100
Hymenophyllum moorei	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	10	100

Korthalsella emersa	2	100	100	100	100	100	100	0	100	100	100	80	100	100	100	70	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	0
Lagunaria patersonia - Class 1	2	100	100	100	100	100	100	0	100	100	100	50	100	100	100	20	100	100	100	100	100	100	100	100	100	70	100	100	100	100	0	100	0
Lagunaria patersonia - Class 2	2	50	50	50	50	50	50	0	50	50	50	25	50	50	50	10	50	100	50	50	50	50	50	50	50	35	50	50	50	50	0	50	0
Lastreopsis nephrodioides	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Lepidium howei-insulae	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	50	100	100	100	100	100	100	100	100	100	100	100	100	100	100	95	80	100
Lepidium nesophilum	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Lepidorrhachis mooreana	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	5	100	100	100	95	100	50	100
Leptopteris moorei	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	20	100
Leptospermum polygalifolium ssp. *howense* - Class 1	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	10	100	100	100	100	100	100	50	100
Leptospermum polygalifolium ssp. *Howense* - Class 2	2	20	20	20	20	20	20	20	20	20	20	20	20	20	20	16	20	100	20	20	20	20	20	20	2	20	20	20	20	20	20	10	20
Lordhowea insularis	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100
Luzula longiflora	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Machaerina insularis	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	50	100
Macropiper hooglandii - Class *1*	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	60	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100
Macropiper hooglandii - Class 2	2	30	30	30	30	30	30	30	30	30	30	30	30	30	30	18	30	100	30	30	30	30	30	30	30	30	30	30	30	30	30	24	30
Marattia howeana - Class 1	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	20	100
Marattia howeana - Class 2	2	50	50	50	50	50	50	0	50	50	50	50	50	50	50	50	50	100	50	50	50	50	50	50	50	50	50	50	50	50	50	10	0
Melaleuca howeana - Class 1	2	100	100	100	100	100	100	0	100	100	100	100	100	100	100	95	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0
Melaleuca howeana - Class 2	2	50	50	50	50	50	50	50	50	50	50	50	50	50	50	47.5	50	100	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50

Melicope contermina	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100
Melicope polybotrya	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100
Melicytus novae-zelandieae ssp. *centurionis*	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100
Metrosideros nervulosa	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0	100	100	100	100	98	100	80	100
Metrosideros sclerocarpa	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100	100	0	100	100	100	100	98	100	100	100
Negria rhabdothamnoides - Class 1	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100
Negria rhabdothamnoides - Class 2	2	10	10	10	10	10	10	10	10	10	10	10	10	10	10	9	10	100	10	10	10	10	10	10	10	10	10	10	10	10	10	8	10
Olearia ballii	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100
Olearia elliptica ssp. *praetermissa*	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Olearia mooneyi	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	95	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	50	100
Pandanus forsteri - Class 1	2	100	100	100	100	100	100	0	100	100	100	40	100	100	100	70	100	100	100	100	100	100	100	100	100	70	100	100	100	98	100	90	0
Pandanus forsteri - Class 2	2	30	30	30	30	30	30	0	30	30	30	12	30	30	30	21	30	100	30	30	30	30	30	30	30	21	30	30	30	29.4	30	100	0
Passiflora herbertiana ssp.insula-howei	2	100	100	100	100	100	100	0	100	100	100	100	100	100	100	20	100	100	100	100	100	100	100	100	100	20	100	100	100	100	100	100	0
Phymatosorus pustulatus ssp. *howensis*	2	100	100	100	100	100	100	0	100	100	100	95	100	100	100	70	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	0
Pimelea congesta	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100	100	10	100	100	100	100	100	100	100	100
Pittosporum erioloma	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100	100	100	60	100	100	100	100	100	50	100
Plantago hedleyi	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	50	100
Plectorrhiza erecta - Class 1	2	100	100	100	5	100	100	0	100	100	100	100	100	100	100	5	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	0

Plectorrhiza erecta - Class 2	2	60	60	60	3	60	60	0	60	60	60	60	60	60	60	3	60	100	60	60	60	60	60	60	60	60	60	60	60	54	60	60	0
Polystichum moorei	4	100	100	100	100	100	100	0	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	10	0
Polystichum whiteleggei	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Psychotria carronis	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100
Pteris microptera	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Rapanea mccomishii	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100
Rapanea myrtillina	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	50	100
Rapanea platystigma	2	100	100	100	100	100	100	0	100	100	100	95	100	100	100	70	100	100	100	100	100	100	100	100	100	80	100	100	100	100	95	100	0
Senecio howeanus	2	100	100	100	100	100	50	100	100	30	100	100	100	100	100	30	90	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100
Senecio pauciradiatus	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	20	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	20	100
Sophora howinsula	2	100	100	100	100	100	100	0	100	100	100	95	100	100	100	70	100	100	100	100	100	100	100	100	100	100	100	100	100	100	95	100	0
Stephania japonica var *timoriensis*	2	100	100	100	100	100	100	0	100	100	100	95	100	100	50	70	100	100	100	100	100	100	100	100	100	80	100	100	100	100	95	100	0
Symplocos candelabrum	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100
Syzygium fullargarii (syn. *Cleistocalyx fullargarii*) - Class 1	2	100	100	100	100	100	100	0	100	100	100	60	100	100	100	30	100	100	100	100	100	100	100	100	0	80	100	100	100	100	100	100	0
Syzygium fullargarii (syn. *Cleistocalyx fullargarii*) - Class 2	2	30	30	30	30	30	30	0	30	30	30	18	30	30	30	9	30	100	30	30	30	30	30	30	0	24	30	30	30	30	30	30	0
Trophis scandens ssp. *megacarpa*	2	100	100	100	100	100	100	0	100	100	100	95	100	100	100	90	100	100	100	100	100	100	100	100	100	80	100	100	100	100	95	100	0
Uncinia debilior	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	50	100
Wahlenbergia insulae-howei	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Westringia viminalis	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Xylosma maidenii	2	100	100	100	100	100	100	0	100	100	100	95	100	100	100	70	100	100	100	100	100	100	100	100	100	80	100	100	100	100	95	100	0
Xylosma parvifolium - Class 1	4	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	20	100

Xylosma parvifolium - Class 2	4	40	40	40	40	40	40	40	40	40	40	40	40	40	40	32	40	100	40	40	40	40	40	40	40	40	40	40	40	40	32	8	40
Zygogynum howeanum (syn. *Bubbia howeanum)* - Class 1	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	20	100	100	100	100	100	100	80	100
Zygogynum howeanum (syn. *Bubbia howeanum)* - Class 2	2	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	100	30	30	30	30	30	30	6	30	30	30	30	30	30	24	30

(b) Vegetation community Threat Table

Species	Priority	No Threat	Thr_01	Thr_02	Thr_03	Thr_04	Thr_05	Thr_06	Thr_07	Thr_08	Thr_09	Thr_10	Thr_11	Thr_12	Thr_13	Thr_14	Thr_15	Thr_16	Thr_17	Thr_18	Thr_19	Thr_20	Thr_21	Thr_22	Thr_23	Thr_24	Thr_25	Thr_26	Thr_27	Thr_28	Thr_29	Thr_30	Thr_31
Aegiceras corniculatum	3	100	100	100	100	100	100	0	100	100	100	100	100	100	100	30	100	100	100	100	100	100	100	100	100	100	100	50	100	100	30	20	0
Alyxia squamulosa - Coprosma inopinata	3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Atriplex cinerea	3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Avicennia marina var. *australasica*	3	100	100	100	100	100	100	0	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	30	20	0
Basalt boulder beach	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	20	100
Boehmaria calcophleba - Macropiper excelsum var. *psittacorum*	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	20	100
Bubbia howeana - dracophyllum fitzgeraldii	3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	50	100	100	100	100	100	100	20	100
Calcarenite/coral boulder beach	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	20	100
Cassinia tenuifolia	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Cassinia tenuifolia/Melaleuca howeana	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Cassinia tenuifolia/Poa poiformis	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Chionanthus quadristamineus	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100
Chionanthus quadristamineus/Howea belmoreana	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100
Cleistocalyx fullageri	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Cliffs	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	60	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Coral sand and beach	3	100	100	100	100	100	100	0	100	100	100	100	100	100	100	40	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	20	0
Cryptocarya gregsonii	3	100	100	100	100	100	100	100	100	60	100	100	100	100	100	60	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	50	100
Cyperus lucidus	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Dodonaea viscosa	2	100	100	100	100	100	100	0	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	100	100	100	100	100	95	100	0
Dracophyllum fitzgeraldii - Metrosideros nervulosa	3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	60	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100
Dracophyllum fitzgeraldii - Metrosideros nervulosa/Lowland Mixed Forest/*Drypetes australasica* - Cry	3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	60	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100
Drypetes australasica - Cryptocarya triplinervis (calcarenite variant)	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	60	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	50	100
Drypetes australasica - Cryptocarya triplinervis (exposed variant)	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	60	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100
Drypetes australasica - Cryptocarya triplinervis on Coral	2	100	100	100	100	100	100	0	100	100	100	80	100	100	100	60	100	100	100	100	100	100	100	100	100	70	100	90	100	100	60	80	0
Drypetes australasica - Cryptocarya triplinervis on Volcanics	2	100	100	100	100	100	100	0	100	100	100	80	100	100	100	60	100	100	100	100	100	100	100	100	100	70	100	100	100	100	95	100	0
Hedyscepe canterburyana	3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	50	100
Hedyscepe canterburyana/Boehmaria calcophleba - Macropiper excelsum var. *psittacorum*	3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	20	100
Howea belmoreana	2	100	100	100	100	100	100	0	100	100	100	90	100	100	100	70	100	100	100	100	100	100	100	100	100	70	100	100	100	95	50	100	0
Howea forsterana on Coral	3	100	100	100	100	100	100	0	100	100	100	90	100	100	100	70	100	100	100	100	100	100	100	100	100	50	100	100	100	90	50	100	0

Howea forsterana on Volcanics	2	100	100	100	100	100	100	0	100	100	100	90	100	100	100	70	100	100	100	100	100	100	100	100	100	50	100	100	100	90	50	100	0
Howea forsterana/Chionanthus quadristamineus	2	100	100	100	100	100	100	0	100	100	100	90	100	100	100	70	100	100	100	100	100	100	100	100	100	50	100	100	100	90	50	100	0
Howea forsterana/Howea belmoreana	2	100	100	100	100	100	100	0	100	100	100	90	100	100	100	70	100	100	100	100	100	100	100	100	100	50	100	100	100	90	50	100	0
Ipomoea cairica - Carpobrotus glaucescens	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Lagunaria patersonia	4	100	100	100	100	100	100	0	100	100	100	0	100	100	100	0	100	100	100	100	100	100	100	100	60	100	100	60	100	100	0	10	0
Lowland Freshwater Community	3	100	100	100	100	100	100	10	100	100	100	100	100	100	100	20	100	100	100	100	100	100	100	100	100	100	100	30	100	100	20	10	10
Lowland Mixed Forest	3	100	70	100	100	100	100	0	50	70	100	80	100	100	100	50	90	100	100	100	100	100	100	100	100	70	100	100	100	100	80	100	0
Melaleuca howeana	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Mixed Fern & Herb	2	100	100	100	100	100	80	100	100	60	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100
Mixed Fern & Herb/*Melaleuca howeana*	2	100	100	100	100	100	80	100	100	60	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	100	100
Padanus forsteri	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	50	100
Poa poiformis	3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	60	60	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
UNTYPED	1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Upland Freshwater Community	3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	70	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	10	100
Waterfall Community	2	100	100	100	100	100	100	100	100	60	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	10	100

(c) Vertebrate Fauna Threat Table

Species	Priority	No Threat	Thr_01	Thr_02	Thr_03	Thr_04	Thr_05	Thr_06	Thr_07	Thr_08	Thr_09	Thr_10	Thr_11	Thr_12	Thr_13	Thr_14	Thr_15	Thr_16	Thr_17	Thr_18	Thr_19	Thr_20	Thr_21	Thr_22	Thr_23	Thr_24	Thr_25	Thr_26	Thr_27	Thr_28	Thr_29	Thr_30	Thr_31
Sea birds:																																	
Pacific Golden Plover	1	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100
Brown Noddy	1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	95	100	100	100	100	95	100	100	100	100	100	100	100
Flesh-footed Shearwater	2	100	100	100	100	100	100	5	100	100	95	80	100	100	100	100	90	100	100	100	100	100	100	100	100	95	100	100	100	100	80	100	5
Grey Ternlet	1	100	100	100	100	100	100	100	100	100	100	100	95	100	100	100	100	100	100	98	100	100	100	100	100	95	100	100	100	100	100	100	100
Kermadec Petrel	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	50	100	100	100	100	100	100	100
Little Shearwater	2	100	100	100	100	100	100	90	80	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	25	100	100	100	100	100	100	90
Masked Booby	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	98	100	100	100	0	100	100	100
Providence Petrel	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Providence Petrel	2	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	100	40	40	40	40	40	40	40	40	40	40	40	40	40	100	40
Red-tailed Tropicbird	2	100	95	100	100	100	100	100	100	100	100	100	100	100	100	95	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Sooty Tern	2	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	100	100	99	99	99	100	100	100	100	95	100	100	100	100	95	100	100
Wedge-tailed Shearwater	1	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	30	100	100	100	100	100	100	100	100	95	100	100	100	100	95	100	100
White-bellied Storm Petrel	2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0	100	100	100	100	100	100	100
White Tern	1	100	100	100	100	100	100	95	100	100	100	100	100	100	100	100	100	100	100	100	80	100	100	80	100	100	100	100	100	100	100	100	95
Black-winged Petrel	1	100	100	100	100	100	100	90	80	100	100	100	100	100	100	80	100	100	100	100	80	100	100	100	100	95	100	100	100	100	100	100	90
Non-sea bird Vertebrates:																																	
Large Forest Bat	1	100	100	100	100	100	100	50	100	100	100	90	100	100	95	100	100	100	100	100	95	100	100	100	100	100	100	100	100	100	80	100	50
Lord Howe Gecko	2	100	100	100	100	100	100	20	100	100	100	90	100	100	100	100	100	100	100	100	100	100	100	100	100	40	95	100	100	100	80	100	20
Lord Howe Gecko	2	50	50	50	50	50	50	10	50	50	50	45	50	50	50	50	50	50	50	50	50	50	50	50	50	20	47.5	50	50	50	40	100	10

Lord Howe Skink	2	100	100	100	100	100	100	20	100	100	100	90	100	100	100	100	100	100	100	100	100	100	100	100	100	40	95	100	100	100	80	100	20
Lord Howe Skink	2	50	50	50	50	50	50	10	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	20	47.5	50	50	50	40	100	10
Long-finned Eel	1	100	100	100	100	100	100	20	100	100	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100	100	100	50	100	100	20	100	20
Short-finned Eel	1	100	100	100	100	100	100	20	100	100	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100	100	100	50	100	100	20	100	20
Common Jollytail	1	100	100	100	100	100	100	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	5	100	100	5	100	0
Bar-tailed Godwit	1	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100
Double-banded Plover	1	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100
Eastern Curlew	1	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100
Emerald Ground-dove	1	100	100	100	100	100	100	0	100	100	98	90	100	100	50	30	100	95	100	100	98	100	100	100	100	100	100	50	100	100	80	100	0
Emerald Ground-dove	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0
Grey-tailed Tattler	1	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100
Japanese Snipe	1	100	100	100	100	100	100	100	100	100	95	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	60	100	100
Lord Howe Currawong	3	100	100	100	100	100	100	10	100	100	100	100	100	100	50	100	100	100	95	100	95	100	100	100	100	100	100	100	100	100	100	100	10
Lord Howe Golden Whistler	3	100	100	100	100	100	100	0	100	100	100	90	100	100	50	80	100	100	100	100	100	100	98	100	100	100	100	100	100	100	90	100	0
Lord Howe Silvereye	3	100	100	100	100	100	100	0	100	100	100	90	100	100	50	80	100	100	100	100	100	100	98	100	100	100	100	100	100	100	90	100	0
Lord Howe Woodhen	4	100	100	80	100	80	100	10	100	100	98	80	100	100	100	30	100	95	100	100	95	100	100	100	100	95	100	100	100	100	80	100	10
Lord Howe Woodhen	4	10	10	8	10	8	10	1	10	10	9.8	8	10	10	10	3	10	9.5	10	10	9.5	10	10	10	10	9.5	10	10	10	10	8	100	1
Red Knot	1	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100
Red-necked Stint	1	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100
Ruddy Turnstone	1	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100
Sharp-tailed Sandpiper	1	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100
Wandering Tattler	1	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100
Whimbrel	1	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	90	100

(d) Invertebrate groups threat table

Species	Priority	No Threat	T_01	T_02	T_03	T_04	T_05	T_06	T_07	T_08	T_09	T_10	T_11	T_12	T_13	T_14	T_15	T_16	T_17	T_18	T_19	T_20	T_21	T_22	T_23	T_24	T_25	T_26	T_27	T_28	T_29	T_30	Thr_31
Ants	1	100	81	81	100	100	100	6	81	100	100	81	100	100	24	81	81	100	100	100	100	81	3	100	100	100	81	100	100	100	96	24	6
Beetles	1	100	81	81	100	100	100	13	81	100	100	81	100	100	24	81	81	100	100	100	100	81	13	100	100	6	81	81	100	6	96	24	13
Spiders	1	100	81	81	100	100	100	13	81	100	100	81	100	100	24	81	81	100	100	100	100	81	13	100	100	100	81	100	100	100	96	24	13
Snails	1	100	81	81	100	100	100	3	81	100	100	81	100	100	24	81	81	100	100	100	100	81	3	100	100	3	81	81	100	66	96	24	3

(e) Threatened Invertebrates threat table

Species	Priority	No Threat	Thr_01	Thr_02	Thr_03	Thr_04	Thr_05	Thr_06	Thr_07	Thr_08	Thr_09	Thr_10	Thr_11	Thr_12	Thr_13	Thr_14	Thr_15	Thr_16	Thr_17	Thr_18	Thr_19	Thr_20	Thr_21	Thr_22	Thr_23	Thr_24	Thr_25	Thr_26	Thr_27	Thr_28	Thr_29	Thr_30	Thr_31
Lord Howe Earthworm	4	100	100	95	100	100	100	100	100	100	100	100	100	100	95	95	100	100	100	100	100	100	100	100	100	100	100	100	100	100	95	100	100
Lord Howe Phasmid	4	100	100	100	100	100	100	0	100	100	100	95	100	50	100	95	100	100	100	100	100	100	100	100	100	0	50	100	100	0	100	50	0
Lord Howe Phasmid	4	50	50	50	50	50	50	0	50	50	50	47.5	50	25	50	47.5	50	100	50	50	50	50	50	50	50	0	25	50	50	0	50	25	0
Lord Howe Cockroach	4	100	100	100	100	100	100	0	100	100	100	100	100	100	100	10	10	100	100	100	100	100	95	100	100	0	100	100	100	100	100	20	0
Lord Howe Cockroach	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lord Howe Placostylus	4	100	100	70	100	100	100	0	100	100	100	20	100	100	100	30	100	100	100	100	100	100	100	100	100	10	100	100	100	70	50	50	0
Lord Howe Placostylus	4	25	25	17.5	25	25	25	0	25	25	25	5	25	25	25	7.5	25	100	25	25	25	25	25	25	25	2.5	25	25	25	17.5	12.5	12.5	0

Threat codes:

Index	Description
Thr_01	Weed invasion - Bitou Bush
Thr_02	Competition and predation from Blackbird &Songthrush
Thr_03	Weed invasion- Bridal Creeper
Thr_04	Competition and predation from Buff-banded Rail
Thr_05	Weed invasion- Cherry Guava
Thr_06	Habitat clearing and modification
Thr_07	Weed invasion - Asparagus Fern
Thr_08	Weed invasion- Crofton Weed
Thr_09	Predation by Dogs
Thr_10	Edge Effects/Vegetation Dieback
Thr_11	Competition from introduced Pigeon
Thr_12	Competition and predation from introduced frog
Thr_13	Introduced invertebrates
Thr_14	Weed invasion - general (merged)
Thr_15	Weed invasion- Introduced grasses
Thr_16	Herbicide Use
Thr_17	Human Interactions
Thr_18	Predation from Introduced Kestrel
Thr_19	Competition and Predation from Introduced Owl
Thr_20	Weed Invasion - Norfolk Island Pine
Thr_21	Competition and Predation from Other Introduced Species
Thr_22	Competition and Predation from LHI Currawong
Thr_23	Impacts from Phytopthora
Thr_24	Predation by the Rodents
Thr_25	Competition and Predation from Introduced Skink
Thr_26	Groundwater Pollution
Thr_27	Weed invasion - Tiger Lily
Thr_28	Collecting (plants and eggs) and Traditional Activities
Thr_29	Trampling Browsing and Grazing
Thr_30	Climate Change
Thr_31	Future Clearing

Appendix 4 Biodiversity Forecasting Tool

4.1 Methods

Introduction

The LHI BMP aims to provide an overview of the LHIG's biodiversity, threats and future management priorities. To achieve this aim, the LHI BMP considered a large number of priority species and their associated threats to identify areas of particular conservation significance (biodiversity "hot spot" areas and areas where threats are causing the most harm to biodiversity), as well as considering individual species requirements.

This approach allowed for landscape scale management actions to be applied where threats affect large numbers of species, while still providing specific actions to manage individual species where warranted.

Biodiversity Forecasting Toolkit

The Biodiversity Forecasting Toolkit (BFT) is a Geographical Information System (GIS) decision support tool (DEC 2004). It has been developed during the past three to four years by the DEC's GIS Research and Development Unit. Biodiversity forecasting focuses on estimating the likely persistence of overall biodiversity. Outcomes from the BFT are modelled using the best available data on the extent and condition of vegetation types and individual species, coupled with data and expert knowledge on various threats and ecological processes. This approach is well suited to landscape-scale planning involving multiple management scenarios.

The LHI BMP is the first time that GIS biodiversity forecasting has been used for regional species recovery planning. The result is an integrated multi-species landscape-level plan that is considered to be a model for future regional multi-species recovery plans. In the case of the LHI BMP, the BFT assists with prioritising conservation management actions and assessing the potential effectiveness of management scenarios in terms of biodiversity outcomes.

The LHI BMP considered a large number of species and vegetation communities individually, including their unique response to habitat, threats, and management. The BFT approach used the quantity and quality of habitat and the degree of threat operating on the habitat for each species or vegetation community, to infer the likelihood of species persistence. More complex biological interactions, such as population dynamics and the spatial configuration of habitat were not included in the modelling approach.

Methodology

Due to the strong linkage between species viability and the occurrence of suitable habitat, the amount of habitat of each species is often used as a surrogate for species persistence where detailed population data is unknown. For flora, vertebrate fauna, threatened invertebrate fauna and invertebrate fauna groups, the data used for the LHI BMP consisted of mapped distributions of threatened and priority species and species groups based on habitat across the LHIG, which was divided into various quality classes where applicable.

Although the LHIG is relatively well-studied in terms of its flora and fauna, little of this information was available in a spatial (mapped) form suitable for GIS processing.

To produce suitable GIS models, habitat and threat data were derived using information provided by a wide range of people with expertise in the taxa of the LHIG. The original and current habitat area for each species was mapped (modelled) using the best available knowledge and information.

Patterns of threatening processes

Representing threats in a spatial manner allows for identification of areas that are subject to multiple threats, or conversely, identification of areas that are subject to fewer threats.

Threat information was generated using expert knowledge and available spatial data. For example, several prominent weed species had been mapped and their impact on various habitats estimated. An example of a threat map is given in Figure A. This shows the distribution of the weed Cherry Guava, classified into two categories of high density and low density. Other threats, such as climate change, were derived by delineating areas that are most likely to be susceptible to this threat. This approach is limited to threats where the spatial distribution could be mapped or estimated (Table 1). Threats that could not be spatially represented, such as long-line fishing, were assessed separately.

Threat ranking

Different threatening processes have different levels of impact on the biodiversity values of the LHIG. Some threats constitute serious problems for the biodiversity of the LHIG, while others represent minor impacts.

The predicted impact of individual threats were ranked by estimating the level of reduction of habitat quantity and quality for each species, species group or vegetation community.

Table 1. Spatial threat models used in the LHI BMP

Threats associated with weed invasion	**Threats associated with pest animals**
Distribution of weed invasion (general)	Predation by the Ship Rat
Bitou Bush distribution	Competition and predation from the feral Pigeon
Bridal Creeper distribution	Competition and predation from Blackbird and Songthrush
Cherry Guava distribution	Competition and predation from Buff-banded Rail
Climbing Asparagus distribution	Competition and predation from introduced Bleating Tree Frog
Crofton Weed distribution	Competition and predation by introduced House Mouse
Ground Asparagus distribution	Predation by domestic Dogs
Lantana distribution	Competition and predation by domestic Chicken
Madeira Vine distribution	Competition and predation by other introduced species
Norfolk Island Pine distribution	Competition and predation by introduced ants
Ochna distribution	Competition and predation by introduced beetles
Pittosporum distribution	Competition and predation by introduced snails
Tiger Lily distribution	Competition and predation by introduced spiders
Areas susceptible to invasion by exotic grasses	Competition and predation by introduced invertebrates - general
Areas at risk from use of herbicide	Competition and predation from the Masked Owl
Miscellaneous threats	Competition and predation from introduced Skink
Current *Phytophthora* distribution	Predation from Australian Kestrel
Potential distribution of *Phytophthora*	**Threats from human impacts**
Vegetation dieback	Habitat clearing and modification
Areas at threat from landslip	Trampling, browsing and grazing
Potential distribution of introduced pests, weeds and disease	Areas most at risk from impacts of humans
Areas most at risk from climate change	Areas most at risk from illegal collection
Threat of groundwater pollution	Collecting (plants and sea bird eggs) and other traditional activities

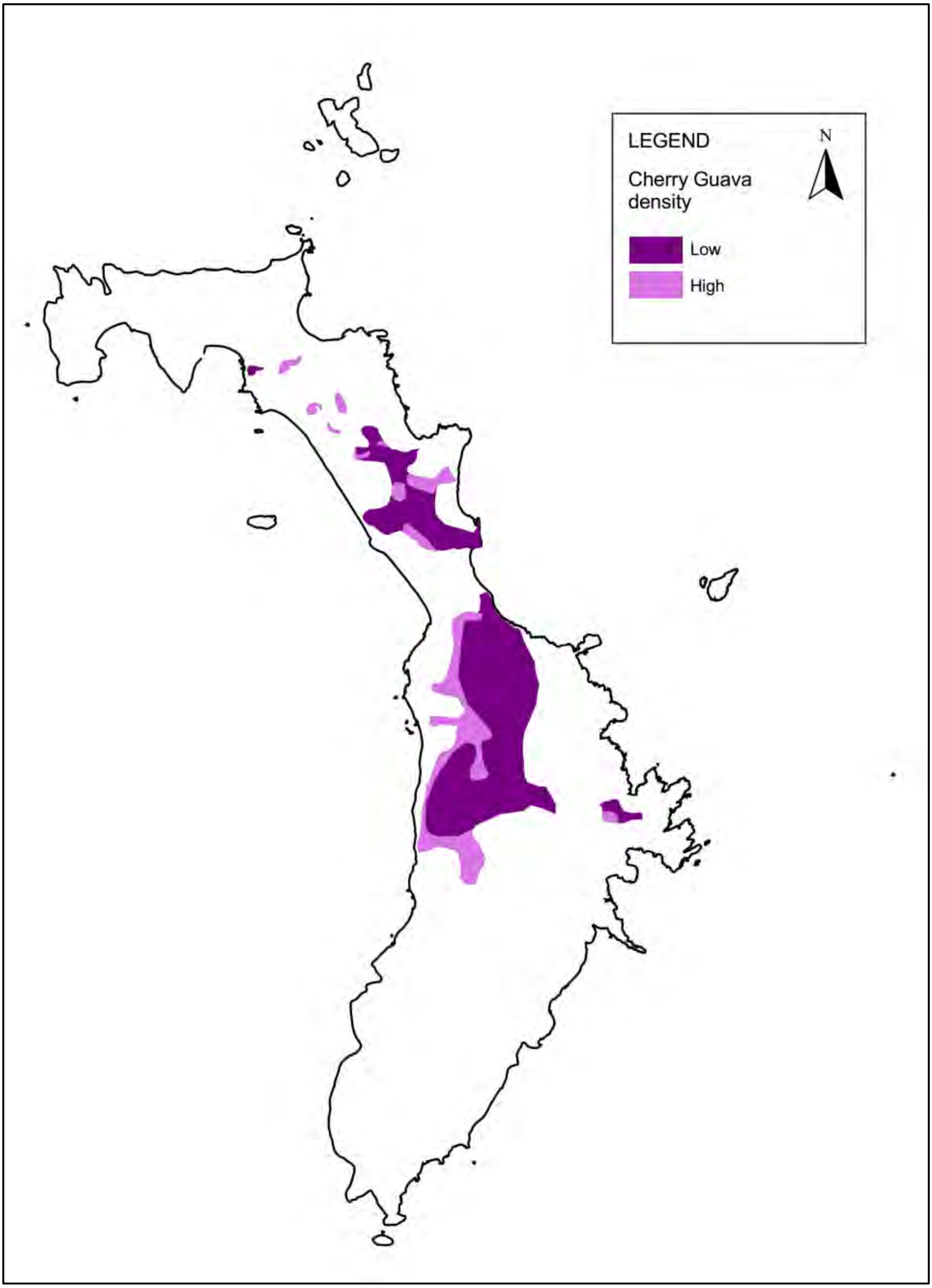

Figure A. An example of a threat layer input for the Lord Howe Island Biodiversity Management Plan - the distribution of Cherry Guava on Lord Howe Island (from Smith 2002)

Derivation of future habitat

An overview of the modelling methodology is outlined in Figure B. This is based on the original habitat extent of a species or vegetation community, and the threats that are acting upon each species or community. The future habitat extent is modelled based on the past habitat extent, threats and the estimated effectiveness of management actions to address threats. The future habitat extent is the habitat that is predicted to remain after the impacts of threats have occurred. Priorities for management action are based on the relative improvements to biodiversity achieved by treating threats.

Limitations of the methodology include its inability to allow for the partial influence of threats that operate over time, nor does it take into account the potential interactions between threats. In this project the threat with the highest estimated impact at any $10m^2$ grid cell is used as the active threat and its impact defines future habitat quality at that point.

Biodiversity persistence index

The objective of a biodiversity persistence index is to identify those species at greatest conservation risk, and thus maximise the probability of overall species persistence. Each species and vegetation community was ranked. The highest ranking was given to species or communities listed as Endangered on either the TSC Act or the EPBC Act. The next priority was vulnerable species, followed by endemics and then natives (Appendix 1). Invertebrate data were dealt with in two ways. Individual species models and rankings were only available for four threatened invertebrate species. Four invertebrate groups (ants, spiders, snails and beetles) were dealt with separately and were assumed to have equal rank.

An approximate estimate of the probability of persistence for each species was calculated by dividing the species' current habitat area by its original habitat area, and then raising this proportion to the power of 0.25 (a widely employed species-area function relating to the proportion of species retained in an area to the proportion of habitat remaining (Figure C). The curve gives added weight to species which have suffered the greatest loss of habitat. The overall biodiversity persistence index therefore, is the sum of individual species probabilities.

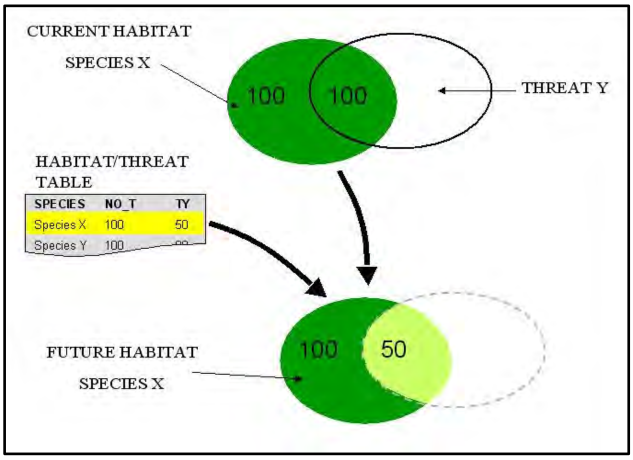

Figure B. Process for deriving future habitat from current habitat, threats and a habitat/threat table

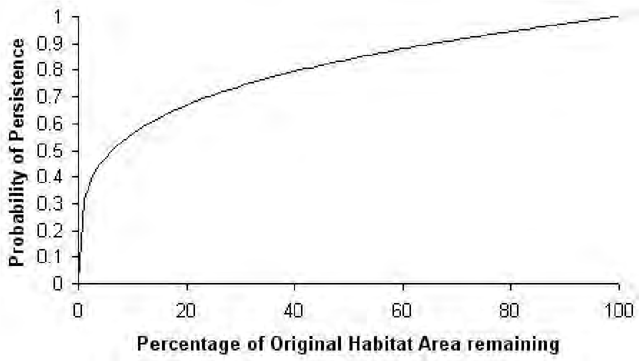

Figure C. Persistence area relationship assumed for the Biodiversity Forecasting Toolkit

Prioritising management actions

Priority areas for appropriate management are the areas where species richness is high, where the habitat of those species is vulnerable to threats, and where management action is considered effective in ameliorating the threat.

The BFT was used to analyse the potential benefit to biodiversity of any particular management action. This was modelled by identifying the maximum threat applying to each gridcell across the LHIG and then the change to the biodiversity persistence index if that threat is removed.

The resulting threat consequence layers provide a prediction of where the greatest conservation gains can be achieved by addressing individual threats. The consequences of individual threats can also be summed to provide a prediction of the overall priority for conservation action.

The BFT was also used to predict the effectiveness of any particular management action. Twenty four management actions were analysed using the BFT. The degree of effect of each management action on each of the threats were ranked using expert opinion.

Although this approach only considers the 'major' spatial threat for each gridcell and is likely to produce some distortions, it is useful as a guide to the development of management actions. The potential cost-benefit of implementing a particular management action or a combination of a number of actions can be tested using the BFT and provides a guide to considering the most appropriate management priorities.

The BFT can be updated as new spatial data becomes available and the outcomes of management actions are monitored and mapped. This will allow the LHIB to use the BFT to assist in evaluating the effectiveness of the plan implementation and reporting requirements.

4.2 Biodiversity Forecasting Outputs

Explanation of Biodiversity Forecasting Outputs

This chapter describes and presents some of the outputs from the BFT. Where relevant, management actions with the greatest predicted biodiversity benefits are incorporated into the management actions listed in Section 6 of the main report.

Habitat richness and threat impacts

Habitat richness and the overall predicted impacts of threats on species groups, vegetation communities and individual species is discussed below for each group, and for listed threatened species and communities.

Flora

Habitat richness and endemicity for flora is greatest in the southern mountains, especially on the high altitude areas of Mounts Gower and Lidgbird (see Figure 2 in DEC 2006).

Habitat richness after threats are applied indicates a similar pattern of richness, but with reduced values, i.e. the habitat richness is still greatest in the southern mountains, but not as rich. Conversely, some parts of the settlement area drop to zero value (cleared areas).

A high significance of the loss of biodiversity is indicated for Sallywood Swamp Forest patches and threatened plant locations of *Calystegia affinis* at Old Settlement, and Knicker Nut at Neds Beach (Figure D). The significance of past clearing in the settlement area is also indicated very highly.

Vegetation communities

Habitat richness for communities does not apply as there is no overlap in their distributions.

An extremely high level of significance of the loss of biodiversity is indicated for Sallywood Swamp Forest Community patches, followed by Mangrove Communities. The significance of the loss of the Waterfall Cliff Community and Freshwater Instream Communities to overall biodiversity are also indicated at very high levels.

High levels of persistence of vegetation communities are predicted for much of the remainder of the LHIG, specifically in the higher elevations of the southern mountains. A high level of persistence is also predicted for offshore islands.

Sea birds

Habitat richness for sea birds is highest on Roach Island, the southern tip of the southern mountains, followed by Muttonbird Island, Muttonbird Point, other offshore Islands and the northern clifflines (see Figure 3 in DEC 2006). The settlement area between Neds Beach and Middle Beach also has a high value, as do the Lagoon Foreshores. Balls Pyramid was not included in the BFT analysis.

Habitat richness after threats are applied identifies threatening processes working most strongly at Muttonbird Point, the Lagoon Foreshores, Mount Eliza and the settlement area from Neds Beach to Clear Place. A high level of sea bird habitat richness is predicted to be maintained on offshore Islands, at King Point and along the northern clifflines.

The persistence of sea bird biodiversity is predicted to be lowest at Muttonbird Point, followed by areas in the settlement area between Neds Beach and Middle Beach. These areas are followed by the offshore islands then remaining areas of identified shoreline and cliffline (Figure E).

Non-sea bird vertebrates

High habitat richness levels are indicated along the shorelines due to the habitat of migratory waders and shore birds, particularly on the Lagoon side.

Also indicated highly are areas along watercourses across the main island due to the habitat of eels and freshwater fish.

Habitat richness after threats are applied predict a fairly uniform loss of habitat across the main island and adjacent offshore islands.

The persistence of biodiversity for non-sea bird vertebrates is predicted to be lowest in watercourse habitats in the Old Settlement Beach area, Cobby's Corner and Soldiers Creek. A low overall loss is predicted for much of the rest of the main island, but does not include shoreline areas, indicating that shore bird habitat is less under threat.

Threatened invertebrates

Habitat richness for threatened invertebrates uses past habitat distributions which include the Lord Howe Island Phasmid and the Lord Howe Island Wood-eating Cockroach, now extinct on the main island. Analysis does not include Balls Pyramid. Threatened invertebrate habitat richness appears greatest in the settlement area followed by the lower slopes in the northern and southern PPP.

Habitat richness is predicted to suffer the greatest loss after threats have been applied at the lower altitudes of the northern and southern PPP, and Intermediate Hill.

The persistence of biodiversity of threatened invertebrates is predicted to be lowest across much of the lower altitude parts of the main island, including the settlement area, and also the cleared parts of Blackburn Island (Figure F). The most secure areas are indicated in the higher parts of the southern mountains.

Invertebrate assemblages (snails, spiders, beetles, ants)

Habitat richness for the invertebrate assemblages used outputs from Cassis *et al.* (2003), where species richness was interpolated between survey sites (see Figures 5 and 6 of DEC 2006). Areas of high species richness are indicated as patchily distributed across the main island, namely Far Flats, Mount Gower, Boatharbour, Intermediate Hill, Transit Hill, the northern settlement area (focussed on Stephens Reserve) and Malabar.

After modelled threats are applied, habitat richness is predicted to suffer a major loss over the entire main island due to the estimated high impact of rat predation. Offshore islands, including the Admiralty Group, Muttonbird, Blackburn and Gower Islands, are predicted to retain a moderate to high level of habitat richness.

The expected persistence of invertebrate biodiversity reflects to a large extent the patterns of richness, indicating areas of greatest species richness suffering the major losses to biodiversity (Figure G).

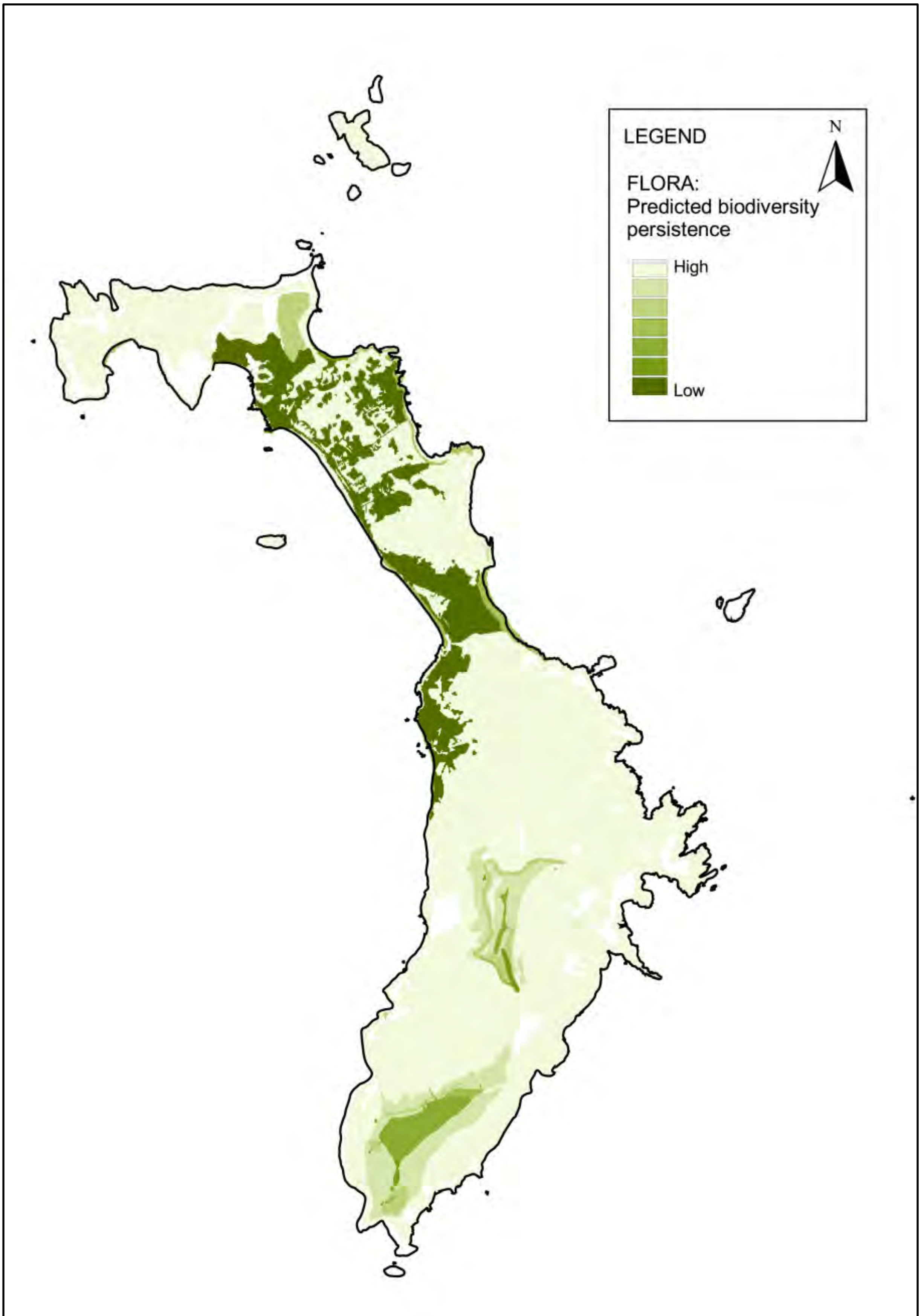

Figure D. Areas of predicted biodiversity persistence for flora of the LHIG

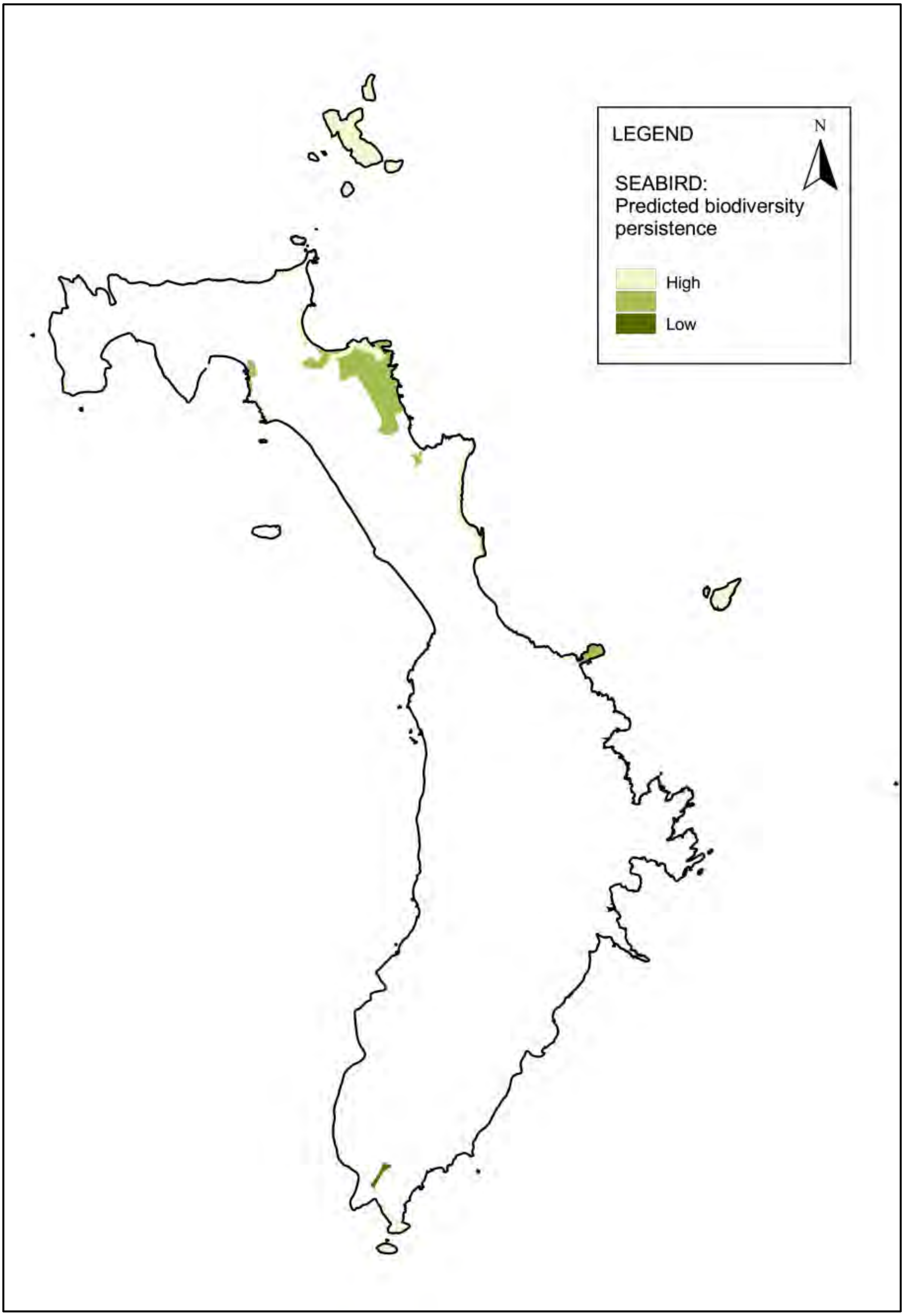

Figure E. Areas of predicted biodiversity persistence for sea birds of the LHIG

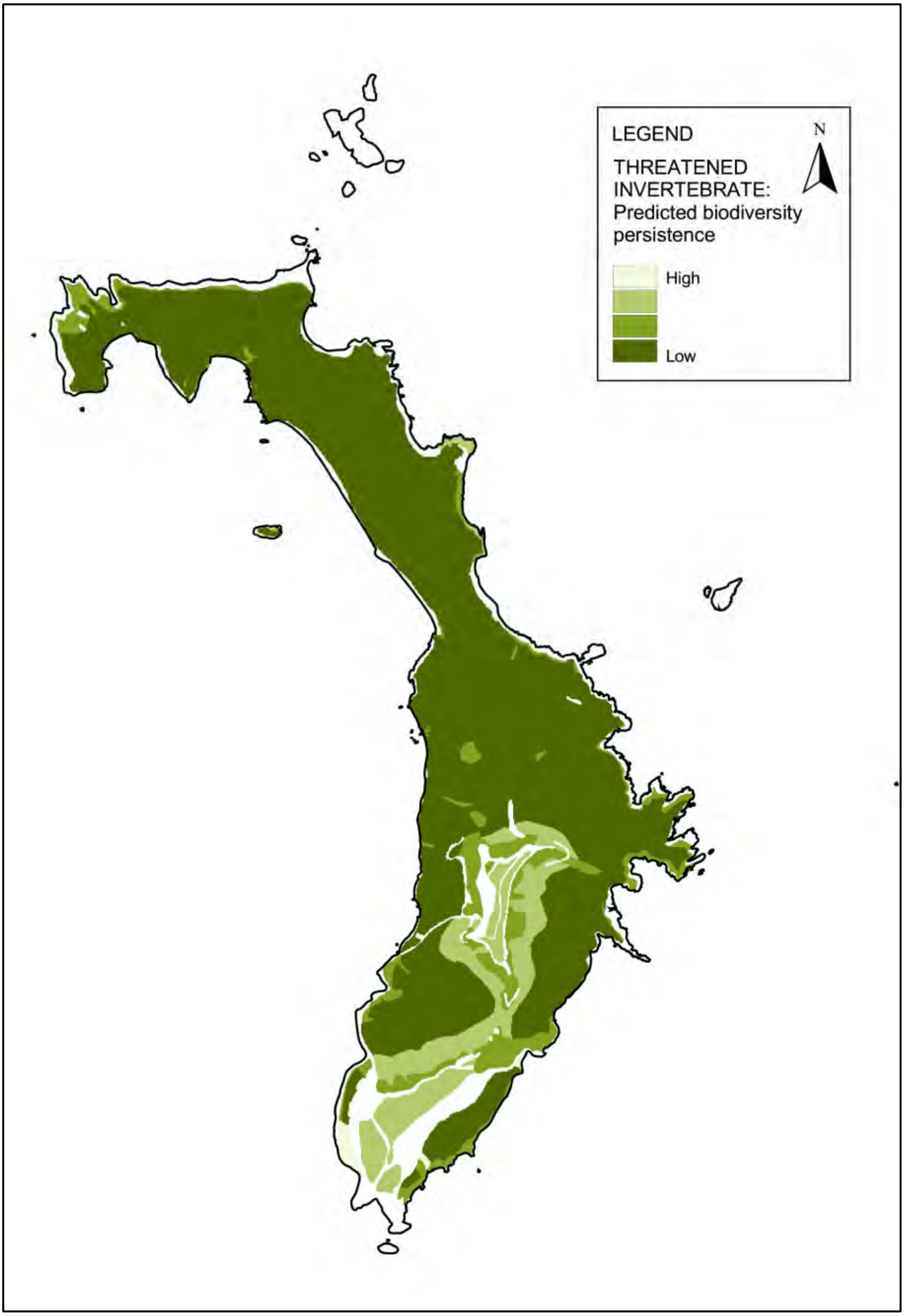

Figure F. **Areas of predicted biodiversity persistence for threatened invertebrates of the LHIG**

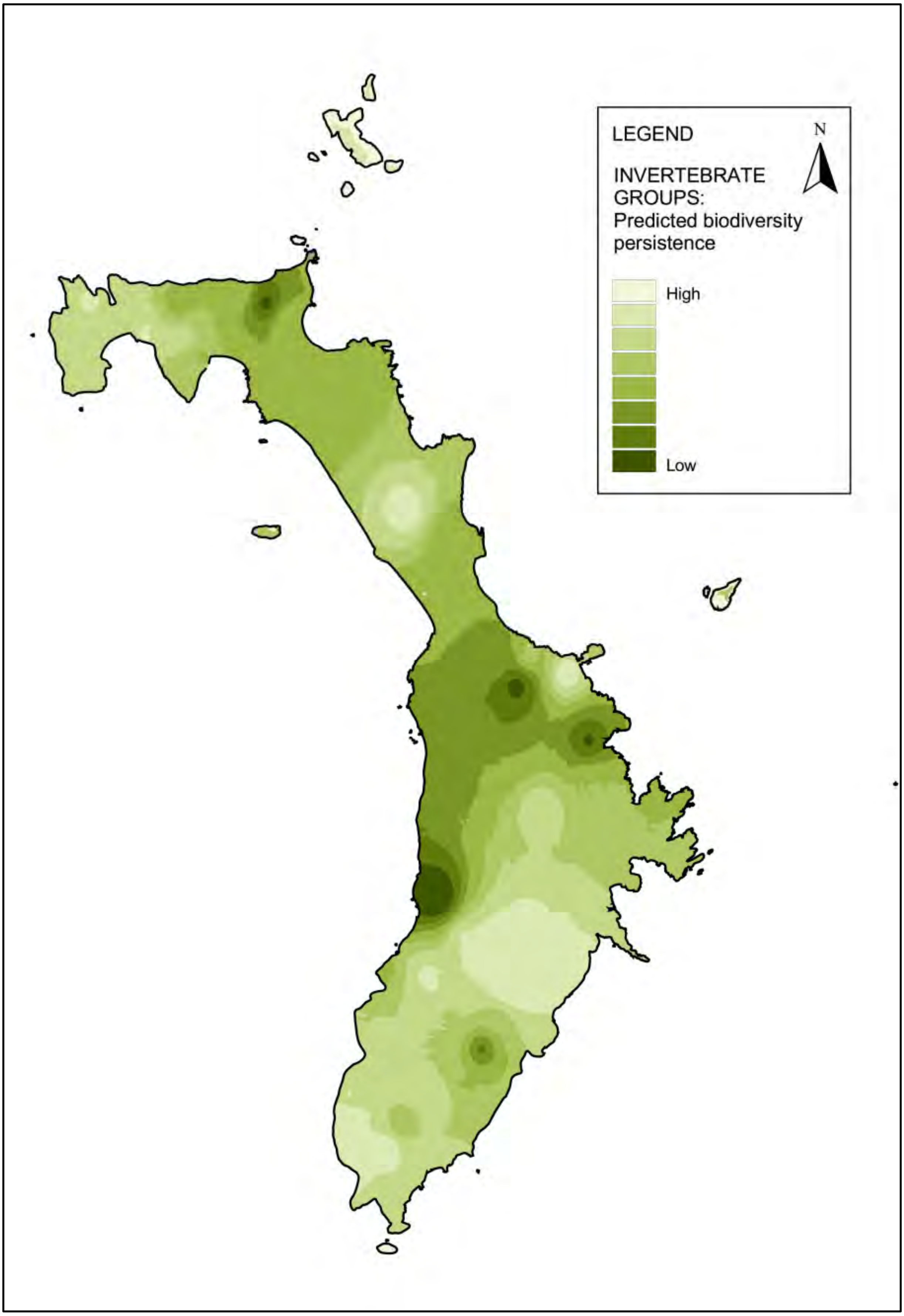

Figure G. **Areas of predicted biodiversity persistence for invertebrate groups**

Taxon Persistence

Taxon persistence is a predicted measure of the likelihood of any individual taxa or group of taxa to persist once modelled threats have impacted upon taxa or groups of taxa.

Individual flora species predicted as least likely to persist were Knicker Nut, *Chamaesyce psammogeton*, *Coprosma inopinata*, *Hymenophyllum howense*, *Hymenophyllum moorei*, Little Mountain Palm, Mountain Rose (*Metrosideros nervulosa*) and *Plectorrhiza erecta.*

The vegetation communities predicted as least likely to persist (in order of communities at greatest risk) were: Sallywood Swamp Forest, Mangroves (*Aegiceras corniculatum*), Lowland Freshwater Instream, Upland Freshwater Instream, Greybark-Blackbutt, Coral Sand and Beach Dune and the Kentia Palm on coral sand Communities.

Vertebrate fauna are generally predicted to have a relatively high probability of persistence. This is likely to be because the impacts of significant threats, such as rodent predation, have already occurred, including the extinction of those species most susceptible to rodent predation.

The threatened invertebrates (Lord Howe Island Earthworm, Lord Howe Island Phasmid, Lord Howe Island Wood-eating Cockroach and Lord Howe Island Placostylus) are most at risk with a predicted likelihood of persistence at less than 50% given the impact of modelled threats. Individual threatened invertebrate species least likely to persist are the Lord Howe Island Phasmid, followed by the Lord Howe Island Wood-eating Cockroach, and the Lord Howe Island Placostylus while the Lord Howe Island Earthworm is predicted to be secure.

Summary of High Conservation Priority Sites

The areas of greatest conservation priority were based on those sites indicated to have high conservation value and the lowest predicted persistence per species, group or vegetation community.

Flora

- Threatened plant habitat in, or adjacent to, the settlement area (*Calystegia affinis* habitat on the Max Nicholls track at Old Settlement and in the southern mountains, Knicker Nut habitat at Neds Beach and between Signal Point and Old Settlement Beach).
- The top of Mounts Gower and Lidgbird, and Waterfall Cliff areas in the southern mountains.
- *Chamaesyce psammogeton* habitat at Blinky Beach, *Polystichum moorei* habitat at Kings Beach.

Vegetation communities

- Sallywood Swamp Forest sites.
- Mangrove communities, especially those within the settlement area.
- Upland and Lowland Freshwater Instream communities and Grey Saltbush community in the northern hills.
- The remainder of vegetated areas in the settlement area.

Vertebrate fauna

- Watercourses in the settlement area (Cobby's Corner, Soldiers Creek and Old Settlement).
- For sea birds, the eastern settlement area between Neds Beach and Middle Beach, offshore islands, Muttonbird Point, Signal Point to Old Settlement Beach.

Threatened invertebrate fauna

- The main island below 300 m elevation and Blackburn Island.
- Sallywood Swamp Forest.
- Soldiers Creek.
- Far Flats, Intermediate Hill, Malabar.

Threat Consequences

Threat consequences predict what impact each modelled threat will have on biodiversity persistence for any group of species or individual species. Areas that are most at risk from each threat are also identified.

A summary of the predicted impacts of threats is provided in Table 2. Those threats that do not measure an impact, or where impacts are very minor, are not included. Example maps of threat consequences are provided to illustrate particular trends or significant areas.

Summary of threat consequences

Threat consequences output by the BFT can be summarised in two ways; by identifying priority sites, and by identifying the most significant threats across all species and vegetation communities. Priority sites based on biodiversity values and the most significant threats as predicted by the BFT are provided below.

There is some repetition in the list of sites depending on areas that were indicated by the BFT outputs, i.e. some areas indicated were broad, whereas others pinpointed more specific areas.

Sites most under threat

First priority

- Sallywood Swamp Forest
- Mangrove communities in the settlement area
- Freshwater instream habitats
- Threatened plant habitat (*Calystegia affinis*, Knicker Nut, *Polystichum moorei)*
- Waterfall Cliff community

Second priority

- Blackburn Island
- southern mountains, in particular Cloud Forest, Mountain Palm Forest and Cliffs.
- *Coprosma inopinata-Alyxia squamulosa* community (southern mountains)
- settlement area

Third priority

- Coral Sand and Beach community
- eastern settlement area
- Muttonbird Point
- Intermediate Hill
- Old Settlement to Signal Point
- Far Flats
- Shorelines of settlement area
- Neds Beach to Clear Place
- Greybark-Blackbutt community
- Mixed Fern and Herbfield community
- Cliffs of the northern hills
- Malabar and northern hills

Fourth priority

- Restricted vegetation communities (Grey Saltbush, *Poa poiformis*, Bully Bush-*Poa*, Leafy Flat Sedge, Hop Bush, *Boehmeria calophleba-Macropiper hooglandii*
- Kentia Palm communities
- Lagoon foreshores
- Muttonbird Island, and other offshore islands (except Blackburn Island)
- Lowland Mixed Forest community
- Transit Hill

Most significant threats to biodiversity

While the BFT is useful in providing guidance on the relative significance and predicted impacts of threats, it is important to acknowledge that only those threats that can be spatially represented are included in the BFT analyses. Significant threats such as the potential for new pest species and disease introductions are not included here.

The most significant threats identified by the BFT outputs are:

- Clearing;
- Trampling, browsing and grazing;

- Weed invasion;
- Ship Rat predation; and
- Climate change.

Table 2. Summary of the predicted impacts of threats on biodiversity persistence

Threat	Consequences
Past Clearing	Significant past consequences for vegetation communities throughout the settlement area. Sallywood Swamp Forest is ranked extremely highly. Other areas that rank very highly include Mangrove communities and freshwater instream habitats in the settlement area. Has significantly impacted on sea bird persistence, particularly in the eastern settlement area where habitat for sea birds is rich. A high impact on persistence for threatened invertebrates is predicted in the settlement area and on Blackburn Island. This is influenced by the lost habitat of the Lord Howe Island Wood-eating Cockroach and the Lord Howe Placostylus.
Future Clearing	Limited to vegetated areas that are at some risk of being cleared in the future (Figure H). Predicted to be a significant threat for vegetation communities throughout the settlement area. Remnant areas of Mangrove community rank extremely highly. Greybark-Blackbutt, Kentia Palm on Coral and Coral Sand and Beach Dune communities rank moderately. Predicted to have an impact on sea bird persistence, particularly in the eastern settlement area where habitat for sea birds is rich. A high level of impact is predicted for non-sea bird vertebrates on vegetated creeklines around Soldiers Creek, Cobby's Corner and Old Settlement Creek and its tributaries. A moderate level of impact is indicated for the rest of the remnant vegetation in the settlement area. Clearing is predicted to have a significant impact on persistence for threatened invertebrates in the settlement area (Lord Howe Placostylus).
Trampling, browsing and grazing	Impacts are patchily distributed across the various vegetation communities of the settlement area. The predicted impact is extremely high for the Sallywood Swamp Forest community, and for non-sea bird vertebrates in the watercourses in the vicinity of Soldiers Creek. Freshwater Instream and Greybark-Blackbutt communities in the northern settlement area are indicated at a lower level.
Weed invasion – combined weed species	Predicted to have a significant impact across the main island and offshore islands for flora (Figure I). Very high levels of impact are predicted for the threatened plant *Calystegia affinis* habitat in the southern mountains and at Old Settlement. High and moderate levels are also indicated for areas in the southern mountains, especially clifflines. Predicted to have a wide extent of impact on the non-sea bird vertebrate group, especially in the southern mountains, northern part of Intermediate Hill, Erskine Creek, Transit Hill and Windy Point. Predicted to have a moderate level of impact on threatened invertebrates for Blackburn Island. Predicted to have the most significant impact on sea birds in parts of the clifflines of the northern hills and around to Neds and Middle Beaches, adjacent to Muttonbird Point and near Boatharbour. Predicted to have an impact on vegetation communities on a large area on the main island and offshore islands. Communities most at risk are of Greybark-Blackbutt in the northern hills, areas of Saltmarsh (*Atriplex* sp.), the *Boehmeria-Macropiper*, followed

	by *Poa poiformis* and Bully Bush-*Poa* in the northern hills and offshore islands, Mixed Fern and Herbfield, *Dracophyllum-Metrosideros* in the southern mountains, and the rare and restricted *Alyxia-Coprosma* also in the southern mountains.
Bitou Bush invasion	Predicted to have an impact on sea birds along the clifflines of the northern hills, and a small part of the southern mountains on the western part of Mount Lidgbird.
Grass Invasion	The impacts of grass invasion on sea birds is predicted to be most significant on the Admiralty Islands, Muttonbird Point, Muttonbird Island, parts of the Lagoon Foreshores, Lovers Bay and King Point. Ant spider, beetle and snail invertebrate assemblages are predicted to be affected by grass invasion, especially on Blackburn Island.
Crofton Weed invasion	Predicted to have a patchy but relatively high impact on vegetation communities in the southern mountains. These impacts are within the Mixed Fern and Herbfield and Waterfall Cliff communities.
Cherry Guava invasion	Predicted to have an impact on flora in the southern mountains, both within and outside of the PPP.
Tiger Lily invasion	A high level of impact is predicted in the Waterfall Cliff community of the southern mountains.
Predation by the Ship Rat	The highest impact for flora is predicted in the Cloud Forest on Mounts Lidgbird and Gower. Moderate impacts are indicated in widespread areas in other parts of the southern mountains as well as areas around North Bay and in the settlement area. Most significant impact for sea birds on Muttonbird Point. A low impact is indicated in the northern hills, lagoon foreshores and Neds Beach to Clear Place. Predicted to have a low level impact on non-sea bird vertebrates across much of the main island. The low impact level most likely reflects that impacts from the Ship Rat have already occurred, including past species extinctions. For threatened invertebrates, the highest impact is predicted in uncleared parts of the settlement area and at lower altitude parts of the northern and southern PPP. For invertebrate assemblages, Far Flats and the Get Up Place are the areas indicated as being most impacted, followed by Boat Harbour, Malabar and parts of the settlement area. The vegetation communities predicted to be most significantly impacted are Kentia Palm, Blue Plum and Curly Palm communities.
Predation by Dogs	Low level impact predicted on sea birds and shoreline wading birds indicated at Clear Place, Middle Beach, Blinky Beach, Lagoon Foreshores and the eastern coastline.
Ground water pollution	High level of impact for non-sea bird vertebrates where potential septic pollution of watercourses may occur.
Climate change	Predicted to have a minor impact on sea bird persistence on the coastline where nesting habitat most commonly occurs. Relatively low level of impact predicted for shore birds. For flora, areas predicted as being most impacted include Knicker Nut habitat, Waterfall Cliff areas, habitat for the Endangered fern *Polystichum moorei* in the southern mountains, Cloud forest and *Alyxia squamulosa-Coprosma inopinata* community in the southern mountains. Vegetation communities predicted to be most impacted include Mangrove, freshwater and Waterfall Cliff Communities, cloud forest and much of the coastline areas.

Management scenarios and review of management

The BFT allows for a number of conservation management actions to be analysed together as management scenarios to predict each scenario's overall benefit to biodiversity. A management scenario, for example, may consist of rat eradication, fencing and weed control management actions.

It is also possible to introduce the cost of implementing each management action within each scenario and thereby estimating the cost/biodiversity benefit of each scenario, thus allowing an assessment of which scenario has the greatest biodiversity benefit given the financial cost of actions. This capability can be used to assist with prioritising management scenarios.

The BFT can also be used to review the impact of implementation of management actions and scenarios and to identify future priorities. It is possible to input management scenarios and costs for the LHI BMP but time constraints have not allowed this capability to be realistically presented for this report.

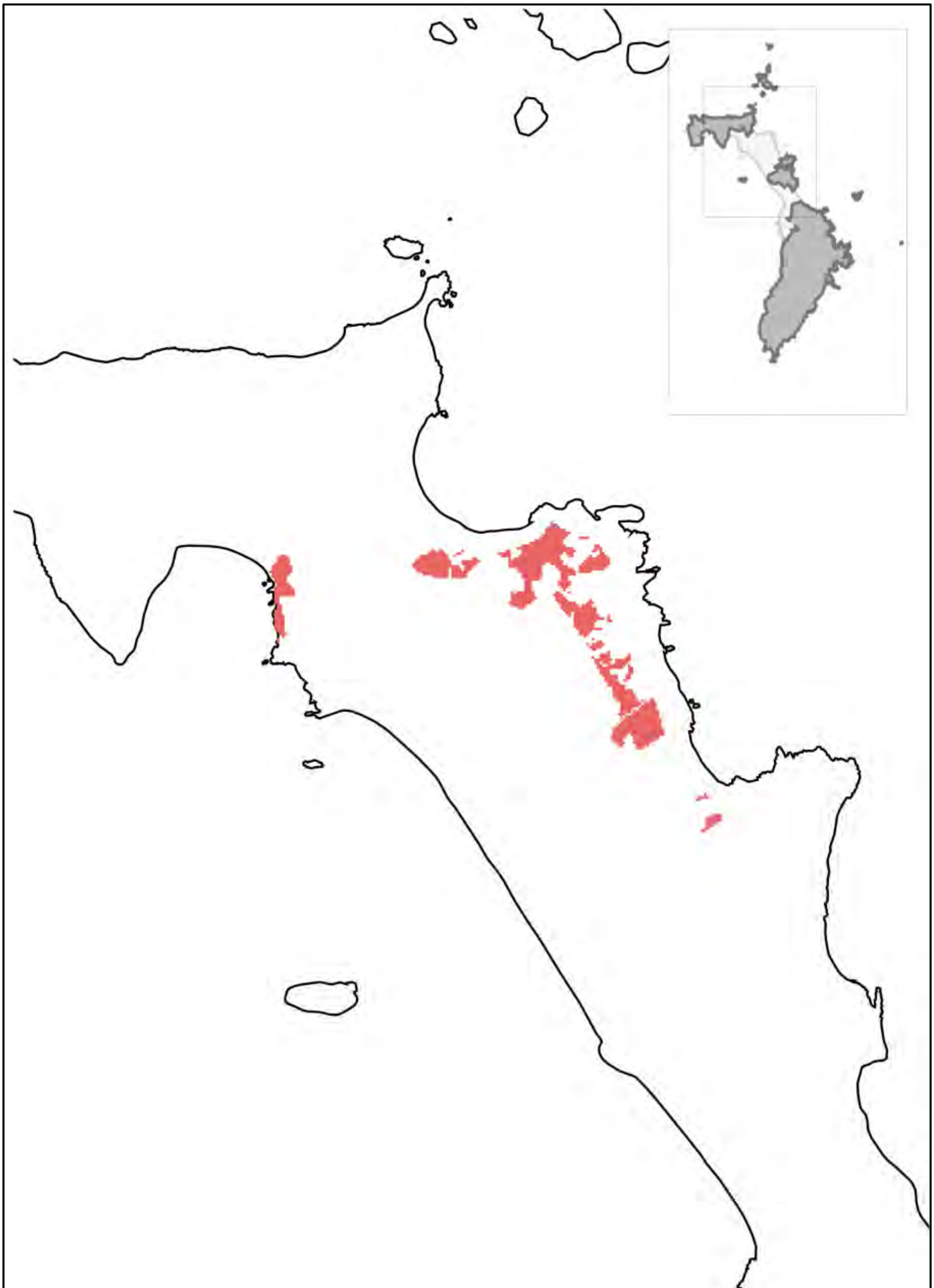

Figure H. Areas where future clearing is predicted to have the greatest impact on sea birds

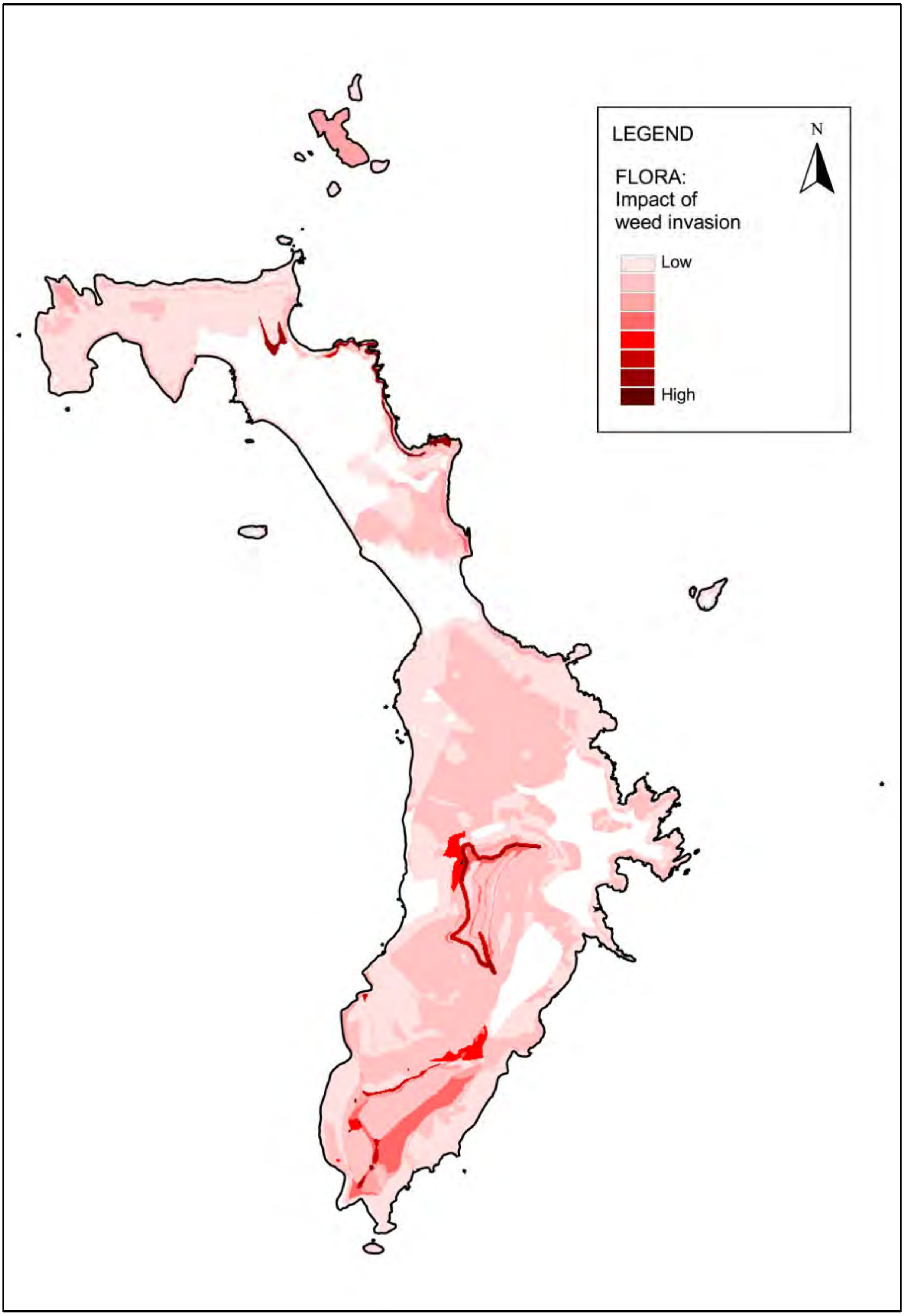

Figure I. Areas where weed invasion is predicted to have the greatest impact on flora biodiversity values

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Lord Howe Island Rodent Eradication Project

NSW Species Impact Statement

February 2017

Appendix I - Island Eradications Using Pestoff

TABLE M . SUCCESSFUL ISLAND ERADICATIONS USING PESTOFF® RODENT 20R (Broome and Fairweather 2016)

SPECIES & LOCATION	YEAR	AREA (sq km)	METHOD & RODENTICIDE USE	POPULATION	REFERENCE
Ship Rat					
Quail (Lyttleton	2002	.850	Bait stations (Pestoff® Rodent 20R) followed up by Talon® WB)	None	Kavermann et al. (2003)
Pearl	2005	5.12	Aerial (Pestoff® Rodent 20R)	None	Pestlink report 0506SIS02
Picker	2005	1.030	Aerial (Pestoff® Rodent 20R)	None	M Aviss pers comm..
Taukihepa (Big South Cape)	2006	9.330	Aerial (Pestoff® Rodent 20R)	None	Pestlink report 0506SIS02
Pukeweka	2006	.032	Aerial (Pestoff® Rodent 20R)	None	Pestlink report 0506SIS02
Rerewhakaupoko (Solomon)	2006	.345	Aerial (Pestoff® Rodent 20R)	None	Pestlink report 0506SIS02
Rangitoto/Motutapu	2009	23,11 / 1509	Aerial (Pestoff® Rodent 20R)	Unknown	Docdm-898404
Macquarie (Australia)	2011	12,876	Aerial (Pestoff® Rodent 20R)	11-100	Springer 2016
Great Mercury	2014	21.756	Aerial (Pestoff® Rodent 20R)	Unknown	DOCDM-1559634
			Aerial (Pestoff® Rodent 20R)		

SPECIES & LOCATION	YEAR	AREA (sq km)	METHOD & RODENTICIDE USE	POPULATION	REFERENCE
Moturua; Okahu; Te Ao; Moturua, Urupukapuka	2009	.5990	Aerial (Pestoff® Rodent 20R)	None	DOCDM-483696
House mouse			Aerial (Pestoff® Rodent 20R)	None	
Enderby (Auckland)	1993	7.1	Aerial (Pestoff® Rodent 20R)	None	Torr (2002)
Motuihe (Hauraki Gulf)	1997	1.79	Aerial (Pestoff® Rodent 20R)		Veitch (2002a)
Mokoia (Lake Rotorua)	2001	1.35	Aerial (Pestoff® Rodent 20R)	None	Pestlink: 0304ROT01
Selvagem Grande (Portugal)	2002	3	Aerial (Pestoff® Rodent 20R)	None	Olivera et al. (2010)
Blumine (Marlborough)	2005		Aerial (Pestoff® Rodent 20R)		M Aviss pers. 2omm..
Ohinau (Coromandel)	2005	.46	Aerial (Pestoff® Rodent 20R)	None	R Chappell DOCDM-314307
Tonga (Abel Tasman)	2007	.146	Aerial (Pestoff® Rodent 20R)	None	Pestlink report 0708MOT06
Adele(Abel Tasman)	2007	.880	Aerial(Pestoff® Rodent 20R)	None	Pestlink report 0708MOT06
Fisherman(Abel Tasman)	2007	.146	Aerial (Pestoff® Rodent 20R)	None	Pestlink report 0708MOT06

SPECIES & LOCATION	YEAR	AREA (sq km)	METHOD & RODENTICIDE USE	POPULATION	REFERENCE
Pomona (Lake Manapouri)	2007	2.62	Aerial (Pestoff® Rodent 20R)	None	Pestlink report 0708TEA10
Rona (Lake Manapouri)	2007	.6	Aerial (Pestoff® Rodent 20R)	None	Pestlink report 0708TEA10
Montague (Australia)	2007	1,128	Aerial (Pestoff® Rodent 20R)	None	http://www.abc.net.au/news/stories/2009/06/24/2606639.htm?site=news
Rangitoto/Motutapu	2009	23	Aerial (Pestoff® Rodent 20R)	Unknown	Docdm-898404
Macquarie (Australia)	2011	12,876	Aerial (Pestoff® Rodent 20R)	11-100	Springer 2016
Maud (Marlborough Sounds)	2014	3	Aerial (Pestoff® Rodent 20R)	None	DOCDM-2617140.
Kiore (Pacific Rat)					
Inner Chetwode (Nukuwaiata)	1993	2.4	Aerial (Wanganui #7)	None	Brown (1997a)
Kapiti	1996	19.6	Aerial & handlaying (Talon® 7-20)	11-100	Empson & Miskelly (1999)
Fanal (Mokohinau)	1997	.73	Aerial (Talon® 7-20)	None	Veitch (2002b)
Whangaokena (East)	1997	3.8	Aerial (Talon® 7-20) plus handlaid Talon® 50WB	None	Bassett (1999)

SPECIES & LOCATION	YEAR	AREA (sq km)	METHOD & RODENTICIDE USE	POPULATION	REFERENCE
Whakaterepapanui	1999	.74	Aerial & handlaying (Pestoff® Rodent 20R)	None	P. Gaze pers. 4omm..
(Rangitoto)					
Mayor (Tuhua)	2000	12.7	Aerial (Pestoff® Rodent 20R)	None	Williams (2002)
Raoul (Kermadecs)	2002	29.3	Aerial (Pestoff® Rodent 20R)	Unknown	M. Ambrose pers. comm Pestlink: 0203WAR37
Hauturu (Little Barrier)	2004	30.8	Aerial (Pestoff® Rodent 20R)	None	Griffiths pers. 4omm Pestlink: 0405WAR03
Bench	2005	1.2	Aerial (Pestoff® Rodent 20R)	None	Pestlink report 0506SIS01
Pearl	2005	5.1	Aerial (Pestoff® Rodent 20R)	None	Pestlink report 0506SIS02
Big Moggy (Mokonui)	2006	.86	Aerial (Pestoff® Rodent 20R)	None	Pestlink report 0607SIS01
Rangitoto/Motutapu	2009	24	Aerial (Pestoff® Rodent 20R)	Unknown	Docdm-898404
Moturua	2009	1.9	Aerial (Pestoff® Rodent 20R)	None	DOCDM-483696
Taranga (Hen)	2011	5	Aerial (Pestoff® Rodent 20R)	None	Pestlink report 1011WNG12
Great Mercury	2014	21	Aerial (Pestoff® Rodent 20R)	Unknown	DOCDM-1559634
Norway rat					
Kapiti	1996	20	Aerial & Bait Stations (Talon® 7-20)	11-100	Empson & Miskelly (1999)

SPECIES & LOCATION	**YEAR**	**AREA (sq km)**	**METHOD & RODENTICIDE USE**	**POPULATION**	**REFERENCE**
Motuihe (Hauraki Gulf)	1997	1.79	Aerial (Talon® 7-20)	None	Veitch (2002a)
Puangiangi	1999	.69	Aerial & handlaying (Pestoff® Rodent 20R)	None	Pestlink: 0203SND07
(Rangitoto)					
Tinui (Rangitoto)	1999	.95	Aerial (Pestoff® Rodent 20R)	None	Pestlink: 0203SND07
Whakaterepapanui (Rangitoto)	1999	.74	Aerial (Pestoff® Rodent 20R)	None	Pestlink: 0203SND07
Mayor (Tuhua)	2000	12.7	Aerial (Pestoff® Rodent 20R)	None	Williams (2002)
Campbell	2001	.67	Aerial (Pestoff® Rodent 20R)	None	McClelland (2001)
Quail (Lyttleton)	2002	.85	Bait stations (Pestoff® Rodent 20R followed up by Talon® WB)	None	Kavermann et al. (2003)
Rakino (Hauraki Gulf)	2002	1.5	Bait stations (Pestoff® Rodent 20R)	11-100	G.Wilson Pestlink: 0405AKD06
Raoul (Kermadecs)	2002	30	Aerial (Pestoff® Rodent 20R)	Unknown	M.Ambroseperscomm Pestlink: 0203WAR37
Rangitoto/Motutapu	2009	24	Aerial (Pestoff® Rodent 20R)	Unknown	Docdm-898404

SPECIES & LOCATION	YEAR	AREA (sq km)	METHOD & RODENTICIDE USE	POPULATION	REFERENCE
{Motuarohia; Moturua; Motukiekie; Poroporo; Urupukapuka; Waewaetorea; Okahu; Rangiatea;	2009	.9	Aerial (Pestoff® Rodent 20R)	None	DOCDM-483696
Motungarara}					
Ulva	2011	2.70	Aerial (Pestoff® Rodent 20R)	None	Masuda et al 2015

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Appendix J - Marine Hypothetical Scenario

J.1 Marine Hypothetical Effects

J.2 Attraction of Fish to Bait

ATTACHMENT 7 – HYPOPTHETICAL MARINE EFFECTS

A hypothetical evaluation of the effect of extreme brodifacoum contamination of the sea around Lord Howe Island on Marine Mammals; a worst-case scenario.

Around 33 species of marine mammal, about two thirds of which are whale species, have been listed as occurring in the waters of the Lord Howe Island Marine Park.

There is no realistic pathway by which these mammals can be exposed to rodenticide at the Lord Howe Island Group because: a) brodifacoum is poorly soluble in water (WHO 1995) therefore dermal absorption of dissolved rodenticide is not a risk; and b) little, if any, brodifacoum is likely to enter the food chain (Cole and Singleton 1996; Empson and Miskelly 1999; Howald et al. 2005; U.S. Fish and Wildlife Service and Hawai'i Department of Land and Natural Resources 2008; Samaniego-Herrera et al. 2009) so the risk of brodifacoum ingestion is also negligible.

One of the most common whale species in the marine park is the Humpback *Megaptera novaeangliae*. Although this is a baleen whale and therefore feeds on krill, the following hypothetical examples either assume that this species will eat pellets (primary poisoning) or will consume more-substantial marine species than krill, and which contain brodifacoum (secondary poisoning). It also assumes that this species is feeding in the marine park on its return to its feeding grounds in the Antarctic. Based on the Ship Rat LD50 value of 0.27 mg/kg body weight, a 45,000 kg Humpback Whale would have to ingest 12,150 mg of brodifacoum to receive an LD50–equivalent dosage. To obtain this amount, the whale would have to consume 607 kg of Pestoff® 20R, or more than 300,000 bait pellets; yet it is unlikely that the number of pellets that fall into the sea would be at a density greater than 14 pellets/100 metres of coastline (Howald et al. 2005).

The possibility of Humpback Whales being harmed by brodifacoum after consuming marine prey items that have ingested the rodenticide is also very remote, based on the analyses in Section 4.5.1.1d Risks to aquatic life above. The most conservative (worst case) analysis of this scenario will be constructed using data from the 18 tonne brodifacoum spill in New Zealand, resulting from a truck crash on the coast (see Appendix 3). This scenario assumes an adult female Humpback Whale (45,000 kg) will feed exclusively in an area massively contaminated to the extent documented at the spill site in New Zealand, and to feed exclusively on the most contaminated organisms collected during the monitoring of that incident (mussels). One day after the New Zealand truck spilt 18 tonnes of bait pellets directly into nearshore marine waters, mussels contained brodifacoum residues of 0.41 ppm. To ingest 12,150 mg of pure brodifacoum to receive an LD50–equivalent dosage (see above) a Humpback Whale would have to consume 29,634 kg of prey, more than half her body weight, contaminated at the 0.41 ppm level found in mussels collected one day after the New Zealand spill; an impossible scenario.

Several species of dolphin, e.g. the Bottlenose Dolphin *Tursiops truncatus*, have been observed in the marine park. Adult Bottlenose Dolphins can weigh between 150 to 650 kg (Western Australian Marine Parks Authority 2010), and consume approximately 15 kg of fish per day. At nine days post-spill in New Zealand, butterfish had residue concentrations of 0.04 ppm in the liver and 0.02 ppm in the gut, and below the method limit of detection (<0.02 ppm) in the muscle tissue (Primus et al. 2005). Assuming that the LD50 of a Bottlenose Dolphin is 0.27 mg/kg, that it has a body weight of 400 kg and that it ate only fish whose whole bodies were as contaminated as the liver sampled at the spill site, it would have to eat 2,700 kg, or more than six times its total body weight, of brodifacoum-contaminated tissue to receive an LD50 dose; another unlikely scenario.

The required amount of brodifacoum to result in an LD50 by dermal absorption for the Ship Rat is 3.16 mg/kg. Assuming this concentration is also required for dolphins, than an adult would need to be in contact with 1,264 mg of brodifacoum, i.e., the amount of brodifacoum in 60 kg of bait or 30,000 pellets. As brodifacoum is practically insoluble in water, the risk posed to dolphins by means of dermal absorption of brodifacoum is negligible at most.

The Australian Fur Seal *Arctocephalus pusillus* and New Zealand Fur Seal *A. forsteri* are occasional visitors to the marine park (MPA 2010). Males weigh between 120 kg to 360 kg, and females between 35 kg and 113 kg (Australian Museum 2010, Western Australian Marine Parks Authority 2010). They feed on fish, squid and octopus therefore it is highly unlikely that direct ingestion of Pestoff® 20R pellets would occur during the proposed baiting. Even in the unlikely event that a fur seal ate bait pellets, a 100 kg fur seal would have to ingest 27 mg of pure brodifacoum to receive an LD50–equivalent dosage (based on the Ship Rat LD50 value of 0.27 mg/kg body weight). To obtain this amount, the seal would have to ingest more than 1.3 kg of Pestoff® 20R bait pellets (i.e. more than 650 pellets). Even if a fur seal was attracted to bait pellets as a food item, it is extremely unlikely that it could find this many as only low numbers of pellets have been recorded to land in the sea (Howald et al. 2005; Samaniego-Herrera et al. 2009) and those that do quickly disintegrate (Empson and Miskelly 1999).

The possibility of fur seals being exposed to rodenticides by consuming marine prey items that have ingested rodenticides is also very remote, based on the analyses in Section 4.5.1.1b above. The most conservative (worst case) analysis of this unlikely scenario will be constructed using data from the 18 tonnes of brodifacoum spilt in New Zealand (Appendix 3). This scenario assumes an adult fur seal of weight 100 kg feeds exclusively in an area massively contaminated by brodifacoum, and only on the most contaminated organisms collected during the monitoring of that incident (i.e., mussels containing brodifacoum residues of 0.41 ppm). Based on the Ship Rat LD50 value of 0.27 mg/kg body weight, a 100-kg fur seal would have to ingest 27 mg of pure brodifacoum to receive an LD50–equivalent dosage. To obtain this amount, the seal would have to eat 65 kg of mussels contaminated at the 0.41 ppm level found in mussels collected one day after the New Zealand spill, i.e., more than half the seal's bodyweight in heavily contaminated prey.

At nine days post-spill in New Zealand, butterfish had residue concentrations of 0.04 ppm in the liver and 0.02 ppm in the gut, and below the method limit of detection (<0.02 ppm) in the muscle tissue. However, conservatively assuming that a fur seal ate only fish whose entire bodies were as contaminated as the liver sampled at the spill site, it would have to eat 675 kg of contaminated tissue (almost seven times its total bodyweight) to receive an LD50 dose. Therefore, even using unrealistic assumptions based on a worst case, no effects to fur seals would be expected to occur from indirect ingestion of rodenticide in contaminated prey.

Dermal absorption of dissolved rodenticide is also not a risk for fur seals due to the virtual insolubility of brodifacoum in water and the low amount of bait that may fall into the sea.

ATTRACTION OF FISH TO BAIT

Attraction of nearshore marine fishes to placebo Ramik Green rat bait pellets (2-3 gram size) at Lehua Island, Hawai'i, September 18-19, 2004

:- data from the *Final Supplemental Environmental Assessment Lehua Island Ecosystem Restoration Project: October 2008* (U.S. Fish and Wildlife Service and Hawai'i Department of Land and Natural Resources (2008), Honolulu, Hawaii) reporting that none of the fish observed consumed bait pellets.

Common Name	**Scientific Name**	**Total # of Fish**	**Inspected Bait***	**Touched Bait***	**Consumed Bait***	**Number of bait interactions per species**
Orangespine Unicornfish	*Naso literatus*	13	10	8	0	18
Convict Tang	*Acanthurus triostegus*	8	0	0	0	0
Whitebar Surgeonfish	*Acanthurus leucopareius*	85	19	0	0	19
Orangeband Surgeonfish	*Acanthurus olivaceous*	7	3	5	0	8
Achilles Tang	*Acanthurus achilles*	2	0	0	0	0
Ringtail Surgeonfish	*Acanthurus blochii*	1	0	0	0	0
Eyestripe Surgeonfish	*Acanthurus dussumieri*	1	0	0	0	0
Lagoon Triggerfish	*Rhinecanthus aculeatus*	1	1	0	0	1
Black Durgon	*Melichthys niger*	6	21	13	0	34
Pinktail Durgon	*Melichthys vidua*	5	13	9	0	22
Moorish Idol	*Zanclus cornutus*	1	0	0	0	0
Ornate Butterflyfish	*Chaetodon ornatissimus*	1	0	0	0	0
Longnose Butterflyfish	*Forcipiger longirostris*	1	0	0	0	0
Cornetfish	*Fistularia commersonnii*	1	0	0	0	0
Gray Reef Shark (juv.)	*Carcharhinus amblyrynchos*	1	1	0	0	1
Blackspot Sergeant	*Abudefduf sordidus*	1	3	0	0	3
Manybar Goatfish	*Parupeneus multifasciatus*	2	0	0	0	0
Blue Goatfish	*Parupeneus cyclostomus*	3	0	0	0	0
Yellowstripe Goatfish	*Mulloidichthys flavolineatus*	1	0	0	0	0
Hawaiian Hogfish	*Bodianus bilunulatus*	1	1	1	0	2
Parrotfish spp.	Family *Scaridae*	2	0	0	0	0

*** some individuals interacted multiple times**

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Appendix K - Land Snail Survey 2016

K.1 Australian Museum Assessment of Potential Impacts on Land Snails Report

Lord Howe Island Rodent Eradication Project: Assessment of potential impacts on land snails

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19 September 2016

Contents

Summary

Predation by introduced rats and mice is the most significant threat to land snails on Lord Howe Island (LHI). This impact is of national environmental significance as it has been causing a long-term decrease in the size of populations of critically endangered species.

Given the restricted distribution and population size of these island endemics, especially the endangered species, addressing this impact will significantly contribute to their long term conservation. A possible side effect of the planned broadcast of poisoned baits (brodifacoum), however, is the lethal poisoning of the snails themselves. The susceptibility of one Lord Howe Island species, *Placostylus bivaricosus*, has been tested in an experimental setup indicating that this species may not be susceptible to this toxin. In other studies, however, it has been shown that some species may be susceptible to brodifacoum poisoning. To some extent, these conflicting results could be explained by differing ecologies and behaviours among the species so far examined. Nevertheless, given these mixed results, it is not possible to fully predict the effects of the baiting on the indigenous land snails on LHI, especially given these species belong to divergent systematic groups.

To assess the potential impact on the local malacofauna, we have reviewed possible bait exposure on a per species basis taking into consideration the respective ecology and behaviour. Accordingly, we consider that all arboreal species are at a low risk of becoming exposed to baits (i.e., only a small number of individuals may get in contact with baits), that minute to small leaf litter-dwellers with small activity ranges are at moderate risk of exposure (i.e., some but not all individuals may get in contact with baits), and that large ground-dwelling species with large activity ranges are at high risk of exposure (i.e., most or all individuals may get in contact with baits).

Three of the critically endangered land snails (*Mystivagor mastersi*, *Peudocharopa ledgbirdi*, *P. whiteleggei*) are placed in the moderate risk category, but the critically endangered subspecies *Gudeconcha sophiae magnifica* is in the high risk category. This taxon belongs to the same family as and is ecologically similar to *Pachystyla bicolor* from Mauritius, a species shown to be susceptible to brodifacoum.

We recommend that for species of the high risk category experimental tests be conducted to examine their susceptibility to brodifacoum in analogy to the tests for *P. bivaricosus*. Individuals of the common subspecies *G. sophiae sophiae* can be used as surrogates for the critically endangered subspecies *magnifica*. More common species of the Charopidae can be used as surrogates for the critically endangered species belonging to the same family.

We also recommend that, where possible, insurance populations of endangered or brodifacoum-susceptible species are kept in captivity over the duration of the baiting program. However, this is probably not a realistic option for the very rare and hard to find species *M. mastersi*, *P. ledgbirdi*, and *P. whiteleggei* and may also prove challenging for the rare taxon *G. sophiae magnifica*.

Lastly, possible effects of the baiting on land snails should be monitored at selected survey sites for the duration of the program.

Overall, we consider the eradication of rodents, which represent the greatest threat to the indigenous snails, to outweigh any potential short-term negative effect. We therefore support the implementation of the program. The alternative not to conduct the program is very likely to result in the extinction of more species, in particular the critically endangered species living at high altitudes, where they are currently largely unprotected from rodent predation due to the inaccessibility of the area.

Introduction: General characterisation of the land snail fauna

Diversity, endemism and distribution

The highly diverse land snail fauna of Lord Howe Island (LHI from here on) comprises 62 extant native species (or subspecies), of which 59 are endemic to the island. One species, *Epiglypta howinsulae*, is thought to be extinct as result of rodent predation. In addition, there are twelve introduced species, some of which are pests (Stanisic et al. 2010; AM 2016) (Tables 1-2, Appendix).

The endemic species represent ten different families of both major non-marine gastropod groups, Pulmonata and Caenogastropoda: Charopidae (13 species), Punctidae (12 species), Microcystidae (11 species), Diplommatinidae (10 species), Helicarionidae (6 species or subspecies), Achatinellidae (4 species), Assimineidae (3 species), Bulimulidae (1 species), and Hydrocenidae (1 species).

In addition, up to 37 potentially undescribed species have been identified among material held by the Australian Museum through curatorial work (Table 3, Appendix). The status of these candidate species requires verification by detailed comparative taxonomic study.

Five species are currently listed as Endangered or Critically Endangered nationally (EPBC Act 1999), and one species is considered to be extinct (Table 1, Appendix). Predation by introduced mice and rats is the single most significant threat causing on-going decline in these species. However, based on the limited distribution of all island species and the predation by rodents, it is probable that additional species are eligible for listing as endangered or critically endangered in accordance with the criteria of the EPBC Act.

Current knowledge of the distribution and abundance of most species is based on several comprehensive surveys undertaken since the early 19070s, namely 1971 (534 lots), 1978 (325 lots), 1999 (866 lots), 2000 (898 lots), 2001 (762 lots), and 2002 (550 lots) (Fig. 1). Previous surveys have covered nearly the entire surface of the island, but some inaccessible parts have remained unsurveyed or poorly represented in the collection (Fig. 2). These past surveys can provide a baseline for estimating trends in the distributions and abundance over the past few decades. Such an assessment, however, would require a comprehensive survey to evaluate their current status, one beyond the scope of the assessment provided herein.

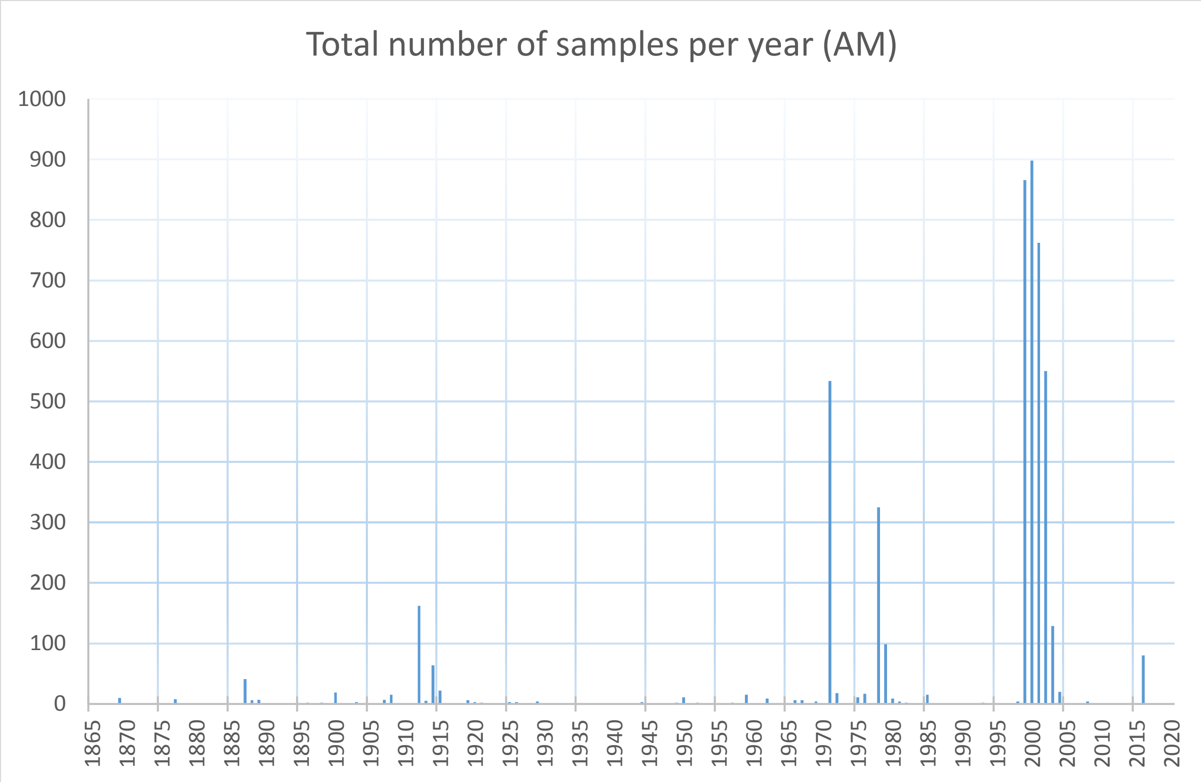

Fig. 1. Time line showing the number of terrestrial land snail samples collected per year based on 4,747 records from the Australian Museum collection between 1865 and 2015, and samples collected during the current survey in September 2016.

Previous surveys provide positive occurrence records that are based on specimens (live specimens, shells) picked up either by hand or from leaf litter samples gathered in the field and sorted subsequently in the lab.

Most species have a patchy distribution by which they are more abundant in suitable landscape pockets but uncommon or absent in habitats with less favourable microclimatic conditions. Therefore, it is almost impossible to establish with certainty that a given species is absent from a given area based on the lack of positive occurrence records. However, because of the comprehensiveness of the historical records, we can identify rare species (i.e., low abundance, locally highly restricted). Species not recorded for several decades in a certain area are likely to be locally extinct.

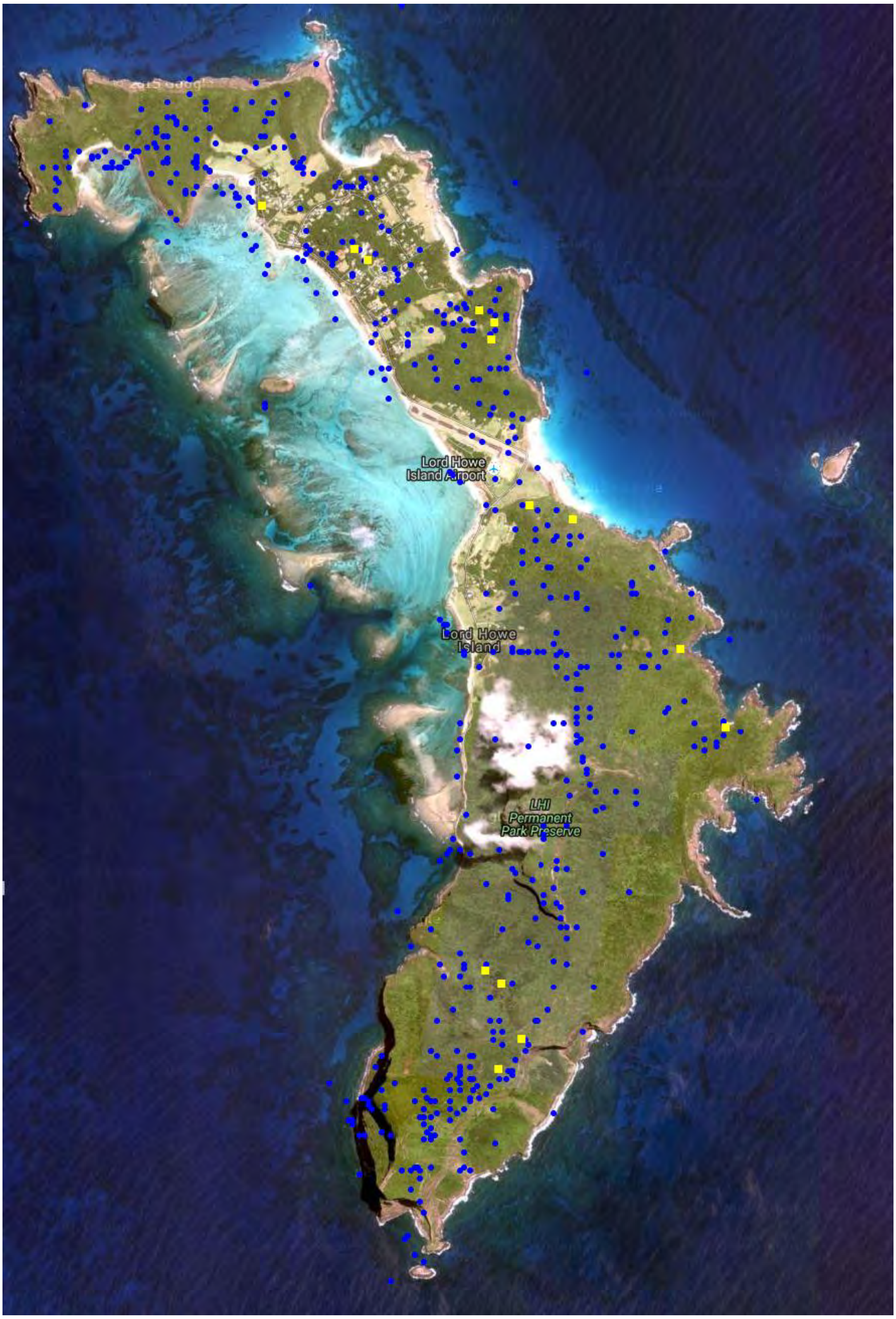

Fig. 2. Dot map showing 4,747 georeferenced occurrence records of terrestrial gastropods from the collection of the Australian Museum from 1865 and 2015 (blue dots) and sampling sites of the current survey (yellow squares).

Biology of the endemic species

Two phylogenetically very distinct major groups are found on LHI, caenogastropods and pulmonates. Caenogastropods are operculate, and breathe though gills or a highly-vascularised mantle cavity. They are generally dioceous and oviparous (Fretter et al. 1998). This group is represented by Assimineidae, Diplommatinidae and Hydrocenidae.

By contrast, pulmonates have no operculum and exhibit a particularly wide range of forms, including slugs and semislugs. They breathe through a pulmonary cavity with a well-developed vascular net and contractile pneumostome. They are generally hermaphrodites and may be oviparous or ovoviviparous. Very little is known about life history and longevity in general (Smith & Stanisic 1998). For *Westracystis lissus*, a helicarionid from the Australian mainland, a two-year life cycle has been postulated (Solem 1982). Most LHI species are likely to have short life spans of one to three years, while few are probably more long-lived, such as in particular *Placostylus bivaricosus*. The New Zealand congener *P. ambagiosus* has a life expectancy of 5 to 10 years (Stringer et al. 2014). A similar life expectancy is considered for the LHI species *P. bivaricosus*.

Overall, land snails exhibit a variety of behavioural and biological traits which may render them susceptible to possible effects of the baiting program to varying degrees. Most land snail species on LHI are small to very small (shell diameter < 6 mm). A few species are of moderate size or large (15 – 50 mm). The fauna is dominated by forest dwellers (leaf litter dwellers, some arboreal species). Many species have a restricted distribution in the south of the island, in particular at higher altitudes, while several other species are considered to be widespread and common. The native species are predominantly herbivorous and feed on fungi, biofilm and detritus. Some may be omnivorous feeding on a wide range of organic matter.

Snail activity depends on availability of moisture. Snails are usually dormant during dry weather, but become active and forage for food whenever rain or clouds provide a certain level of humidity. As the climate of LHI has no marked seasons and rain falls throughout the year, there is no strict seasonality in the activity patterns of snails. The months December to January usually represent the warmest and driest months of the year, and are therefore likely to see the lowest activity of snails. All snails are effectively nocturnal, but may also be crawling around in dim light at day time during or immediately after rain.

The activity radius of single individuals depends on lifestyle and size of the animal. The majority of minute to small leaf litter-dwellers are likely to have a very restricted range of activity; they may forage for no more than a few centimetres per day. By contrast, larger snails may well cover several meters per day (e.g., *G. sophiae*, *P. bivaricosus*). Minute arboreal species are also capable of foraging for several metres per day while crawling up and down the stems of plants from their hiding places (i.e., in bark, palm sheaths etc.) onto leaves. However, they rarely forage for larger distances on the ground since they prefer to move along vertical structures.

General ecology of different land snail families

Assimineidae. The LHI species are comparatively large for the group (< 10 mm shell length). Assimineids are probably herbivorous and live in leaf litter, particularly on fallen palm fronds, as well as under loose bark. The preferred habitat of most Lord Howe species is moist forest or woodland. Two species, *O. howeinsulae* and *L. exquisita*, are common and widespread, one is restricted to rock faces on Mt Lidgbird and Mt Gower (*L. innesi*) (Stanisic et al 2010).

Diplommatinidae. Minute to small in size with a shell of less than 5 mm length. Diplommatinids are herbivorous leaf-litter dwellers that predominantly occur on closed forests and have small ranges of activity. Species are dioceous. Some species are common and widespread (*P. capillacea*, *P. intercollis*, *P. macgillivrayi*, *P. waterhousei*), while others appear to be more localised to uncommon (e.g., *P. deliciosa*) (Stanisic et al 2010).

Hydrocenidae. Snails are rather small with a shell of less than 5 mm length. In adaptation to a terrestrial life the ctenidium in hydrocenids is degenerated and the highly vascularised mantle cavity has taken the role of a lung. Hydrocenids are herbivorous, usually live in leaf litter or on rock surfaces, where they are thought to scrape microflora from the surface. Species are dioceous. Represented by one species on LHI, which is poorly known, has rarely been collected and is considered to be highly localised to the summits of Mt Lidgbird and Mt Gower (Stanisic et al 2010), where it likely dwells on rock surfaces.

Achatinellidae. This family comprises very small species (shell length about 3 mm) and is represented on LHI by four species, of which three are endemic. Achatinellids are arboreal herbivores that feed on the biofilm growing on leafs and bark and inhabit most forest. They also inhabit dense grass on dunes and low littoral vegetation. Reproduction is either oviparous or ovoviviparous. Some species have probably been transported throughout the Indo-West-Pacific by humans in historical times (Stanisic et al 2010).

Bulimulidae. This group is represented by one species, the endangered *Plaocstylus bivaricosus*, which is the largest snail species and has particularly suffered from predation by rats, and probably also introduced blackbirds and song thrushes (Hutton 2007). Animals are rather long-lived (5 to 10 years). Adults are ground dwelling and aestivate buried into the sand during drier periods. They are nocturnal and crawl on the ground during humid or wet nights in the leaf litter in moist forests. Juveniles are arboreal. Reproduction is oviparous (Stanisic et al 2010).

Charopidae. This is group of minute snails with shells of 1.5 to 7 mm in diameter. Three critically endangered species belong in this family: *Mystivagor mastersi*, *Pseudocharopa ledgbirdi*, and *P. whiteleggei*. Species generally favour moist forests where they live in leaf litter and feed on decaying plant matter or biofilm. They have a very small range of activity as they attach themselves to the underside of leaves, bark etc. Limestone areas frequently support higher abundance and diversity of charopids, which also holds for LHI taxa. Most species are highly localized, but some are common and widespread. At least one species (*D. saturni*) has been introduced from the mainland and has since spread throughout most of the lowland. Because of their small size and lifestyle, charopids have a limited dispersal capacity (Stanisic et al 2010).

Helicarionidae. This group is represented by rather large, shelled snails (*G. sophiae sophiae* and the critically endangered subspecies *G. sophiae magnifica*) as well as semislugs (*Howearion* spp., *Parmellops* spp.). The nominate form of *G. sophiae* has been reported to be crawling on the ground during wet nights (I. Hutton pers. comm.) and the subspecies *magnifica* is postulated to have the same behaviour. The semislugs of the genus *Howearion* are usually found to sit on palm leaves on the forest floor and are believed to forage on these and through the leaf litter at night. The two species of *Parmellops* lead a predominantly arboreal life style (hiding in leaf sheaths during the day, crawling on palm leaves at night).

Microcystidae. This group is particularly diverse on LHI forming an important component of the land snail fauna. Species are arboreal (hiding in leaf sheathes during the day, crawling on trees and palms at night or during rain) and most are found in moist forests. Microcystids are herbivores. Reproduction is usually ovoviviparous (Stanisic et al 2010).

Punctidae. Punctids are minute to small snails (shells 1.2-8 mm in diameter). They are thought to be herbivores and detritus feeders; most are leaf litter dwellers, but several LHI species are arboreal and feed on biofilm on leaves and bark. Species inhabit a variety of habitats, but moist forests harbour the most significant proportion of all species. Their life history and reproductive biology is virtually unknown (Stanisic et al 2010).

Current status of the endangered species

Five species are currently listed as endangered or critically endangered. Three of them are members of the family Charopidae (*Pseudocharopa ledgbirdi*, *P. whiteleggei*, *Mystivagor mastersi*), one is member of the Helicarionidae (*Gudeconcha sophiae magnifica*), and one of the Bulimulidae (*Placostylus bivaricosus*).

We surveyed sites from which these species have previously been recorded to achieve a better understanding of their current distribution and abundance. Between 8 and 15 September 2016 we actively searched for shells and live specimens and collected leaf litter samples, which were searched for shells and snails under a microscope in the lab (Table 4).

Table 4. Survey sites, effort per site, and number of specimen found (endangered species only)

Site	Effort	Species (number of specimens)
Mt Gower Summit (31.58 S, 159.08 E, 860 m)	15 man-hours 2 leaf litter bags	*Mystivagor mastersi* (1) *Pseudocharopa whiteleggei* (2)
Mt Gower upper slope (31.58 S, 159.08 E, 600 m)	6 man-hours 1 leaf litter bag	*Pseudocharopa ledgbirdi* (1)
Mt Gower Saddle	2 man-hours	nil
Erskine Valley	6 man-hours 1 leaf litter bag	nil
Research Station	3 man-hours	nil
Transit Hill (3 sites)	9 man-hours 2 leaf litter bags	nil
Intermediate Hill / S End of Blinky Beach	9 man-hours 2 leaf litter bags	nil
Boat Harbour	4 man-hours 1 leaf litter bag	nil
Steven's Reserve	12 man-hours	nil
Old Settlement Beach	4 man-hours	*Placostylus bivaricosus* (3)

We have been able to confirm the presence of four threatened species (i.e., *Mystivagor mastersi*, *Pseudocharopa whiteleggei*, *P. ledgbirdi*, *Placostylus bivaricosus*), but failed to record *Gudeconcha sophiae magnifica*.

Pseudocharopa ledgbirdi. Previously recorded from upper slopes and summits of both Mt Lidgbird and Mt Gower, including Erskine Valley (a total of 33 specimen records between 1887 and 2001). Also recorded during the recent survey on Mt Gower (1 specimen). This species is probably uncommon and has a restricted distribution at high altitudes of Mt Gower and Mt Lidgbird. However, only a very small fraction of its potential distribution has been surveyed due to inaccessibility of the upper slopes and summits of both mountains. No trend in population size or distribution of this species can be inferred from the scarce occurrence data.

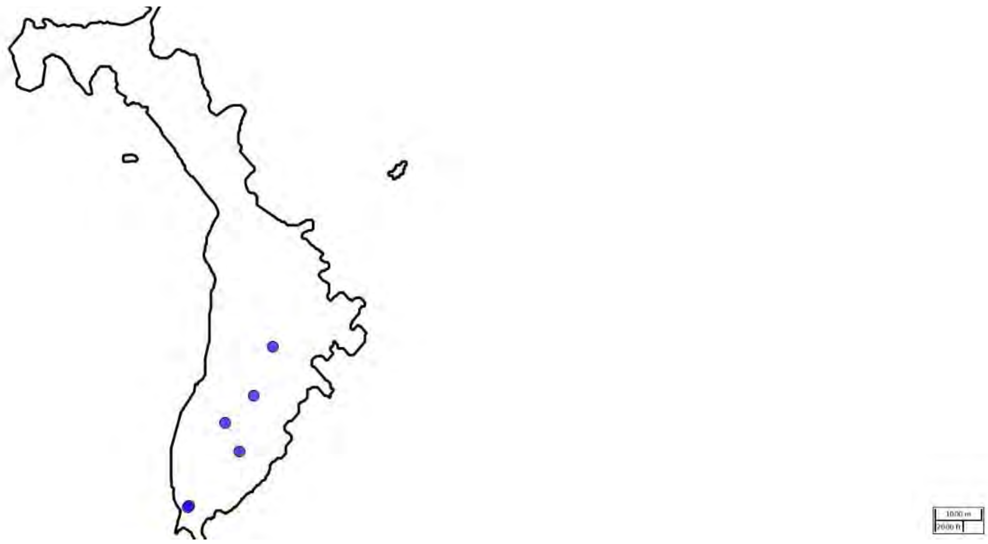

Fig. 3. Occurrence records of *P. ledgbirdi* based on specimens held by the Australian Museum and the recent survey in 2016.

Pseudocharopa whiteleggei. Previously recorded from upper slopes and summits of both Mt Lidgbird and Mt Gower (a total of 14 specimen records from between 1887 and 2002). Also recorded during the recent survey on Mt Gower (2 specimens). This species is probably uncommon and has a restricted distribution at high altitudes of Mt Gower and Mt Lidgbird. However, only a very small fraction of its potential distribution has been surveyed due to inaccessibility of the upper slopes and summits of both mountains. No trend in population size or distribution of this species can be inferred from the scarce occurrence data.

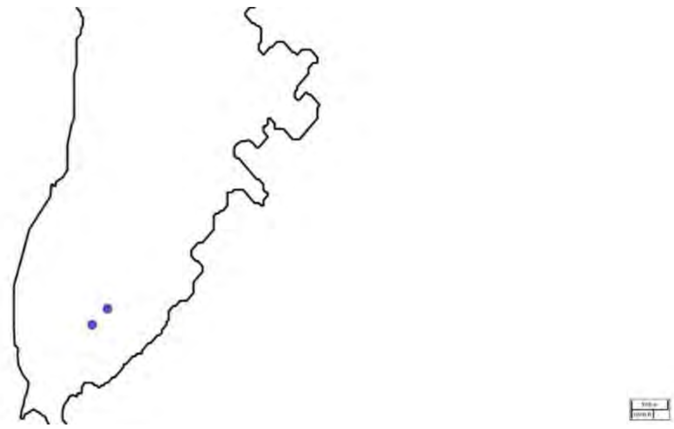

Fig. 4. Occurrence records of *P. whiteleggei* based on specimens held by the Australian Museum and the recent survey in 2016.

Mystivagor mastersi. Very scarce records from lowland sites as well as the summits of Mt Lidgbird and Mt Gower (a total of 10 specimen records from between 1887 and 2002). Specimens from Mt Lidgbird and Mt Gower differ in shell morphology from lowland forms and may represent a distinct, undescribed species pending further examination. The lowland form has last been recorded in 1971 near Old Settlement Beach. It has not been recorded during the comprehensive surveys between 1999 and 2002, nor during the current survey. Therefore, the lowland form may be very rare or possibly extinct.

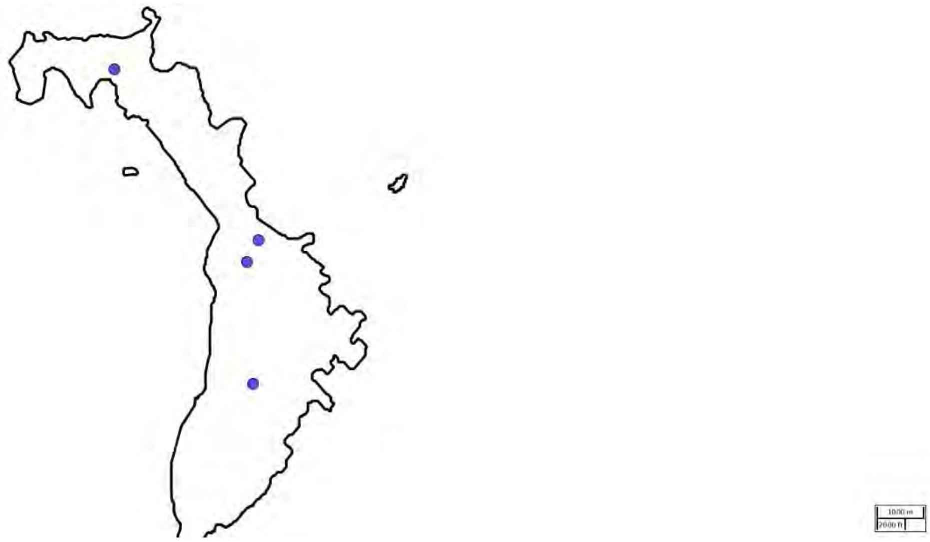

Fig. 5. Occurrence records of *M. mastersi* based on specimens held by the Australian Museum.

By contrast, there are several more recent records of *Mystivagor* from the summit of Mt Gower, including one specimen found in the recent survey. This species is likely uncommon or rare but only a very small fraction of its potential distribution has been surveyed due to inaccessibility of the upper slopes and summits of both mountains. No trend in population size and distribution in high altitudes can be inferred from the scarce occurrence data.

Gudeconcha sophiae magnifica. Previously recorded from upper slopes and summits of both Mt Lidgbird and Mt Gower (a total of 18 specimen records from between 1914 and 2002). This species has not been recorded during our recent survey on Mt Gower despite considerable efforts. This lack of positive records suggest that the species is absent from or rare in the surveyed area of the summit of Mt Gower. However, only a small part of the potential distribution of this species has been surveyed due to inaccessibility, and well-informed conclusions on trends in population size or distribution of this species cannot be inferred from the scarce occurrence data. The subspecies is probably uncommon or rare with a distribution restricted to high altitudes of Mt Gower and Mt Lidgbird.

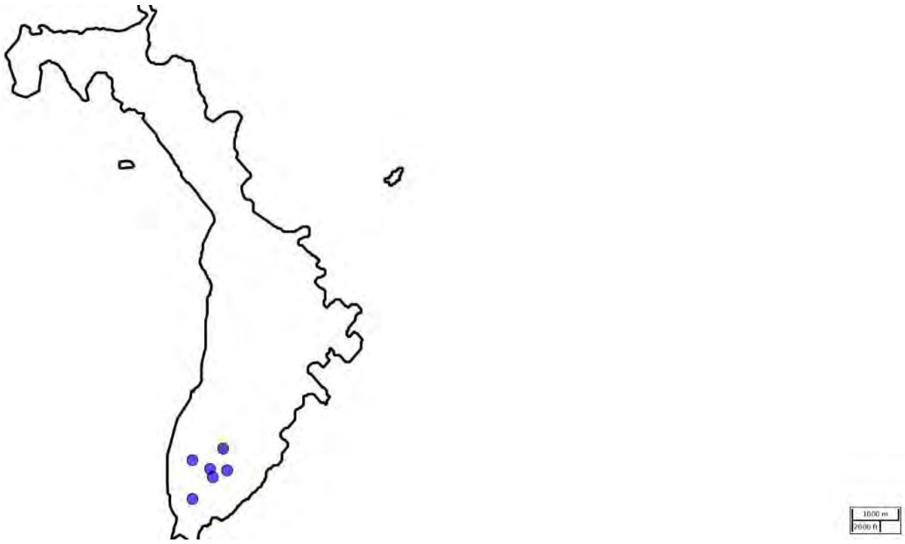

Fig. 6. Occurrence records of *G. sophiae magnifica* based on specimens held by the Australian Museum.

Placostylus bivaricosus. Once rather common throughout much of the lowland, live individuals of this species have been recorded in targeted surveys at 14 out of selected 20 sites in 2006/2007 (Hutton 2007) and in seven out of 21 selected sites in 2010 (Hutton & Hiscox 2010). We have found this species at one site from which it had previously been reported (near Old Settlement Beach), but could not find live animals in Steven's Reserve. Also Hutton (2007) and Hutton & Hiscox (2010) could not find living animals at Steven's reserve. Altogether these negative records indicate that the species is probably locally extinct at Steven's Reserve, where it once was very common.

Hutton & Hiscox (2010) concluded that the greatest density of live *Placostylus* snails appear to be where the practice of a good rat baiting program is exercised and where dense, heavy leaf litter exists that precludes the snails from predation by introduced birds, which have been identified as a second probable threat. Our survey at Old Settlement Beach indicates that the species is still relatively abundant at this site, but overall the species is considered to be in decline. The removal of predators from all its current and previous occurrences is necessary to ensure its long-term survival.

Apart from the species that are formally assessed as Endangered or Critically Endangered, probably all native and endemic species of LHI qualify at least for a listing as Vulnerable based on the fact that their Area of Occupancy (AOO) is likely below the 10 km^2 threshold (the entire island area is about 15 km^2, but the AOO of many species is smaller than that). As for the formally listed species, all other species are impacted by predation through introduced rodents and exotic birds (blackbird, song thrush) to varying degrees (the gravity of this impact depending on their reproductive biology, body size, life style, and attractiveness as food source for the introduced predators). The impact of rodent and bird predation has not generally been assessed for most species. However, it is clear that if any of them were declining due to this threat that than these species would also qualify for listing as Critically Endangered in accordance with the criteria of the EPBC Act.

Susceptibility to the baiting program

Toxicity of brodifacoum

Toxicity of brodifacoum was tested in a small number of land snail species with contradicting results (reviewed in Broome et al. 2016): In New Zealand introduced slugs (*Deroceras* sp., family Agriolimacidae) and snails (*Cornu aspersum*, Helicidae) were found not to be susceptible to brodifacoum poisoning in experimental setups. Common garden snails were exposed to soil contaminated with brodifacoum at up to 1000 mg/kg soil as well as to Talon® 20P pellets. No snail mortality was observed in these experiments. Bowie and Ross (2006) allowed introduced slugs held in captivity, to feed freely for 40 days on Talon 50WB® wax baits containing 0.05 mg/kg brodifacoum. No mortality was observed. These species are not very closely related to any of the LHI species.

Brooke et al. (2011) held native snails from Henderson Island, Pitcairn group, in plastic boxes to which broken pieces of Pestoff 20R cereal pellets containing 20mg/kg brodifacoum were added. A control group of snails was kept under similar conditions with no exposure to brodifacoum. Each of the seven species (*Orobophana* spp. [Helicinidae], Achatinellidae spp.) was tested this way for 10 days. After 10 days of exposure there were no detectable differences in the survival between the snails kept with and those kept without access to brodifacoum. Among those with access, there were no significant differences in brodifacoum concentrations between the minority that died and the majority that survived. In fact, brodifacoum was detected in only a few samples.

The tested species were arboreal and ecological similar to the arboreal species on LHI. Because they are caenogastropods, species of *Orobophana* are more closely related to the Assimineidae, Diplommatinidae and Hydrocenidae on LHI than any of the other tested land snail species. The family Achatinellidae is represented by four species on LHI (Table 1, Appendix).

The susceptibility of the endangered species *Placostylus bivaricosus* to brodifacoum poisoning has also been tested in an experimental setup. Animals held in captivity were exposed to two experimental protocols. The first, using nontoxic baits, involved a choice-based feeding trial to ascertain if snails fed on the baits. The second, using toxic baits, aimed to determine if individuals were killed by the toxin. The lack of pyranine fluorescing faeces in the non-toxic food choice test suggests that when presented with a choice, as would occur in an eradication where poison baits would be distributed on the forest floor among the leaf litter, *Placostylus* prefer their natural diet. This finding is significant as it indicates that the potential for a significant proportion of the population to ingest toxic pellets would be extremely low. More importantly, the test revealed no mortality in the toxic bait trial indicating that *Placostylus* is not susceptible to brodifacoum (Wilkinson & Hutton 2009).

By contrast to these findings, Gerlach & Florens (2000) reported 100% mortality of two snails from the Seychelles, *Pachnodus silhouettanus* (Cerastidae) and *Achatina fulica* (Achatinidae), in an experimental setup. A dosage of 0.002mg brodifacoum was sufficient to kill *P. silhouettanus* in 4 days, higher dosages of up to 0.1 mg resulted in death within 12 hours. *Achatina fulica* were killed by a dose of 0.04 mg toxin in 72 hours. However, Gerlach & Florens (2000) provided no description of their experimental methodology nor did they explain how they quantified the ingested amount of toxin. Both species are ground-dwellers and ecologically similar to the larger, ground-dwelling species on LHI, such as *P. bivaricosus*, *G. sophiae sophiae* and *G. s. magnifica*. Gerlach (2005) reported that the two land snail species from the Seychelles have declined significantly after the broadcast use of brodifacoum.

In Mauritius, snails of the species *Pachystyla bicolor* (Helicarionidae) were observed eating baits containing poison at bait stations, and dead snails were found in the vicinity of bait tubes. The number of live snails recorded on plots was lower in the poisoned area compared with the non-poisoned area. However, the number of observed snails was generally small and therefore the result can be regarded only as preliminary (Booth et al 2001). *Pachystyla* belongs to the same family as some LHI species and is ecologically similar to both subspecies of *G. sophiae*.

Based on the abovementioned tests, we formulate the following assumptions about the toxicity of brodifacoum for LHI species:

(1) *Placostylus* is probably not susceptible as shown in experimental setup,
(2) Achatinellids are likely not susceptible (Brooke et al 2011),
(3) susceptibility of caenogastropods is uncertain; species of the family Helicinidae from NZ were found not to be susceptible, but this family is not represented on LHI,
(4) susceptibility of most pulmonate species, including the endangered Charopidae, is uncertain for no closely related species have been tested so far,
(5) Helicarionidae (*G. sophiae sophiae*, *G. sophiae magnifica* (CE), *Howearion* spp., *Parmellops* spp.) may be susceptible based on the presumed susceptibility of the Mauritian species *Pachystyla bicolor*.

Likelihood of toxin intake

Poisonous baits are going to be broadcasted at a density of on average one bait per 2 m^2 (LHIB 2016). The likelihood that snails ingest toxin from these baits depends on their feeding and foraging behaviour. While our knowledge of feeding behaviour is not very detailed, we presume that all native species primarily feed on biofilm, and that the baits are unlikely to be an attractive food source for these snails. This conclusion is underpinned by the observation that *Placostylus* did not ingest baits when presented with its preferred source of food.

A large number of species on LHI lead a predominantly or exclusively arboreal life style and are thus considered to be at low risk of being exposed to bait on the ground. This conclusion holds for all species of the family Microcystidae and several species of the Punctidae (Table 1, Appendix). A night survey conducted on 13 September 2016 in Stephens Reserve revealed that the helicarionid semislug *Parmellops etheridgei* (this applies probably also to *P. perspicuus*) is arboreal as well and therefore considered to be at a low risk of exposure to baits (Table 1, Appendix).

None of the endangered species of LHI is arboreal.

Many minute to small leaf-litter dwellers live within the leaf litter layer and have small ranges of activity. They may be moving for less than 20 cm per day, probably less, as they sit predominantly on the underside of leaves. These species are considered to be at a moderate risk to be exposed to bait based on their ecology. Given the average distribution of 1 bait per 2 m^2 and the small range of these snails, it is considered likely that a fair proportion of the population of any of these species will not come in contact with baits. Three critically endangered species belong in this cohort: *Mystivagor mastersi*, *Pseudocharopa ledgbirdi*, *P. whiteleggei*.

By contrast, ground-dwelling species that forage actively over larger distances (many metres per night) are considered to be at high risk of exposure to bait. This applies to the larger species, such as *Gudeconcha sophiae* (both subspecies; the subspecies *magnifica* being critically endangered), *Placostylus bivaricosus* (endangered, but see above for resilience against brodifacoum), and possibly also *Howearion hilli* and *H. belli*.

Risk assessment for land snails and mitigation

The impact of introduced rodents on the native and endemic species on LHI, in particular the critically endangered species, is of national environmental significance because of its harmfulness for the snails (i.e., by causing a long-term decrease in the size of populations of endangered and critically endangered species). Therefore, the program is in principal expected to have a significant, long-term benefit for the endangered and all other land snail species. This benefit cannot be achieved through alternative measures. The current rodent control through baiting stations has reduced rodent populations only locally, but has not been able to prevent or reverse the on-going decline of land snail populations as is evident from the continuing decline of *P. bivaricosus* in well-baited lowland areas. Four critically endangered species live in rather inaccessible high altitude areas, where baiting stations cover only a small fraction of the potential ranges of these snails. This renders the majority of the population of these species exposed to unmitigated rodent predation. While we cannot infer a trend in their distribution and population size, it is evident from the scarce occurrence records that all these species are rare and restricted in occurrence. This rarity could in part be attributable to rodent predation. Establishing and maintaining bait stations throughout the high altitude areas of Mt Gower and Mt Lidgbird indefinitely is virtually impossible. Hence, the outlook for the endangered land snails under a continuation of the current rodent management is bleak and their long-term survival appears questionable under a scenario of continued rodent predation.

The eradication of rats and mice (both equally important!) is the most cost efficient and only feasible way to ensure the survival of the critically endangered species in the long-term. We fully support the implementation of the eradication program, but recommend measures aimed at mitigating possible side effects of the bait broadcast.

We have grouped the assessed species into three risk classes (low, moderate, high) in consideration of their potential of exposure and their susceptibility to brodifacoum. Snails documented not to be susceptible to poisoning in experimental setups are considered to be at low risk overall (*P. bivaricosus*). For all species with unknown tolerance to the toxin (all others), the assigned risk class is reflective of the likelihood of coming into contact with the baits, given the size, dispersal capacity and ecology (ground dwelling vs arboreal) of species (Table 1). Highly mobile, ground-dwelling species are treated as being at high risk (the critically endangered subspecies *G. sophiae magnfica* belongs here), leaf litter species with restricted mobility at moderate risk (the three critically endangered species *M. mastersi*, *P. ledgbirdi*, *P. whiteleggei* belong in this group), and arboreal species at low risk overall. We have not assessed the vulnerability of introduced and non-endemic species. Native, non-endemic species are usually widespread on the mainland and highly mobile. Most of them may have been introduced on LHI through human activities. Even if island populations of these species were affected by the program, their mainland populations would remain of Least Concern.

Land snails are known to undergo significant fluctuations in population size under natural conditions due to variations in climate, predation, parasites or diseases. We are therefore confident that even under a worst case scenario whereby brodifacoum exposure is lethal, species in the low and moderate risk classes will be able to recover from a possible population decline in particular in the absence of on-going rodent predation. Hence, for these species the advantage of a permanent relief from predation clearly outweighs any potential impact of the baiting program. This applies to the critically endangered species *M. mastersi*, *P. ledgbirdi*, and *P. whiteleggei*.

A recovery of snail populations after successful rodent eradiation has also been observed in an eight-year research project on *Placostylus ambagiosus* in northern New Zealand. Here, pulse baiting four times a year to control rodents resulted in increased adult recruitment of the snails (Sherley et al. 1998). This was attributed to the reduction in predation pressure by rodents as a result of the baiting. The clear increases in population indicated that any impacts that the toxin may have had were more than offset by the long-term benefits of rodent eradication.

Species in the high risk category, however, may potentially be gravely affected by the baiting program if they were susceptible to poisoning. For these species mitigation measurements are advised (see below).

Recommendations to manage potential impacts on snails:

1. Species at low risk are very unlikely to be impacted by the program; no specific measure of mitigation is required.
2. Species at moderate risk may be impacted by the program if species were susceptible to brodifacoum. However, any potential short-term reduction in population sizes due to increased mortality is likely going to be outweighed by the long-term benefits of lack of on-going rodent predation. Hence, in the long term species are going to benefit from the program. Species from this class can be downgraded into the low risk class if experimental tests confirmed that they were not susceptible to brodifacoum. In such tests more commonly found charopids can be used as surrogates for the critically endangered charopid species. No specific mitigation measure is required, but monitoring of populations during the program is advised.
3. Species at high risk are very likely to be exposed to bait. Their susceptibility to the toxin should be tested in experimental setups to enable downgrading into the low risk class. The susceptibility to brodifacoum can be tested using the more common subspecies *G. sophiae*

sophiae as surrogate for the critically endangered subspecies *magnifica*. The two species of *Howearion* can also be used as surrogates of each other.

4. For species in this class found to be susceptible to brodifacoum, specific mitigation measures will need to be developed and implemented (e.g., breeding in captivity) to ensure their survival.

Assessment summary for endangered and critically endangered species

Species	Current status and trend	Outlook under no-change scenario	Expected impact of rat eradication program
Placostylus bivaricosus	EN Small number of extant populations. In decline.	Continuing decline as current management practices are not preventing decline	Not susceptible to brodifacoum. Short-term population increase.
Mystivagor mastersi	CR Possibly extinct in lowland, rare at high altitudes. Largely unprotected from rodent predation due to inaccessibility of its range. Trend unknown.	Continuing decline as rodent control is not practicable throughout most of its extant range.	Susceptibility unknown. Moderate risk category. Long-term population increase.
Pseudocharopa ledgbirdi	CR Rare at high altitudes. Largely unprotected from rodent predation due to inaccessibility of its range. Trend unknown.	Continuing decline as rodent control is not practicable throughout most of its extant range.	Susceptibility unknown. Moderate risk category. Long-term population increase.
Pseudocharopa whiteleggei	CR Rare at high altitudes. Trend unknown.	Continuing decline as rodent control is not practicable throughout most of its extant range.	Susceptibility unknown. Moderate risk category. Long-term population increase.

Gudeconcha sophiae magnifica	CR Rare at high altitudes. Largely unprotected from rodent predation due to inaccessibility of its range. Trend unknown.	Continuing decline as rodent control is not practicable throughout most of its extant range.	Susceptibility unknown. High risk category. Impact of baiting needs further study to better understand possible impact of the program.

Abbreviations: EN – endangered, CR – critically endangered.

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Appendix

Table 1. Native species: Endemism, conservation status, ecology and risk assessment.

Family	Species	Endemic	Threat status	Life style / substrate preference	Activity range	Brodifacoum Susceptibilty	Risk class
Achatinellidae	*Elasmias wakefieldiae* (Cox, 1868)			arboreal	moderate	?	low
Achatinellidae	*Tornatellides lordhowensis* Shea & Griffiths, 2010	E		arboreal	moderate	?	low
Achatinellidae	*Tornatellinops jacksonensis* (Cox, 1864)			arboreal	moderate	?	low
Achatinellidae	*Tornatellinops lidgbirdense* (Iredale, 1944)	E		arboreal	moderate	?	low
Assimineidae	*Limborelia exquisita* (Pfeiffer, 1855)	E		leaf litter	small	?	moderate
Assimineidae	*Limborelia innesi* (Iredale, 1944)	E		leaf litter	small	?	moderate
Assimineidae	*Opinorelia howeinsulae* (Iredale, 1944)	E		leaf litter	small	?	moderate
Bulimulidae	*Placostylus bivaricosus* (Gaskoin, 1855)	E	EN	leaf litter	large	No	low
Charopidae	*Charopella wilkinsoni* (Brazier, 1889)	E		leaf litter	small	?	moderate
Charopidae	*Charopella zela* Iredale, 1944	E		leaf litter	small	?	moderate
Charopidae	*Gowerconcha waterhousiae* (Hedley, 1897)	E		leaf litter	small	?	moderate
Charopidae	*Gowerconcha wenda* Iredale, 1944	E		leaf litter	small	?	moderate
Charopidae	*Gowerconcha wilsoni* Iredale, 1944	E		leaf litter	small	?	moderate
Charopidae	*Gyropena minuta* Shea & Griffiths, 2010	E		leaf litter	small	?	moderate
Charopidae	*Gyropena verans* Iredale, 1944	E		leaf litter	small	?	moderate
Charopidae	*Hedleyoconcha addita* Iredale, 1944	E		leaf litter	small	?	moderate
Charopidae	*Mystivagor mastersi* (Brazier, 1872)	E	CE	leaf litter	small	?	moderate
Charopidae	*Pseudocharopa exquisita* Peile, 1929	E		leaf litter	small	?	moderate
Charopidae	*Pseudocharopa ledgbirdi* (Brazier, 1889)	E	CE	leaf litter	small	?	moderate
Charopidae	*Pseudocharopa whiteleggei* (Brazier, 1889)	E	CE	leaf litter	small	?	moderate
Charopidae	*Pulcharopa plesa* Iredale, 1944	E		leaf litter	small	?	moderate
Diplommatinidae	*Palaina arborfumosa* Shea & Griffiths, 2010	E		leaf litter	small	?	moderate
Diplommatinidae	*Palaina capillacea* (Pfeiffer, 1855)	E		leaf litter	small	?	moderate

Diplommatinidae	*Palaina deliciosa* Iredale, 1944	E		leaf litter	small	?	moderate
Diplommatinidae	*Palaina edwardi* Iredale, 1944	E		leaf litter	small	?	moderate
Diplommatinidae	*Palaina embra* Iredale, 1944	E		leaf litter	small	?	moderate
Diplommatinidae	*Palaina intercollis* Shea & Griffiths, 2010	E		leaf litter	small	?	moderate
Diplommatinidae	*Palaina levicostulata* Iredale, 1944	E		leaf litter	small	?	moderate
Diplommatinidae	*Palaina lucia* Iredale, 1944	E		leaf litter	small	?	moderate
Diplommatinidae	*Palaina macgillivrayi* (Pfeiffer, 1855)	E		leaf litter	small	?	moderate
Diplommatinidae	*Palaina waterhousei* Iredale, 1944	E		leaf litter	small	?	moderate
Helicarionidae	*Epiglypta howinsulae* (Cox, 1873)	E	EX	?	?	?	n. a.
Helicarionidae	*Gudeconcha sophiae sophiae* (Reeve, 1854)	E		ground	large	?	high
Helicarionidae	*Gudeoconcha sophiae magnifica* Iredale, 1944	E	CE	ground	large	?	high
Helicarionidae	*Howearion belli* Iredale, 1944	E		leaf litter	moderate	?	high
Helicarionidae	*Howearion hilli* (Cox, 1873)	E		leaf litter	moderate	?	high
Helicarionidae	*Parmellops etheridgei* (Brazier, 1889)	E		arboreal	large	?	low
Helicarionidae	*Parmellops perspicuus* Hyman, 2016	E		arboreal	large	?	low
Hydrocenidae	*Monterissa gowerensis* Iredale, 1944	E		rock face	small	?	low
Microcystidae	*Deliciola charis* Iredale, 1944	E		arboreal	moderate	?	low
Microcystidae	*Dignamoconcha dulcissima* Iredale, 1944	E		arboreal	moderate	?	low
Microcystidae	*Innesoconcha aberrans* Iredale, 1944	E		arboreal	moderate	?	low
Microcystidae	*Innesoconcha catletti* (Brazier, 1872)	E		arboreal	moderate	?	low
Microcystidae	*Innesoconcha princeps* Iredale, 1944	E		arboreal	moderate	?	low
Microcystidae	*Innesoconcha segna* Iredale, 1944	E		arboreal	moderate	?	low
Microcystidae	*Melloconcha delecta* Iredale, 1944	E		arboreal	moderate	?	low
Microcystidae	*Melloconcha flavescens* (Iredale, 1944)	E		arboreal	moderate	?	low
Microcystidae	*Melloconcha miranda* (Iredale, 1944)	E		arboreal	moderate	?	low
Microcystidae	*Melloconcha prensa* Iredale, 1944	E		arboreal	moderate	?	low
Microcystidae	*Melloconcha rosacea* (Iredale, 1944)	E		arboreal	moderate	?	low
Punctidae	*Allenella formalis* Iredale, 1944	E		arboreal	small	?	low
Punctidae	*Allenella planorum* Iredale, 1944	E		arboreal	small	?	low
Punctidae	*Charopinesta goweri* Iredale, 1944	E		leaf litter	small	?	moderate

Punctidae	*Dignamoconcha dulcissima* Iredale, 1944	E		arboreal	moderate	?	low
Punctidae	*Goweriana berniceae* Shea & Griffiths, 2010	E		leaf litter	small	?	moderate
Punctidae	*Paralaoma caputspinulae* (Reeve, 1851)			leaf litter	small	?	moderate
Punctidae	*Pernastela charon* Iredale, 1944	E		leaf litter	small	?	moderate
Punctidae	*Pernastela gnoma* Iredale, 1944	E		leaf litter	small	?	moderate
Punctidae	*Pernastela howensis* Iredale, 1944	E		leaf litter	small	?	moderate
Punctidae	*Semilaoma costata* Shea & Griffiths, 2010	E		leaf litter	small	?	moderate
Punctidae	*Semilaoma laevis* Shea & Griffiths, 2010	E		leaf litter	small	?	moderate
Punctidae	*Semilaoma lidgbirdensis* (Iredale, 1944)	E		leaf litter	small	?	moderate
Pupillidae	*Pupisoma evada* (Iredale, 1944)			arboreal	moderate	?	low

Abbreviations: E = endemic species, EN = endangered, CE = critically endangered.

Table 2. Introduced land snails on LHI

Family	Species
Agriolimacidae	*Deroceras invadens* (Reise, Hutchison, Schunack & Schitt, 2011)
Bradybaenidae	*Bradybaena similaris* (Férussac, 1821)
Charopidae	*Diphyoropa saturni* (Cox, 1864)
Gastrodontidae	*Zonitoides arboreus* (Say, 1817)
Helicidae	*Cornu aspersum* (Müller, 1774)
Hygromiidae	*Prietocella barbara* (Linnaeus, 1758)
Limacidae	*Lehmannia nyctelia* (Bourguignat, 1861)
Limacidae	*Limax maximus* Linnaeus, 1758
Subulinidae	*Allopeas clavulinus* (Potiez & Michaud, 1838)
Valloniidae	*Vallonia excentrica* Sterki, 1893
Zonitidae	*Hawaiia minuscula* (Binney, 1840)
Zonitidae	*Oxychilus alliarius* (Miller, 1822)

Table 3. Possibly undescribed species

Family	**Species**
Assimineidae	Assiminea LHI 1
Assimineidae	Assiminea LHI 2
Assimineidae	Assimineidae LHI 3
Assimineidae	nitida-like sp.
Charopidae	Mystivagor msp LHI 1
Charopidae	N.genus 1 LHI 3
Charopidae	N.genus 1 LHI 4
Charopidae	Pernastela LHI 2
Diplommatinidae	Palaina LHI 1
Diplommatinidae	Palaina LHI 2
Diplommatinidae	Palaina LHI 3
Diplommatinidae	Palaina LHI 4
Diplommatinidae	Palaina LHI 5
Diplommatinidae	Palaina LHI 7
Diplommatinidae	Palaina LHI 8
Punctidae	Allenella LHI 1
Punctidae	Allenella LHI 2
Punctidae	Allenella LHI 3
Punctidae	Iotula LHI 3
Punctidae	Iotula LHI 13
Punctidae	N.genus 1 LHI 8
Punctidae	N.genus 2 LHI 5
Punctidae	N.genus 2 LHI 9
Punctidae	N.genus 3 innesi
Punctidae	N.genus 4 LHI 10
Punctidae	N.genus 6 LHI 12
Punctidae	Paralaoma LHI 14
Punctidae	Paralaoma LHI 15
Punctidae	Paralaoma LHI 6
Punctidae	Punctidae LHI 1
Punctidae	Punctidae LHI 10
Punctidae	Punctidae LHI 16
Punctidae	Punctidae LHI 18
Punctidae	Punctidae LHI 20
Punctidae	Punctidae LHI 21
Punctidae	Punctidae LHI 8
Punctidae	Semilaoma LHI 7

Plate. Photographs of some relevant species.

a) *Howearion bell* – Mount Gower, b) *Pseudocharopa whiteleggi* – Mount Gower, c) *Parmellops perspicuous* – Mount Gower*,* d) *Mystivagor mastersi* – Mount Gower*,* e) *Placostylus bivaricosus bivaricosus* – Old Settlement Beach*,* f) *Goweroconcha sp.* – Mt Gower*,* g) *Parmellops ethridgei* – Steven's Reserve, h) *Howearion hilli* – Steven's Reserve.