Application for a Minor-use Permit to bait Lord Howe Island with the Unregistered Rodent Bait Pestoff 20R

Applicant: Lord Howe Island Board

Contents:

Australian Government
Australian Pesticides and Veterinary Medicines Authority

Item 21
DC21-96187242

Application for a permit where the proposed use meets the requirement for a minor use

1. Purpose of the Application

a). This application is for:

- ☑ **a new minor use permit**
- ☐ an extension of the duration of a minor use permit which requires technical assessment (this does not include state extension)
- ☐ a permit based on an existing or previously issued permit

b). The permit is for:

- ☑ **Agricultural chemical product**
- ☐ Veterinary chemical product

c). Product and active constituent details:

- ☐ This application involves a Registered Product
- ☑ **This application involves an Unregistered Product**

Product name	**Pestoff 20R Rodent Bait**

☐ Include all similar registered products in permit

Active constituent name	Active constituent concentration
Brodifacoum	**0.02 g/kg**

2. Applicant Contact Details

Full name of applicant:			
Name of contact person:			
Position/title:			
ACN / Overseas equivalent number:			
Street address:			
Postal address:			
Email:		Telephone:	Facsimile:

3. Authorised Agent Details

☐ Authorised Agent (can be employee of the applicant)

☑ **No Agent**

Full Name of agent (can be a company):			
Name of contact person in the company:			
Position/title:			
Postal address:			
Email:		Telephone:	Facsimile:

4. Fit for Purpose Declaration

☑ **I declare that in accordance with paragraph 112(4)(b) of the Agvet Code, neither the:**

- the applicant for the permit (the Applicant); or
- any person who makes, or participates in making, decisions that affect the whole, or a substantial part, of the Applicant's affairs; or
- if the Applicant is a body corporate, a person who is a major interest holder of the body corporate

has, within the 10 years immediately before this application:

- been convicted of an offence against an agvet law; or
- been convicted of an offence against a law of this or another jurisdiction relating to chemical products; or
- been convicted of an offence against a law of the Commonwealth or a law of a State or Territory involving fraud or dishonesty; or
- been proven guilty of an offence include above where the court has not recorded a conviction; or
- been ordered to pay a pecuniary penalty for the contravention of an agvet penalty provision; or
- been ordered to pay a pecuniary penalty for the contravention of another law of this or another jurisdiction relating to chemical products; or
- been ordered to pay a pecuniary penalty for the contravention of a civil penalty provision of a law of the Commonwealth or a law of a State or Territory involving fraud or dishonesty; or
- held a permit that was cancelled under subsections 119(2) or section 119B of the Agvet Code or under a corresponding provision of the Agvet Code of another jurisdiction; or
- been a manager, or major interest holder, of a body corporate in respect of which any of the matters, noted above, applied in that 10 year period, if the conduct resulting in that matter occurred when the person was a manager or major interest holder of the body corporate.

☐ **cannot make the above declaration in accordance with paragraph 112(4)(b) of the Agvet Code**

5. Correspondence

Correspondence about this application is to be addressed to:

☑ **Applicant**

☐ Authorised Agent

6. Declaration

☑ I declare that I am making this application on behalf of the Commonwealth, a State or Territory or associated authority or agency in support of their core activities and that the permit is for a use that does not have a commercial benefit.

☐ **I have submitted the template(s) for the approved label.**

☑ **I have submitted all related information online.**

☐ I have more information to be posted to APVMA within 7 days.

☑ **I declare that the information provided with this application is complete and correct.**

Electronic Signature: 780435335

Date: 19 April 2016 12:44:23 PM

Giving false or misleading information is a serious offence and may lead to prosecution for an offence against the Agricultural and Veterinary Chemicals Code.

7. General Details

Modules: '6.3','7.3', '11.3'

Proposed duration of permit.

First date of proposed use	**1 June 2017**
Annual timing of use (ie. from Sep - Mar or ongoing throughout year)	**June - November**
Proposed permit duration (ie. 1, 2, 5, 10 years or ongoing)	**5 Years**

Location of proposed use.

Locations	☐ ACT ☑ **NSW** ☐ NT ☐ QLD ☐ SA ☐ TAS ☐ VIC ☐ WA
Specific locations	**Lord Howe Island and associated islets**

Persons to be covered by the permit.

Persons	☐ 'All persons' (includes everyone - ie no restrictions) ☑ **A specific group** ☐ One or more nominated individuals
Details of persons	**Employees of the Lord Howe Island Board including temporary contractors**

Scale of use.

Estimated or proposed scale of use (area, tonnage, number of trees, number of animals, number of doses etc.)	**The proposed one off eradication will be at a nominal treatment rate of 12kg of Pestoff 20R pellet bait/hectare on the first application; to be followed by a second application of 8kg of bait/ hectare approximately 14-21 days after, weather permitting, for a total nominal treatment rate of 20 kg/ha averaged over the island. The island is 1455 ha in the 2D view and approximately 2100 ha in the 3D view. A maximum of 42 tonnes would be used.**

8. Proposed Use

Target crop or situation (1)		**Apply cereal baits aerially, by hand-broadcasting and placing in bait stations and bait trays on Lord Howe Island and associated islands and islets (hence referred to as the Lord Howe Island Group or LHIG or Island Group) to eradicate introduced rodents. Area to be baited is approximately 2,100 hectares (3D). The Lord Howe Island Group (31°31'S, 159°03'E) is located 760 kilometres north east of Sydney. It comprises the main island (Lord Howe Island) and 28 smaller islets and emerged rocks** ☐ Crop ☑ **Situation**
Target disease, pest or purpose	Common name	**Black or Ship Rat and House Mouse**
	Scientific name	**Rattus rattus and Mus musculus**
Application rate (eg 100mL or 100g product / 100L and/or 1L or 1Kg/ha)		**The total amount of bait applied will be nominally 20kg of Pestoff 20R bait/ha, comprising two applications, the first being at nominally 12 kg/ha, the second at nominally 8 kg/ha.**
Spray volume (eg 500L/ha)		**N/A**
Addition of wetter (eg plus 200mL/100L - please specify wetter)		**N/A**
Timing of application/growth stage (eg apply at budburst, blossom boom etc)		**The baiting is planned to occur in winter (June - Aug) 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. The operation will take place in a single year sometime between 2017 and 2019. Uncertainty remains concerning the year because there are a number of approvals that have not yet been obtained (e.g. environmental approvals from the Commonwealth and New South Wales governments).**
Maximum number of applications		**The treatment will involve two applications of bait dispersed over the Island Group; the first application will be at the nominal rate of 12kg per hectare, the second at approximately 8kg/ hectare. per year**
Minimum re-treatment interval (days) between consecutive applications		**Weather permitting, approximately 7 - 21 days**
Application method (eg foliar, drench, in-furrow, aerial)		**Aerial dispersal of bait over most of the Lord Howe Island Group. Dispersal by hand around dwellings. Placement of bait into either bait trays (and these trays put into buidings in locations such as ceiling spaces, under floors), or into bait stations. Application methods are detailed in Part 7**
Application equipment (eg knapsack, air-blast sprayer, boomspray)		**Aerial dispersal to be done by helicopter with underslung bucket; mechanical spinner attached to bucket to dispense cereal baits horizontally up to approximately 40 metres from the helicopter. A trickle shute may also be attached to the bucket which will allow the bait to be dropped immediately below the helicopter. Hand distributing by fertilizer spreader or similar**
Proposed withholding periods (food and/or	Number of days or weeks between	**Approximately 100 days after baiting until livestock returned, dependent on monitoring of bait breakdown**

livestock feed crops only).	last application and harvest	
	Grazing and cutting for livestock	**Grass cut to feed penned livestock to be raked prior to cutting to remove any bait pellets.**
Any special precautions / critical use comments		**A large proportion of the populations of vulnerable non-target species is to be housed in captivity during the period that brodifacoum may be available in the environment. Beef cattle to be removed from the island or slaughtered prior to the baiting operation.. Dairy cattle housed in a pen to prevent them eating bait pellets dispersed onto paddocks; milk tested for brodifacoum during the critical period. In-shore fish tested for brodifacoum residue. Supplies of Vitamin K, the antidote for brodifacoum poisoning, to be kept on Lord Howe Island in the event people or pets are poisoned. No aerial baiting to be done over the settlement. Information about brodifacoum, the baits and timing of baiting disseminated to residents and tourists. The special precautions that will be taken are detailed in modules 6, 7 and 8.**
Is the chemical product intended to be applied to a genetically modified crop?		☐ Yes ☑ **No**

9. Justification for the proposed use

a). Provide reasons as how the proposed use qualifies as a minor use:

Currently registered rodenticides are considered unsuitable because they are not designed or approved for aerial distribution, contain higher concentrations of toxin which could have greater non target impacts and contain Bitrex which may cause bait aversion in target species.
The LHI REP is considered to trigger the Minor use category based on either of the following:
• Schedule 2: Limited use in a Major Non food Situation (agricultural non-crop areas, domestic and public service areas, non crop areas, bushland / native forests) or other Situation (pastures). Limited use area of 1,400 ha 2D (or 2,100 ha 3D) on Lord Howe Island only. Or
• Schedule 3: Insufficient economic return – one off pest eradication of small area only.
Further detail is provide in Module 7.

b). Are any products currently registered or approved for the proposed use?

☐ Yes ☑ **No**

c). Has an application been made to register the product?

☐ Yes ☑ **No**

Provide the reasons as to why no application has been made:

Insufficient economic return – one off pest eradication of small area only.
Further detail is provide in Module 7.

10. Formulation Details

FULL formulation details - every constituent must be listed. Indicate how the formulation details are supplied:

☐ I provide the full details below.

☑ **The manufacturer(s) will provide details to the APVMA separately.**

11. Active Constituent Details

Minimum purity or pharmacopoeial standard:	**2.5% Brodifacoum**		
IUPAC Name:	**Brodifacoum**		
Common Names:	**Brodifacoum**		
CAS Number:	**56073-10-0**		
Is the active constituent a genetically modified organism (GMO) or manufactured using genetically modified (GM) materials?		☐ Yes	☑ **No**
Does the active constituent contain any material intentionally engineered to be < 100 nm in one or more dimensions?		☐ Yes	☑ **No**

12. Manufacturer Details

Please include details of ALL sites of manufacture for this product, including current approved sites and proposed sites.

SITE 1:	
Manufacturer:	☐ Australian site of manufacture ☑ **Overseas site of manufacture** ☐ Exempt Product (Vet only)
Full name of company:	**Animal Control Products Ltd**
ABN/ACN or overseas equivalent:	**N/A**
Street Address:	**408 Heads Road** **Wanganui, 4501 New Zealand**
Steps of manufacture:	**Pelleting**
Flow diagram:	

13. Manufacturers of Active Constituents (immunobiological products)

This section is for immunobiological veterinary products only.

14. Active Constituent Manufacturer Details

Manufacturer's business name	ACN or overseas equivalent	Manufacturer's business address	Manufacturing site name and physical address
Taegeuk Corporation	**N/A**	**Chongu Trade Center, #888 Sajik-1 Dong, Chonju-City, Chungbuk, Korea**	**Taegeuk Corporation 189-2 Naeuea-RI, Goa-Myen Kumi City Kyunbuk Korea**

15. Overseas registration

Are you aware if this pattern is registered overseas?

☑ **Yes** ☐ No

Please name the country (or countries) and provide a copy of label and assessment report, if available.

New Zealand.
Product registered by the Ministry of Agriculture and Forestry's (MAF), Pesticides Board on 27 August 1997. Registered number 5137. Re-registered on 6 November 2001 under the Agricultural Compounds and Veterinary Medicines Act 1997. Registered number V9014.
NZ Label to be provided by Manufacturer.

Label file name:

Assessment report file name:

16. Registered Product Holder/Manufacturer Support of product in Australia

Have you contacted the Registered Product Holder/Manufacturer for support of this use?

☑ **Yes** ☐ No

Do they have any data that would support this application

☐ Yes ☑ **No**

17. Importation Details

- ☐ a separate application for a consent to import has been lodged
- ☑ **a separate application for a consent to import will be lodged**
- ☐ not applicable

18. Product Supplier Details

The supplier will be the:

- ☐ Permit applicant
- ☑ **Other**

Name of supplier:	**Animal Control Products Ltd**
ACN details:	**N/A**
Address of supplier:	**408 Heads Road Wanganui, 4501 New Zealand**

19. Container and Net Content Details

Proposed net content(s)	Brief description of the packaging and closure material, including that which is in direct contact with the product	Method of label attachment
25 Kg bags	**At the manufacturing plant in New Zealand, the bait will be packaged into 25 kg multi-wall paper sack bags and loaded in approximately 1 tonne weatherproof bait pods for transport by ship to mainland Australia**	**Attached to Bag**

Provide details of product presentation (eg single glass bottle inside individual cardboard carton with enclosed leaflet).

At the manufacturing plant in New Zealand, the bait will be packaged into 25 kg multi-wall paper sack bags and loaded in approximately 1 tonne weatherproof bait pods for transport by ship to mainland Australia

20. Storage Stability Details

For veterinary chemical products and date controlled agricultural chemical products only. **Non-date controlled agricultural chemical products are expected to demonstrate acceptable storage stability of at least 2 years under normal conditions.** The proposed shelf life from the date of manufacture:	**6 months**
The proposed storage conditions: (eg below 30°, room temperature; normal conditions of humidity/light)	**At the manufacturing plant in New Zealand, the bait will be packaged into 25kg 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 barged 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. This product is not defined as hazardous by IATA or IMO rules (covering international air and sea freight) or under land transportation rules in most countries world wide. There are no quantity restrictions for the transportation of this product and hazardous substance signage is not necessary because the product falls well below the minimum criteria classifications for defining products as hazardous or non-hazardous goods.
Have data to support the storage stability of the product been provided with this application? **If no stability data have been submitted, ensure that a suitable scientific argument has been provided in the chemistry section of the Application Overview.**	☐ Yes ☑ **No**

21. Executive Summary

Describe the purpose of the application.

The Lord Howe Island Board is applying for an APVMA Minor Use Permit for use of an unregistered product (Pestoff 20R) with an approved active constituent (Brodifacoum) for the Lord Howe Island Rodent Eradication Project (LHI REP).

The project 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, hereafter referred to as the Lord Howe Island Group (LHIG).

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 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 the remaining dairy herd containment area. Given the size and rugged terrain of the LHIG, 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.

22. Chemistry and Manufacture

Have you provided a separate Chemistry and Manufacture data package?

☐ Yes

☐ No, the proposed product is registered and is supplied in an approved container

☑ **No, justify why a separate Chemistry and Manufacture data package has not been provided:**

The product will use an approved Active Constituent.The Brodifacoum that the manufacturer of Pestoff 20R uses is currently registered for use in Australia under Product No: 56139. therefore a Limited Chemistry Assessment only applies. A Chemistry and Manufacture Module (Level 3 Limited Chemistry Assessment) will be submitted separately by the manufacturer under Commercial in Confidence.

The APVMA has granted minor-use permits (permit numbers 13966, 13536, 12498 10895, 10788, 8423) to use Pestoff 20R on a number of Australian islands. These include Montague Island in NSW, Hermite Island in WA and Macquarie Island in Tasmania.

23(a). Toxicology

Have you provided a separate Toxicology data package?

☐ Yes

☐ No, the proposed product is registered or contains a currently approved active constituent

☑ **No, justify why a separate Toxicology data package has not been provided**

Application is made for a minor-use permit for the use of an unregistered product (Pestoff 20R) where the active constituent (brodifacoum) does have some regulatory standards established in Australia.

The intent is to aerially apply Pestoff 20R on an island to poison rodents.

Pestoff 20R is registered in New Zealand for use as a rodenticide and for aerial application onto islands.

Brodifacoum acts by interfering with the normal synthesis of vitamin K-dependent clotting factors in the liver of vertebrates (in the liver cells the biologically inactive vitamin K1-2,3 epoxide in reduced by a microsomal enzyme into biologically active vitamin K. which is essential for the synthesis of prothrombin and other clotting factors; brodifacoum antagonises the enzyme vitamin K1-epoxide reductase in the liver which leads to a decline in vitamin K and, consequently, disrupts the formation of vitamin K-dependent clotting factors).

Although Pestoff 20 R is not registered for use in Australia, reduced assessment by the APVMA is sought in the matter of Module 3 Toxicology because:
1) the APVMA has already assessed registered rodenticides (namely Ratsak and Talon) that contain the same active constituent (brodifacoum) found in Pestoff 20R, albeit at a concentration 250% times that found in Pestoff 20R. As such, some regulatory standards are currently established in Australia for brodifacoum, including poisons scheduling;
2) The APVMA has granted minor-use permits (permit numbers 13966, 13536, 12498 10895, 10788, 8423) to use Pestoff 20R on a number of Australian islands. These include Montague Island in NSW, Hermite Island in WA and Macquarie Island in Tasmania.

23(b). Poisons Scheduling

Have you provided a separate Scheduling data package?

☐ Yes

☐ No, the proposed label is consistent with the current Poisons schedule and the use pattern will not result in additional risk to users

☑ **No, justify why this data package has not been provided**

Module not triggered.
Application is made for a minor-use permit for the use of the rodenticide Pestoff 20 R which is not registered for use in Australia. However, its active constituent, brodifacoum, is present in existing registered rodenticides, e.g. Talon and Ratsak, therefore brodifacoum has previously been assessed by the APVMA, and some regulatory standards are currently established in Australia for it, including poisons scheduling.

Brodifacoum currently has a poison classification in the Poison Standard. It is classified as a Schedule 6 Poison in preparations containing 0.25 per cent or less of Brodifacoum and as a Schedule 7 Poison except when included in Schedule 6. Concentration proposed for this permit is 0.002%

The APVMA has granted minor-use permits (permit numbers 13966, 13536, 12498 10895, 10788, 8423) to use Pestoff 20R on a number of Australian islands. These include Montague Island in NSW, Hermite Island in WA and Macquarie Island in Tasmania.

24. Metabolism and Kinetics

Have you provided a separate Metabolism and Kinetics data package?

☐ Yes ☑ **No**

Justify why a separate Metabolism and Kinetics data package has not been provided:

Module not triggered.
Application is made for a minor-use permit for the use of the rodenticide Pestoff 20 R which is not registered for use in Australia. However, its active constituent, brodifacoum, is present in existing registered rodenticides, e.g. Talon and Ratsak, therefore brodifacoum has previously been assessed by the APVMA, and some regulatory standards are currently established in Australia for it, including poisons scheduling.

Brodifacoum currently has a poison classification in the Poison Standard. It is classified as a Schedule 6 Poison in preparations containing 0.25 per cent or less of Brodifacoum and as a Schedule 7 Poison except when included in Schedule 6. Concentration proposed for this permit is 0.002%

The APVMA has granted minor-use permits (permit numbers 13966, 13536, 12498 10895, 10788, 8423) to use Pestoff 20R on a number of Australian islands. These include Montague Island in NSW, Hermite Island in WA and Macquarie Island in Tasmania.

25(a). Residues Safety Criteria

Have you provided a separate Residues data package?

☐ Yes

☐ No, food, processed commodities, by-products or animal feed will not be available for consumption by humans or animals

☐ No, food, processed commodities, by-products or animal feed may be available for consumption, however, current Maximum Residue Limits (MRLs) are appropriate or the use is exempt from the requirements of an MRL

☑ **No, justify why a separate Residues data package has not been provided:**

Module not triggered. Will not be used on or in crops. No trade implications from this Application as no food commodity export. Brodifacoum has established MRL in Australia

25(b). Trade Criteria

Have you provided a separate Trade data package?

☐ Yes

☑ **No, food or stockfeed commodities derived from treated crops, animals or other situations will not be made available for export or sold into a market where export may occur**

☐ No, justify why a separate Trade data package has not been provided:

26. Work Health and Safety Criteria

Have you provided a separate Work Health and Safety data package?

☑ **Yes**

☐ No, the product is registered or the proposed use pattern will not change the currently approved user safety/re-entry or handling directions

☐ No, justify why a separate Work Health and Safety data package has not been provided:

☐ This application involves persons generally use of a new active/product never previously considered

☑ **This application involves currently approved products which require assessment of user safety/re-entry or handling directions associated with new proposed uses**

Data item 1.	
Reference No:	**LHI APVMA_WHS_Final_18Apr16**
Type:	**OH and S**
Sub-Type:	
Study Date:	**April 2016**
Authors:	**Lord Howe Island Board**
Title:	**Application for a Minor-use Permit to bait Lord Howe Island with the Unregistered Rodent Bait Pestoff 20R. Part 6: WORK HEALTH AND SAFETY**
Publication:	**N/A**
File attachment:	**LHI APVMA_WHS_Final_18Apr16.pdf;874858 bytes**
Authorising Party:	☑ **Applicant** ☐ Public Domain ☐ Other Party ☐ Previous Submission, Protected ☐ Previous Submission, Not Protected

27. Environmental Safety Criteria

Have you provided a separate Environmental Safety data package?

☑ **Yes**

☐ No, the proposed use pattern is equivalent to currently registered products in terms of risks to the environment

☐ No, justify why a separate Environmental Safety data package has not been provided:

☐ This application involves a new active or combination of approved actives or use in a situation that will increase environmental exposure where extensive consideration of fate, effects, environmental monitoring data or exposure modelling is required

☑ **This application involves use of an approved active in a situation that will increase environmental exposure where some consideration of fate effects, environmental monitoring data or exposure modelling is required**

Data item 1.	
Reference No:	**LHI APVMA_Env_Final_18Apr16**
Type:	**Environment Fate**
Sub-Type:	
Study Date:	**Apr 2016**
Authors:	**Lord Howe Island Board**
Title:	**Application for a Minor-use Permit to bait Lord Howe Island with the Unregistered Rodent Bait Pestoff 20R Part 7: ENVIRONMENT**
Publication:	**N/A**
File attachment:	**LHI APVMA_Env_Final_18Apr16.pdf;2869355 bytes**
Authorising Party:	☑ **Applicant** ☐ Public Domain ☐ Other Party ☐ Previous Submission, Protected ☐ Previous Submission, Not Protected

Data item 2.	
Reference No:	**Non toxic Trials research report161007**
Type:	**Environment Toxicology**
Sub-Type:	
Study Date:	**2007**
Authors:	**Lord Howe Island Board**
Title:	**Report on non-toxic bait trials Lord Howe Island – August 2007**
Publication:	**Unpublished**
File attachment:	**Non toxic Trials research report161007.pdf;2701317 bytes**
Authorising Party:	☑ **Applicant** ☐ Public Domain ☐ Other Party ☐ Previous Submission, Protected ☐ Previous Submission, Not Protected

Data item 3.	
Reference No:	**Taronga Zoo Captive Trial**
Type:	**Environment Toxicology**
Sub-Type:	
Study Date:	**2014**
Authors:	**Taronga Conservation Society Australia**
Title:	**Captive management for Woodhen and LHI Currawong associated with the Lord Howe Island Rodent Eradication project**
Publication:	**Unpublished**
File attachment:	**Taronga Zoo Captive Trial.pdf;243887 bytes**
Authorising Party:	☑ **Applicant** ☐ Public Domain ☐ Other Party ☐ Previous Submission, Protected ☐ Previous Submission, Not Protected

28. Target Animal/Crop Safety

Have you provided a separate Target Animal/Crop Safety data package?

☑ **Yes** ☐ No

Data item 1.	
Reference No:	**LHI APVMA_Efficacy and Human Safety_Final_18Apr2016**
Type:	**General**
Sub-Type:	
Study Date:	**Apr 2016**
Authors:	**Lord Howe Island Board**
Title:	**Application for a Minor-use Permit to bait Lord Howe Island with the Unregistered Rodent Bait Pestoff 20R Part 8: EFFICACY AND SAFETY**
Publication:	**Unpublished**
File attachment:	**LHI APVMA_Efficacy and Human Safety_Final_18Apr2016.pdf;864876 bytes**
Authorising Party:	☑ **Applicant** ☐ Public Domain ☐ Other Party ☐ Previous Submission, Protected ☐ Previous Submission, Not Protected

Data item 2.	
Reference No:	**Rodent bait uptake trial 2008**
Type:	**Efficacy and Safety**
Sub-Type:	
Study Date:	**2008**
Authors:	**Lord Howe Island Board**
Title:	**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**
Publication:	**unpublished**
File attachment:	**Rodent bait uptake trial 2008.pdf;1981151 bytes**
Authorising Party:	☑ **Applicant** ☐ Public Domain ☐ Other Party ☐ Previous Submission, Protected ☐ Previous Submission, Not Protected

Data item 3.	
Reference No:	**Carlile and Wheeler _Efficacy Trials 2013**
Type:	**Efficacy and Safety**
Sub-Type:	
Study Date:	**2013**
Authors:	**Wheeler, R. and Carlile, N.**
Title:	**Testing for brodifacoum resistance in invasive rodents on Lord Howe Island: Summary of Work Undertaken by the Office of Environment and Heritage in 2013**
Publication:	**unpublished**
File attachment:	**Carlile and Wheeler _Efficacy Trials 2013.pdf;416798 bytes**
Authorising Party:	☑ **Applicant** ☐ Public Domain ☐ Other Party ☐ Previous Submission, Protected ☐ Previous Submission, Not Protected

Data item 4.	
Reference No:	**Toxikos Human Health Risk Assessment Report FINAL Nov 2010**
Type:	**Efficacy and Safety**
Sub-Type:	
Study Date:	**2010**
Authors:	**Toxikos Pty Ltd**
Title:	**Human Health Risk Assessment for the use of Brodifacoum for the Lord Howe Island Rodent Eradication Plan**
Publication:	**unpublished**
File attachment:	**Toxikos Human Health Risk Assessment Report FINAL Nov 2010.pdf;704991 bytes**
Authorising Party:	☑ **Applicant** ☐ Public Domain ☐ Other Party ☐ Previous Submission, Protected ☐ Previous Submission, Not Protected

Data item 5.	
Reference No:	**NSW Health review of Human Health Risk Assessment**
Type:	**Efficacy and Safety**
Sub-Type:	
Study Date:	**2010**
Authors:	**NSW Health**
Title:	**Human Health Risk Assessment on the Use of Brodifacoum for the Lord Howe Island Rodent Eradication Plan**
Publication:	**Unpublished**
File attachment:	**NSW Health review of Human Health Risk Assessment.pdf;220811 bytes**
Authorising Party:	☑ **Applicant** ☐ Public Domain ☐ Other Party ☐ Previous Submission, Protected ☐ Previous Submission, Not Protected

Data item 6.	
Reference No:	**SA Health review of Human Helath Risk Assessment**
Type:	**Efficacy and Safety**
Sub-Type:	
Study Date:	**2010**
Authors:	**SA Health**
Title:	**Review of Human Health Risk Assessment**
Publication:	**Unpublished**
File attachment:	**SA Health review of Human Health Risk Assessment.pdf;1833799 bytes**
Authorising Party:	☑ **Applicant** ☐ Public Domain ☐ Other Party ☐ Previous Submission, Protected ☐ Previous Submission, Not Protected

Data item 7.	
Reference No:	**Pacific Environment - Response for Lord Howe Island Board re Toxikos Report 2015**
Type:	**Efficacy and Safety**
Sub-Type:	
Study Date:	**2015**
Authors:	**Pacific Environment Pty Ltd**
Title:	**LORD HOWE ISLAND RODENT ERADICATION PROGRAM – RESPONSE TO LETTER**
Publication:	**unpublished**
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Authorising Party:	☑ **Applicant** ☐ Public Domain ☐ Other Party ☐ Previous Submission, Protected ☐ Previous Submission, Not Protected

29. Efficacy Criteria

Have you provided a separate Efficacy data package?

☐ Yes

☐ No, the proposed use pattern is exempt from efficacy requirements

☑ **No, justify why a separate Efficacy data package has not been provided:**

Considered in Efficacy and Safety Module Part 8 uploaded with previous section

30. Non-food Trade Aspects

Have you provided a separate non-food trade data package?

☐ Yes

☑ **No, non-food commodities derived from treated crops, animals or other situations will not be made available for export or sold into a market where export may occur**

☐ No, justify why a separate non-food trade data package has not been provided:

31. Special Data

Have you provided a separate special data package, relating to antibiotic resistance, genetically-modified organisms, GMP licencing requirements or other special cases as required by data requirements?

☐ Yes

☑ **No, this section is not applicable to the current application**

☐ No, justify why a separate special data package has not been provided:

Application for a Minor-use Permit to bait Lord Howe Island with the Unregistered Rodent Bait Pestoff 20R

Part 6: WORK HEALTH AND SAFETY

MODULE 6.3: Level 3 Limited WH&S Assessment
In relation to agricultural chemical products containing an approved active constituent and for which the product involves a new application method or a new use situation and where the permit applies to nominated persons, namely staff and contractors of the Lord Howe Island Board.

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PART 6-1: PRODUCT AND USE SUMMARY

The Lord Howe Island Board (LHIB) is applying for an APVMA Minor Use Permit for use of an unregistered product (Pestoff 20R) with an approved active constituent (Brodifacoum) for the Lord Howe Island Rodent Eradication Project (LHI REP).

The project 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, hereafter referred to as the Lord Howe Island Group (LHIG).

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 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 the remaining dairy herd containment area.

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

A summary of the LHIG, the impact of rats and mice on the LHIG and justification for the eradication are described in detail in Part 7.

6-1.1. *JUSTIFICATION FOR MINOR USE*

The justification of an APVMA Minor Use permit for the LHI REP is detailed below.

Unsuitability of currently registered products

Brodifacoum rodent baits currently registered in Australia are not suitable for this project chiefly because they pose a significantly greater threat to non-target wildlife than the preferred, but locally unregistered, Pestoff Rodent Bait 20R. The concentration of Brodifacoum in Pestoff 20R is 0.02g/kg or 20 parts per million, which is only 40% of the concentration of Brodifacoum in those baits registered in Australia (0.05g /kg).

Another important difference between the locally registered baits and Pestoff 20R is that the registered baits contain Bitrex, a bitter-tasting compound. Bitrex is added to the baits to deter people from eating them. There are indications that this additive may cause bait aversion in some rodents and this may have contributed to the failure of at least one island operation targeting mice. Because the project aims to eradicate rodents from the LHIG, it is imperative that all rodents eat the bait that will be dispersed onto the area. Consequently, Bitrex will not be incorporated into baits used in the eradication on LHI.

The available baits are not suitable for distribution by helicopter as the wax baits clog the bucket spinner and the grain baits do not spread well. As well as distributing issues, wax blocks are extremely long lasting in the environment and do not breakdown with weathering for a very long timeframe. Pestoff 20R baits have been field tested in over 50 eradications.

Pestoff bait pellets come in two sizes; a 10mm diameter pellet and a 5.5 mm pellet. The 10mm baits increases the precision with which they can be dispersed from the spreader bucket because the helicopter pilot can see their line of fall much easier than if smaller baits are used. Therefore, it is easier for the pilot to avoid dropping baits into areas excluded from aerial baiting where these areas adjoin sections of the island that are to be aerially baited.

The cereal base of the pellet allows quicker environmental breakdown of the bait again reducing non target impacts. Pestoff 20R has been specifically designed for use by the manufacturer in conjunction with New Zealand Department of Conservation for aerial eradication of rodents on islands and has been used in Australia for several island rodent eradications. The rugged terrain of Lord Howe Island makes the aerial application of the bait, along with dispersal by hand and through bait stations, the only feasible option to cover the Island Group with the density of bait required to kill every rodent.

Pestoff 20R pellets have been manufactured so as to be able to withstand aerial dispersal from mechanical spreaders without excessive fragmentation. Rodent baits currently registered in Australia are registered for use in bait stations or trays; they are not registered for aerial application.

Minor Use:

The LHI REP is considered to trigger the Minor Use category based on either of the following:

- Schedule 2: Limited use in a Major Non food Situation (agricultural non-crop areas, domestic and public service areas, non crop areas, bushland / native forests) or other Situation (pastures). Limited use area of 1,400 ha 2D (or 2,100 ha 3D) on Lord Howe Island only. Or
- Schedule 3: Insufficient economic return – one off pest eradication of small area only.

Unregistered product

Pestoff Rodent Bait 20R w Brodifacoum @ 20mg/kg is not currently registered in Australia (previous permits have been issued for the product and for use in eradications with aerial baiting components).

Approved active constituent

The Brodifacoum that the manufacturer of Pestoff 20R uses is currently registered for use in Australia under **Product No: 56139**.

The APVMA has granted minor-use permits (permit numbers 13966, 13536, 12498 10895, 10788, 8423) to use Pestoff 20R on a number of Australian islands. These include Montague Island in NSW, Hermite Island in WA and Macquarie Island in Tasmania.

The Minor Use Permit is for an existing active constituent and for which the product involves a new application method or a new use situation and where the permit applies to nominated persons, namely staff and contractors of the Lord Howe Island Board.

The product has a different formulation to existing products and has a different application method (i.e. aerial application. This means Module 6.3—Level 3 Level 3 Limited WH&S Assessment applies).

Both the active constituent and the end-use product are manufactured overseas and the finished product is imported fully-packaged into Australia; no further mixing or preparation of the product is required prior to its use. Accordingly, in relation to this application, potential exposures associated with the manufacture of the active constituent and product does not require assessment.

6-1.2. *PRODUCT SUMMARY*

This section details the bait and toxin release estimates and methods of application of Brodifacoum during the proposed LHI REP.

Given that Brodifacoum is already a registered active constituent in Australia and has established regulatory standards, this section focuses on its use in Pestoff 20R and for the specific manner of use proposed for the LHI REP. Application methods and rates have been developed from numerous similar rodent eradication operations globally and particularly in New Zealand. Many of these eradication operations assist in forming the mitigation measures for WHS exposure presented below.

Physical and chemical properties:
Data requirements for finished product imported into Australia

Product

- Formulation type: BA (bait).
- Colour and physical appearance: green cylindrical pellets, one size has a diameter of 10 mm and weight of 2 grams, the other 5.5 mm and 0.6 grams (approximate weights).
- Odour: cereal.
- Vapour pressure: N/A
- Volatility: non-volatile.
- Hazardous properties: Pestoff® 20R is not corrosive, flammable nor an oxidiser. It is neither explosive nor an irritant. It is not known to be mutagenic or a carcinogenic (World Health Organisation 1995). Brodifacoum is an anti-coagulant. Its concentration in the bait, at 20 parts per million or 0.02g per kg, is low; equivalent to 40% of the concentration of brodifacoum in rat poison presently available off the supermarket shelf (the brodifacoum in Talon®, for example, has a concentration of 0.05g/kg). A fatal dose rate for a human of 0.25 mg per kg of body weight (the lowest recorded value for eutherian mammals), suggests that 20 mg of brodifacoum, the amount of brodifacoum in 1 kg of bait, may be required to kill a person weighing about 80 kg. The consumption of such an amount, by accident, is extremely unlikely. However, repeated oral exposure may cause the poison to accumulate in internal organs and may affect the clotting ability of the blood. At 20 parts per million the concentration of brodifacoum in Pestoff® 20R is less than the cut-off level to declare the product harmful in contact with skin (R21/22), as defined by the Australian Safety and Compensation Council.
- Australian Code for the Transport of Dangerous Goods:

UN No.	Name and description	Class	Packing group	Special provisions	Limited quantities	Packing instructions	Special packing provisions	Instructions	Special provisions
3027	Coumarin pesticide,	6.1	I	61 274	0	P002 IBC07	B1	T6	TP 33

	solid, toxic								
		6.1	II	61 274	500 g	P002 IBC08	B2,B3	T3	TP 33
		6.1	III	61 223 274	5 kg	P002 IBC08 LP02	B3	T1	TP 33

- Particulate formulations: The likelihood of people on the ground breathing in poison dust as a result of the aerial baiting is so low as to be virtually non-existent. Pestoff® 20R is manufactured to stringent specifications to contain little, if any, dust. On average, it contains less than 0.6% of fine particles (less than 2 mm in diameter). Studies indicate that when Pestoff® 20R is aerially distributed through a spreader bucket the amount of fine particles increases, but does not exceed 2% (range: 0.78–1.92%) (Torr and Agnew (2007).
- Packaging information: 25 kg of bait supplied in poly bags.

Individual constituents

- Name: the active constituent is brodifacoum (3-[3-(4'-bromobiphenyl-4-yl)-1,2,3,4-tetrahydro-1-naphthyl]-4-hydroxycoumarin) incorporated into bait at a level of 0.002% (20 parts per million or 0.02 g/kg). The rest of the bait is made from cereal meal, sugars, waxes and binders.
- CAS number: 56073-10-0.
- Hazardous classification: the minimum concentration cut-off level for brodifacoum under the Approved Criteria for Classifying Hazardous Substances issued by the Office of the Australian Safety and Compensation Committee is 0.1% or 1 g/kg. This is substantially higher than the concentration of brodifacoum in Pestoff® 20R (0.002% or 0.02 g/kg). Therefore the bait is not classified as hazardous.
- Exposure standard: the bait is in pellet form. Two pellet sizes will be used; one weighing about 2 grams, the other ~ 0.6 grams. The bait is not an atmospheric contaminant as such but it is possible for some dust from the pellets to be air-borne (see comments in "Particulate formulations" above).
- Concentration: 0.02 grams of brodifacoum per kilogram of bait.

Toxicology: Brodifacoum inhibits the production of Vitamin K epoxide reductase in the liver. This enzyme is responsible for maintaining active vitamin K in the blood. Vitamin K is essential for the formation of prothrombin which, in turn, is crucial for blood clotting. Brodifacoum also increases the permeability of blood capillaries, resulting in blood leaking from small blood vessels. In large enough doses brodifacoum results in uncontrolled bleeding from wounds and/or internal bleeding from weakened blood vessels (Toxikos 2010).

It is a cumulative poison, being stored in fatty tissue, the liver and kidneys. It is toxic to mammals, birds and fish. However, the brodifacoum in Pestoff® Rodent Bait 20R is a relatively low hazard to humans because of its low concentration (0.002%), slow onset of symptoms (often several days) and the existence of a highly effective antidote (namely Vitamin K).

Detailed assessment of human health risks are presented in Module 8.

Manufacturing Plant (Active Constituent)
The active constituent, Brodifacoum is manufactured overseas and is imported into Australia already incorporated into the finished product. The active constituent sourced for the product is currently registered in Australia under APVMA Product Number 56139.

Therefore assessment of the extent of and potential for environmental exposure as a result of the manufacture of the active constituent is not relevant to this Module.

A Chemistry and Manufacture Module (Level 3 Limited Chemistry Assessment) will be submitted separately by the manufacturer under Commercial in Confidence.

Formulating Plant (Product)
The product, Pestoff 20R, is a cereal-based bait containing 0.02g/kg Brodifacoum. Pestoff 20R pellets are made from ground wheat, glycerine, cane sugar and food flavouring. Wheat used in manufacture is ground to flour, screened to 1.5mm and heated with dry steam at a temperature of 130^{O} C for approximately 30 seconds to denature proteins required for germination. 10 mm or 5.5 mm diameter cereal pellets are made using a pellet press with a radial ring-die and rotating internal rollers which press the loose bait pre-mix material through the radiating apertures in the ring with a pressure of approximately 10 tonnes per square centimetre, to form cylindrical pellets as the material emerges from the outside of the die. The product is cooled to ambient temperature through a cooler/drier and then packaged and sealed to prevent post- manufacture contamination.

The active ingredient found in the bait is brodifacoum (3-[3-(4'-bromobiphenyl-4-yl)-1,2,3,4-tetrahydro-1-naphthyl]-4- hydroxycoumarin; C31H23BRO3) incorporated into bait at a level of 0.002% (20 parts per million)

It is manufactured overseas and is imported into the country as the finished product. Therefore the assessment of the extent of and potential for WH&S exposure as a result of the manufacture of the finished product is not relevant to this Module. The finished product is manufactured by:

Animal Control Products Ltd
408 Heads Road
Wanganui, New Zealand

A Chemistry and Manufacture Module (Level 3 Limited Chemistry Assessment) will be submitted separately by the manufacturer under Commercial in Confidence.

6-1.3. *USE AND APPLICATION*

Amount of Chemical to be used
The proposed treatment rate will be a nominal 12kg of Pestoff 20R pellet bait/hectare on the first application; to be followed by a second application of 8kg of bait/hectare approximately 14-21days after, weather permitting, for a total nominal treatment rate of 20 kg/ha averaged over the island.

To achieve the nominal treatment rate across the island, it is expected that the maximum bait used would be 42 tonnes of Pestoff 20R pellet baits containing 0.02g/kg (20ppm) Brodifacoum. This amount considers operational flexibility, contingency and differences in vegetation and topography across the island (i.e. the 3-Dimensional area of LHI is approximately 2,100 ha taking into account its rugged topography).

Therefore the maximum total amount of Brodifacoum used over the entire island is in the order of 840g which equates to ~ **0.40g/ha.**

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 occur on offshore islands and islets close to the main island. 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, 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.

The operation is programmed to take place in winter 2017 (June-August), when the availability of natural food for rodents is low and breeding is greatly reduced or absent. 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 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.

Given the operational window, a permit is sought for at least a three year period to account for unforeseen delays beyond winter 2017.

Aerial baiting

Aerial baiting will be conducted throughout the LHI Permanent Park Preserve and other areas of the main island excluding the settlement area and identified buffer zones. In all areas baited aerially, 10 mm baits (approximately 2g 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.

The bait will be dispersed using a purpose built spreader bucket (see Figure 1) slung below a helicopter. A rotating disc throws the bait 360^{o}consisitently to 35 m (note outlier pellets maybe 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 2). Application rates are adjusted to account for the 50% overlap (i.e. for the first drop 6kg/ha on each swathe with 50%

overlap will be applied to achieve a 12kg/ha application rate). Each bait drop will take approximately two days to complete dependant on weather.

Figure 1: Custom built spreader bucket being prepared on LHI.

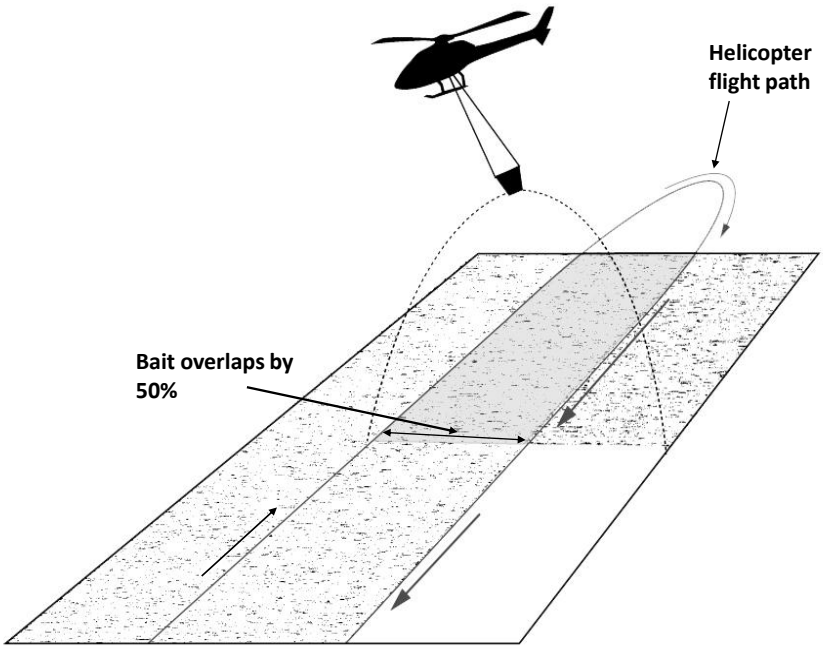

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Figure 2: Aerial Application Method

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 50m 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 180^{o}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 dose 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 turning off or removal 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 method 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 30m to dwellings. In these buffer zones bait will either be applied by hand or if agreement to the contrary is not reached, then the buffer zone will be 150 m, and will be baited by hand. This will be covered in a Property Management Plan for each property. 30m 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 after 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 technique 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 and Broughton islands in New South Wales and Hermite Island in Western Australia. It was also used on World Heritage listed Macquarie Island, south of 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 (LHIB 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 provided an opportunity to establish the correct flight configuration: air speed and settings to produce the required flow rate to achieve the on grounds 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 and operational readiness check overseen by an international eradication expert 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 (2g 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 half square metre on average) for the first application of bait and at 8kg/ha for the second application.

Provisional areas to be hand-baited are subject to completion of individual Property Management Plans.

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 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). These 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.

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 take will provide an indication of rodent activity. Bait in these locations will not be exposed to weathering, and so any remaining bait will be removed after approximately 100 days or after mice or rats are no longer detected.

When using bait stations or trays it is important that they are set close enough together that individual rats and mice come across at least one station during their nightly movements. Rats are wide-ranging and can be eradicated using a grid spacing of 25 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.

Elimination of survivors
The settlement area and other selected areas of LHI will be monitored for the presence of rodents throughout the 100-day period of the baiting operation. Detection of surviving rodents will be evidenced by bait take from bait trays and bait stations and observations of droppings or rodent activity. Residents will be asked to report any such evidence to the project team.

In addition, trained detector dogs will be deployed throughout the settlement area to find and locate any surviving rodents. In the unlikely event that rodents are detected, action will be taken to eliminate them. A Contingency Plan will be developed prior to the REP to guide selection of appropriate actions in the event that surviving rodents are detected. This could include targeted hand baiting or bait stations.

Ongoing Monitoring
Monitoring of the rodent-free status of LHI following the eradication of rats and mice will be achieved by monitoring for rodent activity at bait stations, in tracking tunnels strategically placed at stratified locations across the island and with the use of rodent detector dogs. 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.

Product storage
At the manufacturing plant in New Zealand, the bait will be packaged into 25kg 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 barged 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.

There is a risk of exposure if a physical impact rips through both the wrapping and the bag walls primarily from a forklift, while they are being transported. This could result in a small amount of bait being spilled. A "spill kit- broom, shovel, plastic bags and appropriate PPE will be kept with the bait at all stages of its transport and storage once it is removed from the shipping containers. A record of any spills will be kept.

Product Disposal

A limited amount of contingency bait will be purchased with the order in case of physical damage or weathering 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 clean up or incursion response, or 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.

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 either be incinerated on island or transported back to the mainland for disposal at an appropriately licensed facility.

PART 6-2 OCCUPATIONAL EXPOSURE ASSESSMENT

6-2.1. WH&S EXPOSURE

During the LHI REP workers may be exposed to Brodifacoum via direct ingestion, inhalation or dermal exposure during the following operational components.

- Mixing and Loading
    - in preparation for aerial dispersal - opening 25 kg bags, and emptying contents into large containers (e.g., tubs or spreader buckets);
    - for hand broadcasting - opening 25 kg bags, and emptying contents into small containers (e.g., buckets)
- Product Application
    - dust from aerial application
    - loading pellets into small trays or bait stations which are to be placed into and under buildings or animal pens;
- Rehandling and re-entry
    - disposal of empty bags and any spilt pellets;
    - collection of bait trays and stations at the end of the baiting programme, and disposal of pellets
    - collection of dead or dying animals, presumably poisoned by Pestoff 20R

These operational components are further detailed below.

Mixing and loading

- Equipment/system: pellets are supplied in bags direct from the manufacturer. They will need to be opened before tipping the contents into fadges (large bags) with a capacity between 500 and 800 kg. A Hi-ab crane will be used to load these large bags into the spreader bucket. The spreader bucket has a capacity similar to that of the fadges.
- Container volume: bait is in 25 kg bags.
- Tank volume: not applicable.
- Number of loading operations per day: Up to approximately 50 loads per day depending on the successful tender operator. Each aerial baiting treatment of the islands is expected to be completed within five days.
- Duration of treatment season: under optimal weather conditions the two applications of bait will be separated by approximately 14 to 21 days.
- Amount of product used per day: the first application will be at the nominal rate of 12 kg per hectare. The second application will be at 8 kg per hectare. Area of the islands is 2,100 hectares. Therefore approximately 25,000 kg will be spread on the first application, and approximately 17,000 kg on the second application. It is planned to complete aerial baiting within 2-5 days and hand broadcasting of bait within a maximum of 5 days for each application.

- Proposed personal protective equipment: personnel handling baits or open containers will be issued with protective clothing as per the label instructions for given tasks. Those loading the bait into the fadges will also be issued with overalls, safety glasses and dusk masks.
- Worker inhalation exposure studies of Pestoff ® 20 R: none known.
  However, the low concentration of brodifacoum in the baits plus the safety measures outlined in this module show that the potential exposure levels associated with the aerial application of this bait are sufficiently low not to warrant measured exposure studies.

Product application

The product will be applied through a combination of aerial application, hand broadcasting and the use of bait stations as described in section 6.1.3. Only trained LHIB staff will be permitted to apply Pestoff® 20R during the program.

Non toxic Pestoff ® 20R has been trialled on Lord Howe Island using baits of exact size dimensions as the proposed LHI REP. Trials were conducted for spreader- bucket calibration determinations to deliver the product at the prescribed 12kg and 8 kg per hectare.

During the REP the product will be applied as below:

- Crop/use situation: elimination of introduced rodents from the Lord Howe Island Group of islands.
- Application method/equipment: the baits will be applied either
  - Aerially - dispersed from a spreader-bucket slung below a helicopter, the ground. Helicopter pilots will be appropriately licensed and experienced to distribute baits from the air. The aerial application will involve the helicopter flying along parallel transects over the islands. Flight lines will be followed with the aid of an on-board Global Position System (GPS) unit. The spreader-bucket will disperse the bait in a swathe of known width (typically 70 metres). Swathe width is the total distance either side of the helicopter that baits are thrown by the spinner on the spreader-bucket. Swaths will overlap to minimise the risk of gaps in baiting coverage with the combined total planned to give the prescribed bait rate on the ground. The accurate plotting of transects with GPS and the pre-determined swathe width will ensure that the minimum amount of bait to target all rodents is used to fully cover the islands.
  - Hand broadcasting - the pellets would be carried in containers such as 10-litre buckets or tree planting bags
  - Bait stations - the use of bait trays and bait stations in parts of the settlement areas and in buildings including animal pens for the dairy herd, horses and goats. Where residents wish to apply bait in the own homes, a commercially available and registered bait (e.g. Talon) will be used by non trained residents.
- Application rate: two applications from the air are proposed. The first drop will be at the nominal rate of 12 kg of bait per hectare. 14 to 21 days later a second drop at the nominal rate of 8 kg per hectare will take place.
- Concentration of active constituent: 0.02g/kg.
- Total time for application per day: all daylight hours (dawn to dusk) to maximise potential to complete baiting within favourable weather periods.
- Total area treated: 2100 Hectares
- Proposed personal protective equipment- as per the product label instructions depending on the task undertaken.

Re-entry and re-handling
Personnel from LHIB Project Team will collect and dispose of the remains of rodents and non-target species wherever possible, however due to the large size of the island and rugged and inaccessible terrain this will not be possible across most of the island. Remains will be buried, incinerated or shipped to the mainland to an appropriate landfill processing facility. Because the concentration of brodifacoum in the baits is low and the density of baits on the ground is sparse (estimated to be 0.6 of the bigger pellet per m^2, two of the smaller pellets per m^2) no specific restrictions on the presence/movement of people are proposed during the eradication program. Handling dead animals will not lead to contamination with brodifacoum but, nonetheless, direct contact with carcasses will be avoided by the use of impervious gloves due to the risk from disease.

- Task-specific worker-exposure studies: not available. Workers will all follow on label safety requirements as per instruction.
- Foliar residue studies: not applicable.
- Soil dissipation studies: not applicable as soils are not being fumigated. Brodifacoum has very low water solubility; consequently the distance it will disperse beyond each pellet is not expected to be more than a few centimetres (WHO 1995).
- Withholding period: not applicable for OHS module.
- Personal protective equipment: impervious gloves to be issued if bait pellets are to be handled. Impervious gloves, plastic bags or tools such as spades to be used if dead animals are collected. This will prevent direct contact with poisoned rodents.
- Restricted entry or rehandling period: Permanent Park Preserve (PPP) areas where aerial baiting will be undertaken (e.g. Mt Gower track) will be closed to public and non project Board staff access during the days baiting will occur. Information on the baiting programme, the nature of the brodifacoum, symptoms of poisoning and the recommendation that direct contact with dead or dying animals be avoided, will be provided to locals and tourists through formal meetings, articles in the local newspaper, letter drops, and pamphlets distributed at the airport and accommodation lodges.

6-2.2. *POTENTIAL EXPOSURE PATHWAYS*

The possible exposure to staff of Pestoff® 20R during the LHI eradication program will be via 3 main routes. Risks of the pathways were assessed

1. Ingestion (extremely unlikely)
2. Inhalation (possible)
3. Dermal exposure (possible)

These exposure pathways are detailed below, however detailed assessment of human health risks is considered in Module 8 Efficacy and Safety. A Human Health Risk Assessment has also been undertaken for the project (Toxikos, 2010) and updated in 2015. These are supplied as supporting documents to the application.

Direct ingestion

Although toxic, the concentration used during the LHI REP (20ppm) means that the amount of bait needed to be ingested to be a threat to human life is significant so much so that accidental poisoning is extremely unlikely. An LD_{50} value (i.e. the dose of poison likely to kill 50% of those exposed to it) for humans of 0.25 mg per kg of body weight means about 20 mg of brodifacoum, the amount of

brodifacoum in 1 kg of bait pellets, would be required to probably kill, or cause serious illness to, a person weighing about 80 kg. The poison is slow acting, taking several days to produce a clinical effect. Vitamin K is a readily available antidote to the poison. The likelihood that a staff member will unintentionally ingest bait during the eradication program is extremely low due to the unlikely event of pellets accidently entering the mouth.

Dermal absorption

Brodifacoum is readily absorbed into the body from the gastrointestinal tract and lungs, but much less through the skin (Toxikos 2010). It is classified as a slight skin irritant. However the concentration of brodifacoum in Pestoff® 20R is so low that the threat of absorption through the skin is negligible and technically, the product is not rated as harmful if in contact with skin (R21/22), as defined by the Australian Safety and Compensation Council. Pestoff® 20 R baits only contain 40% of the brodifacoum that can be found in a similar weight of Ratsak or Talon, both of which have been registered in Australia for sale to the general public. Nevertheless, all staff involved in handling the pellets will be issued with the appropriate protective clothing, including impervious gloves, overalls, dusk masks and eye protection to avoid any unnecessary dermal contact as well as being instructed to wash the affected areas if the bait comes into contact with the skin.

Inhalation

It is theoretically possible that project staff could be exposed to bait dust either during loading or that is broadcast by helicopters during the program. The concentration of brodifacoum in the air following aerial distribution of baits is so low that it poses negligible risk to human health (Toxikos 2010).

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% (Torr and Agnew), 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.

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.

In reality the actual dust levels are likely to be considerably less than those quoted and more dispersed in the atmosphere. Not only is this much lower than the accepted standard, this concentration would quickly be dissipated by wind and settling. Once on the ground the particles will rapidly break down, with the actual rate depending on precipitation and soil moisture and the toxicant will bond to the organic material until it has broken down.

OH&S risks associated with inhalation of poison dust will be negligible for most staff given the pellet nature of baits and the low levels of dust associated with this particular product. The exception being staff working beneath the chopper, opening the fadge to allow the bait to flow into the bucket, where the dust is more concentrated and the down wash of the helicopter can cause the dust to circulate. In line with standard OH&S procedures, personnel distributing baits by hand will be issued with protective impervious gloves and to eliminate the minimal risk posed by inhaling or absorbing the poison through the skin. Staff working underneath the helicopter will wear face mask, goggles,

overalls and protective footwear in addition to the gloves. This is as per label conditions recommended by the manufacturer.

Estimates made of the amount of brodifacoum that might be inhaled during the eradication program are 5 million times less than a dose that will affect the body. This means that more than 200 million tonnes of bait would have to be dropped on Lord Howe Island to expose workers and residents to a level of dust that might delay blood clotting time. This program is planned to broadcast 42 tonne (Toxikos 2010).

6-3 RISK MANAGEMENT AND WORKPLACE INFORMATION

6-4.1. MEASURES TO CONTROL OCCUPATIONAL EXPOSURE

A project OH&S plan will be developed for all aspects of the project (not just handling Brodifacoum) to:

1. identify the hazards and risks from project activities and the working environment
2. mitigate the risks to the extent reasonably practical and ensure the residual risk is acceptable
3. Ensure the project team understand the risks and the proposed mitigation and are empowered to stop work if they feel unsafe
4. Ensure the team are properly qualified, trained, experienced and physically able to do the job safely.
5. Develop emergency and contingency procedures so the team knows what to do when something goes wrong

Staff will be issued appropriate safety equipment (overalls, safety glasses, impervious gloves and face masks) when opening or emptying the bags containing the pellets. Similarly, protective clothing will be issued to those staff disposing of used bags and spilt, unusable baits. Disposal may take place on LHI (e.g. at the island's waste-disposal facility or by burning and/or burial in a secure area) or at a waste-disposal facility on the mainland. Staff collecting any dead animals suspected of being poisoned will be instructed not to touch such animals directly but to use impervious gloves, plastic bags or some other means to prevent direct contact with skin or clothing. Most of these animals will be disposed of as soon after collection as possible but some non-targets may be retained for post-mortem examination. Only project staff who are required to be handling Pestoff ®20 R for project application or who are required to be in the vicinity of operational procedures will be exposed to Pestoff ®20 R.

The issuing of protective clothing and appropriate instructions and warnings will result in the baiting posing minimal risk to those who will handle the pellets during the rodent eradication. Information sheets outlining the hazards of touching baits and animals suspected of being poisoned will be issued to island residents and tourists. Visits to the local school will also be undertaken by project staff to inform children of these dangers in consultation with school staff and parents.

Operational precautions including a flying buffer around dwellings, maximum operational wind strength of 30ktss and removing all bait from within buildings after the completion of the operation will reduce exposure to bait and dust.

Use of 5.5mm baits around dwellings will make accessing a hazardous dose of toxicant difficult for children or persons of impaired interpretive ability due to the number of baits they would need to locate and consume.

A detailed WH&S Risk Assessment is attached as Appendix 6.1.

The Pest off 20R Material Safety Data Sheet is attached as Appendix 6.2.

6-4.2. *TRAINING REQUIREMENTS*

Staff will be thoroughly trained in all safety aspects of using and handling Pestoff® 20R baits and advised of the following safety precautions:

- baits are poisonous if swallowed. If ingested, do not induce vomiting, do not touch bait, wear impervious gloves when handling baits or open bait containers;
- that if baits come into contact with the skin, wash the relevant area thoroughly with soap and water;
- that if baits or dust come into contact with eyes, wash eyes immediately;
- after removing contaminated clothing wash with hot and soapy water before re-use;
- not to eat, drink or smoke while handling baits. Remove protective clothing and wash hands and exposed skin thoroughly before meals;
- not to directly touch dead and dying animals, regardless of cause of death;
- To use face masks, goggles gloves and overalls and protective footwear when loading pellets into hoppers
- that clinical symptoms may be delayed for several days after ingestion, and can include pale mucous membranes; excessive bleeding from minor cuts; haemorrhaging around the nose, mouth, eyes and anus; blood-tinged froth around the nose and mouth; blood in urine (haematuria); tar-like faeces; vomiting blood; ataxia or lack of co-ordination; swollen joints; and easy bruising. Death due to hypoxia and hypovolemic shock may occur from 48 hours to several weeks after exposure. However, there may be no apparent symptoms so a physician should be consulted if poisoning is suspected.
- having Field First Aid Training personnel on site as a prerequisite to undertaking field baiting programs;

Staff training requirements are currently being discussed and developed with consultation with Environment Protection Authority (EPA). Initial discussions have focussed on the requirement for project staff to hold a pest management technician or similarly tailored package of competency training for the occupational use of pesticides in NSW. The requirements for project staff will continue to be assessed and developed with EPA to determine what level is required for Team Leaders and field staff.

Selection of helicopter crews is conditional that they will have the appropriate aerial licence to disperse baits from the air. Previous experience working in mountainous terrain and island eradication projects using Pestoff® 20R will be a major consideration on selection criteria when tenders are developed.

6-4.3. *OCCUPATIONAL EXPOSURE MONITORING*

Atmospheric monitoring: **Not applicable**.

Health surveillance: Although extremely unlikely to affect project staff due to low brodifacoum levels in Pestoff ®20R and the use of recommended PPE, staff will be advised to monitor themselves and work colleagues for the early signs of toxicity which include-

- Gum bleeding
- Nosebleeds
- Small red rashes or purple spots caused by minor haemorrhage
- Instant bruising after minor bumps

- Bruising around the joints of the body
- Blood in the urine
- Black tarry faeces

A resident doctor is located on Lord Howe Island for any unlikely emergency situation regarding brodifacoum health issues with workers and residents. Vitamin K will be available on the island as a further precaution.

Tank mixing **- Not applicable.** No tank mixing of Pestoff ®20 R will be occurring during the project

Contraindication**- Not applicable.**

PART 6-4: REFERENCES

Broome, K.G.; Fairweather, A.A.C.; Fisher, P. (2016). Brodifacoum Pesticide Information Review. Version 2016/1. Unpublished report docdm-25436, Department of Conservation, Hamilton, NZ.

LHIB (2007). Report on non-toxic bait trials Lord Howe Island – August 2007. Unpublished report for the Lord Howe Island Board.

Toxikos (2010). Human Health Risk Assessment in the use of Brodifacoum for the Lord Howe Island Rodent Eradication Plan. Toxicos Report Pty Ltd.

Torr, N.and Agnew, D. (2007).Trial to determine differences in bait fragmentation in various spreader bucket designs used during aerial application of toxic bait. Department of Conservation, New Zealand Government. February 2007.

World Health Organisation (1995). Anticoagulant rodenticides. International Programme on Chemical Safety .Environmental Health Criteria 175. World Health Organisation, Geneva.

APPENDIX 1 – OCCUPATIONAL HEALTH AND SAFETY RISK ASSESSMENT FOR THE BAITING OF LORD HOWE ISLAND USING PESTOFF 20®

Risk	Consequences	Likelihood	Risk treatment	Level of risk after treatment
Poisoning of staff by the brodifacoum used in the baits.	Moderate	Unlikely	The concentration of brodifacoum in the baits is so low that dermal absorption is almost nonexistent. The consumption of approximately 750 grams or more is required to place an adult human at risk of serious injury or death. The consumption of such a large amount would need to be deliberate. The poison is slow acting i.e. over several days. It is also effectively treated with Vitamin K. Personnel involved in the baiting, medical staff in the local hospital and island residents will be informed of the symptoms of brodifacoum poisoning well in advance of the baiting operation. Stocks of Vitamin K will also be on hand in the local hospital with the local Doctor well informed on brodifacoum exposure treatment	Negligible
Staff involved in ground baiting of aerial-exclusion zones absorb brodifacoum through the skin.	Minor	Unlikely	The concentration of brodifacoum in the baits is so low that the risk of dermal absorption is virtually non-existent. Even if brodifacoum was absorbed, the amount would be so low that brodifacoum poisoning would not manifest. However, as a precaution, staff will be issued with gloves.	Negligible
Those involved in loading pellets into the fadges absorb brodifacoum through the skin or inhale	Minor	Unlikely	There is only a small amount of particulate matter associated with the pellets .Even so, loading the spreader buckets will take place in the open i.e., not in a confined space, and the personnel doing the loading will be issued with dust masks and safety glasses, overalls	Negligible

bait dust.			and gloves.. Pellets will be tipped straight from the bags in which they were shipped from the manufacturer, into larger bags to facilitate loading the spreader bucket for aerial dispersal. Direct contact with the bait will be limited, especially as the loaders will be issued with appropriate PPE. Add to these precautions the fact that the concentration of brodifacoum in the baits is so low that the risk of dermal absorption is virtually non-existent then the risk of poisoning during this process is extremely unlikely.	

APPENDIX 2 – MATERIAL SAFETY DATA SHEET

ANIMAL CONTROL PRODUCTS LTD
SAFETY DATA SHEET
Revised 2011

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Product Name: (a) PESTOFF RODENT BAIT
PESTOFF RODENT BAIT 20R
Synonyms: Pestoff bait, Pestoff blocks.
Supplier: Animal Control Products Ltd
Street address: Physical address: 408 Heads Road, Whanganui 4501, New Zealand.
Postal address: Postal address: Private Bag 3018, Whanganui 4540, New Zealand.
Telephone: 64 (0) 6 344 5302
Facsimile: 64 (0) 6 344 2260
After hours telephone numbers: 0274798 318 or 0274798 319
ACCIDENTAL HUMAN POISONING
National Poisons Centre:
Emergency phone number for spills, transport emergencies and risk mitigation:
Call a doctor or hospital without delay and seek medical advice. Provide information from the product label to medical personnel.
Free phone 0800 764 766
Dial 111

2. COMPOSITION / INFORMATION ON INGREDIENTS

Product Name: (a) PESTOFF RODENT BAIT
((c) PESTOFF RODENT BAIT 20R
Synonyms: Pestoff bait, Pestoff blocks
Active Ingredient: Brodifacoum 0.002% w/w
Other Ingredients: Cereals, sugars, waxes and binders.
Molecular Weight of Active: 523.4
Molecular Formula of Active: $C_{31}H_{23}O_3Br$
Recommended Use: Cereal based baits for rodent or possum control.
Appearance: Extruded solid cereal blocks or baits dyed blue or Green

3. HAZARDS IDENTIFICATION

STATEMENT OF HAZARDOUS NATURE: This product is a Harmful Substance.
HSNO Approval Code: HRC000004
HAZARD CLASSES (HSNO): 6.9B, 9.1D
HAZARD IDENTIFIERS: Priority Identifiers – Harmful, Ecotoxic, Keep out of reach of children.

Secondary Identifiers - Harmful substance.
Repeated oral exposure may cause toxin toaccumulate in internal organs and may affect the clotting ability of the blood.
Brodifacoum 20ppm
Brodifacoum 20ppm Revised May 2011 Page 2 of 4
DANGEROUS GOODS CLASS: Not classified Dangerous Goods as toxicity falls below Packing Group III threshold.
SYMPTOMS OF POISONING: No symptoms may be apparent for several days if poisoning has occurred. Can kill if swallowed in large quantities. The active constituent (brodifacoum) is an anticoagulant chemical, which if taken by humans, domestic animals or pets, will reduce the clotting power of the blood. Nausea and vomiting may occur soon after ingestion, however in some cases effects from exposure may be delayed for several days or may not be evident unless checked by physician. Typical overt symptoms of poisoning include bleeding gums, increased tendency to bruising, blood in urine and faeces and excessive bleeding from minor cuts. Haemorrhagic shock, coma and death may follow in cases of severe poisoning.

4. FIRST AID MEASURES

Ingestion: In the event of ingestion, do not induce vomiting. Consult a physician and provide an estimation of the amount of product ingested. In the case of very small amounts of product (< 10 grams) being taken, no symptoms may develop but larger amounts may affect blood clotting times. A physician can assess this and provide Vitamin K_1 therapy as necessary.
Eye Contact: Wash eyes with water.
Skin Contact: Wash exposed area with soap and water.
Contaminated Clothing: Remove contaminated clothing and wash before re-use. Wear gloves and overalls when handling baits. Do not eat, drink or smoke. Clothing and gloves should be decontaminated by washing in hot soapy water.
AS THE SYMPTOMS OF POISONING WILL BE DELAYED FOR SEVERAL DAYS, ALWAYS SEEK MEDICAL ADVICE IF POISONING IS SUSPECTED.

5. FIRE FIGHTING MEASURES

The product contains no toxic emissions as vapours, gases or odours. The principle hazard route is via ingestion.

6. ACCIDENTAL RELEASE MEASURES

In the event of a spill, isolate the spill area and take all practicable steps to manage any harmful effects of a spillage including preventing baits from entering streams or waterways. Scoop spilled baits into secure containers. Recover any undamaged bait for later use by placing in appropriately labelled containers and dispose of spoiled bait as directed in the disposal section below. Use a broom to collect fine material and wash down the spill area with copious water only after all spilled bait has been removed. Give consideration to possible hazards arising from irrigating spill sites .Brodifacoum is not water soluble but fine bait material may pose a risk to people, pets, livestock, wildlife and fish.

7. HANDLING AND STORAGE

When handling open containers or baits, wear latex or rubber gloves. When loading aircraft or working in windy conditions, wear overalls, goggles and a dust mask as protection against dust entering the eyes or mouth. Do not eat, drink or smoke when using the product or handling open containers. Wash protective clothing and equipment after use. Remove the

outer layer of clothing and wash hands and exposed skin thoroughly before meals and after any contact.
Store in original container, tightly closed and away from feed or foodstuffs. Keep out of reach of children, pets and livestock.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Occupational Exposure Limits: Not applicable (not assigned).
Brodifacoum 20ppm Revised May 2011 Page 3 of 4
Engineering Measures: Decontamination is through microbial decomposition in a biologically active medium.
Personal Protection Equipment: Operators using or handling the product in open containers must wear gloves. When working around aircraft, wear overalls, a dust mask and goggles to prevent the inhalation of airborne particles.

9. PHYSICAL AND CHEMICAL PROPERTIES

Form / Colour / Odour: Pellet and block baits have a solid cylindrical form, are dyed blue or green
and may have an odour of cinnamon, fruit flavouring, or chocolate.
Solubility of technical grade brodifacoum Water at pH 5.2 = 0.00
7.4 = 0.38
9.3 = 1.00
Toluene 0.72
Acetone 2.30
Methanol 0.27

10. STABILITY AND REACTIVITY

Brodifacoum cereal based baits are stable and non-reactive under normal storage and use conditions.

11. TOXICOLOGICAL INFORMATION

The baits present a very low hazard to operators unless taken orally.
*TOXICITY DATA FOR THE ACTIVE INGREDIENT - VARIOUS SPECIES**
White laboratory rat (oral) LD_{50} 0.26 mg//kg B/W
Brush-tailed possum (oral) LD_{50} 0.8 mg/kg B/W
Dog (oral) LD_{50} 3.56 mg/kg B/W
Cat (oral) LD_{50} 25.0 mg/kg B/W
Mouse (oral) LD_{50} 0.4 mg/kg B/W

12. ECOLOGICAL INFORMATION

Use the products only for the purpose indicated and in the manner prescribed by the product label.
Brodifacoum may persist for many months in the fatty tissue, liver and kidneys of sub-lethally poisoned animals. Mortally poisoned animals may present a secondary poisoning risk to carnivorous birds and mammals and in addition a tertiary poisoning risk where for example feral pigs eat poisoned possums and are subsequently taken and eaten by pig hunters. Take steps to mitigate any potential non-target exposure by wildlife, domestic animals or humans. Studies have shown that brodifacoum concentrations will decline within decaying carcasses. Improper disposal of unwanted pesticide is unlawful. If wastes cannot be disposed of according to label instructions, contact your local Regional Council hazardous waste advisor for guidance.

13. DISPOSAL CONSIDERATIONS

Product which is surplus or spoiled should be disposed of by burying with other organic material on the active tip face of an appropriately managed landfill or buried within the biologically active layer of soil elsewhere within a secure area. Ensure that a good covering of earth is applied over the bait immediately to prevent access by scavenging birds. Avoid deep disposal.
Alternatively, burn unwanted bait material in a suitably constructed and appropriately located incinerator and bury any residues as above. As the smoke and fumes produced by burning is irritating and potentially harmful, ensure wind does not carry smoke plume towards populated areas.
Treating the baits through a sewage oxidation facility or other chemical treatment facility is also an acceptable means of disposing of unwanted bait material where this is allowed by local by-laws and regulations.
Burn empty bags or bury in a suitable location at a landfill. Do not use the empty container for any other purpose.

14. TRANSPORT INFORMATION

Proper Shipping Name: Not Applicable – Not classified as Dangerous Goods due to low toxicity
U.N. NO: Not Applicable
Class: Not Applicable
Packing Group: Below PG III threshold for Dangerous Goods
Maximum transport quantity when for use as tools of trade = No limits

15. REGULATORY INFORMATION

Registered Pesticides: The New Zealand registration and classification details for these
brodifacoum products are:
(a) PESTOFF RODENT BAIT – V005137 HSNO Approval HRC000004
(b) PESTOFF RODENT BLOCKS – V005099 HSNO Approval HRC000004
(c) PESTOFF RODENT BAIT 20R – V009014 HSNO Approval HRC000004
(d) PESTOFF BRODIFACOUM POSSUM BAIT – V004991 HSNO Approval HRC000004
(e) PESTOFF WAXED POSSUM BAIT – V005136 HSNO Approval HRC000004

16. OTHER INFORMATION

Do not use poisoned or contaminated animals for food or feed.
This product is toxic to most wildlife. Birds and mammals feeding on carcasses of contaminated animals may be killed. Take measures to minimise the chance of baits entering any body of water.
Apply the product only as specified by its label directions.
Where practicable, the exposed bodies of all poisoned animals should be collected and destroyed by complete burning or deep burial at a landfill approved for hazardous wastes.
CONSULT NEAREST POISON CONTROL CENTER FOR CURRENT INFORMATION.

All information contained in this Data Sheet is as accurate and up-to-date as possible. Since Animal Control Products Ltd cannot anticipate or control the conditions under which this information may be used, each user should review the information in the specific context of the intended application.

Application for a Minor-use Permit to bait Lord Howe Island with the Unregistered Rodent Bait Pestoff 20R

Part 7: ENVIRONMENT

MODULE 7.3: Limited Level Environmental Assessment
In relation to chemical products containing an approved active constituent where some consideration of fate, effects or environmental monitoring data or exposure modelling are required.

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PART 7-1: PROBLEM FORMULATION

The Lord Howe Island Board (LHIB) is applying for an APVMA Minor Use Permit for use of an unregistered product (Pestoff 20R) with an approved active constituent (Brodifacoum) for the Lord Howe Island Rodent Eradication Project (LHI REP).

The project 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, hereafter referred to as the Lord Howe Island Group (LHIG).

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 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 the remaining dairy herd containment area. Given the size and rugged terrain of the LHIG, 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.

This section summarises the problem including important features of the LHIG with relevance to the proposed REP, the current impact of rats and mice on the LHIG, the current control program, justification for eradication and justification for a minor use permit.

7-1.1. LORD HOWE ISLAND SUMMARY

The Lord Howe Island Group (LHIG; 31°31'S, 159°03'E) is located 760 kilometres north east of Sydney. It comprises the main island (Lord Howe Island) and 28 smaller islets and rocks (Figure 1). The most significant of the outer islands are the Admiralty Islands (1 km to the north of LHI) and Balls Pyramid, (approximately 23 km south –east from LHI). Balls Pyramid will be excluded from baiting due to the absence of rodents and separation distance to LHI.

The main island is 12 km long, 1–2.8 km wide with a two dimensional area of 1455 ha. It is formed in the shape of a crescent with a coral reef enclosing a lagoon on the western side (Figure 1). 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 (Figure 2). The settlement area is restricted to the central lowlands and covers about 15% of the island. North of the settlement area the land rises gradually to about 200 m at the top of the sheer sea cliffs that fringe the northern end of the island. The terrain in the northern and southern mountains is extremely rugged and many parts cannot safely be traversed by foot. 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. Lord Howe Island was permanently settled in 1833. The resident population is now about 350. LHI is the only island within the LHIG on which settlement has occurred. Tourism and the export of Kentia Palm (*Howea forsteriana*) seedlings are the island's two major sources of income. About 16,000 tourists visit the island each year, but numbers are regulated, with a maximum of 400 allowed on the island at any one time.

Figure 1. The Lord Howe Island Group (DECC 2007).

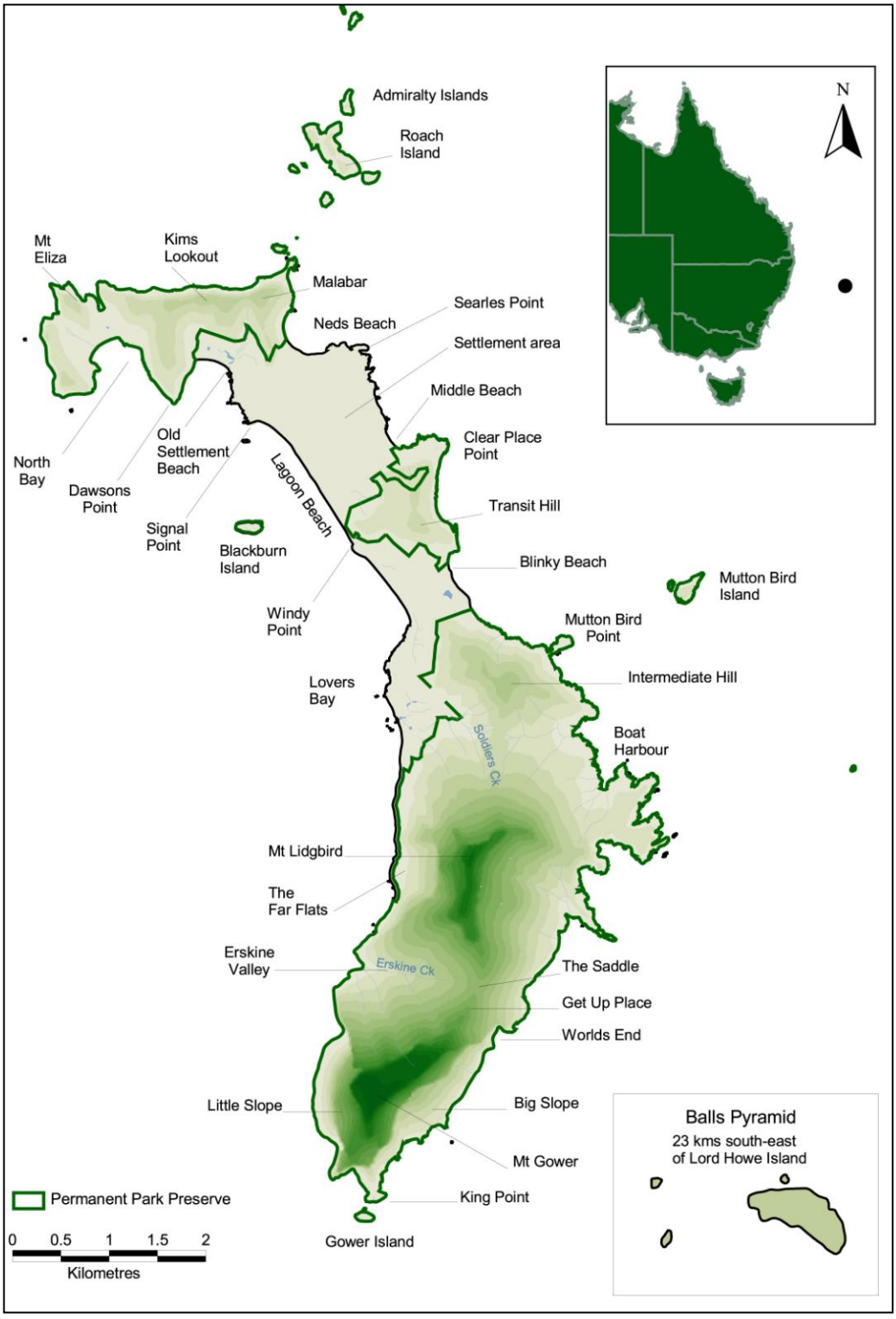

Figure 2. Lord Howe Island as seen from the north (DECC 2007).

Fish are harvested and sold locally, but there is no export of fish from the island. There are approximately 100 beef cattle on the island and a small dairy herd of approximately 14 cattle. The beef herd will be removed prior to the REP; however the dairy herd will remain. The dairy herd will be contained in a small area treated with bait stations only and hand fed during the REP. Many residents keep chickens, which in total number approximately 300. These will also be removed prior to the REP. Beef cattle and chickens will be reintroduced after the REP; once bait breakdown monitoring has confirmed break down of all baits (~100 days).

Other livestock includes 2 horses and approximately 4 goats, These will also be contained in small areas treated with bait stations during the REP. There are also around 50 pet dogs on the island. During the REP residents will be given the option of kennelling their dogs off island during the REP or muzzling their dogs. Cats are prohibited.

The LHIG falls under the jurisdiction of the New South Wales State Government. The LHIB is responsible for the care, control and management of the LHIG in accordance with the *Lord Howe Island Act 1953*. Approximately 75% of the main island plus all outlying islands, islets and emergent rocks within the LHIG are protected under the Permanent Park Preserve (PPP), which has similar status to that of a national park. The LHIG is on the Register of National Estate and was listed as a World Heritage Area in 1982.

The LHIG is an outstanding example of an oceanic island of volcanic origin with a unique biota of plants and animals and important and significant natural habitats for in-situ conservation of biological diversity, including those containing species of plants and animals of outstanding universal significance from the point of view of science and conservation.

The LHIG supports a diverse terrestrial flora and fauna with a high degree of endemic species and communities. Most of the LHIG is protected under the 1,300 ha PPP which includes both the northern and southern mountains of the main island, the Admiralty Islands, Balls Pyramid and surrounding islands. Examples of World Heritage values of the LHIG specific to the terrestrial environment (Environment Australia, 2002) include:

- the diversity of bird taxa comprising 164 bird species, including species of conservation significance with many endemics
- seabird breeding habitats which, together, comprise one of the major breeding sites in the southwest Pacific, including habitat for species of conservation significance
- high levels of species richness of terrestrial invertebrate taxa of which 50% are endemic including 100 species of spiders
- the diversity of vegetation communities which includes 25 associations, 20 alliances and 14 sub-formations
- the diversity of indigenous vascular plant taxa comprising at least 241 species, including species of conservation significance with many endemics (44%).

Many of these species are threatened and are listed under either New South Wales legislation or Australian Commonwealth Government legislation (DECC 2007). Over 60 bird species recorded on the LHIG are listed as migratory under international agreements.

Populations of house mouse and ship rat were accidentally introduced to LHI. Mice are thought to have arrived around 1860 and rats arrived in 1918. Both species have had, and continue to have, significant adverse impacts on the unique flora and fauna of the LHIG.

7-1.2. THE IMPACT OF HOUSE MICE AND SHIP RATS ON THE LHI GROUP

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 & 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 droppings, 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 can be 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 (*Cyclodina 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 probably 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 fledglings 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 & 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 & 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 affects 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 & Skeenkamp 1990).

From the perspective of the human population, rats and mice are major domestic pests. They infest residences, destroy foodstuffs 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.).

7-1.3. CURRENT CONTROL PROGRAM

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 coumatetryl. The prolonged use of warfarin has led to house mice becoming resistant to this poison.

The LHIB currently use an alternative poison to Brodifacoum (Coumatetryl in the product Racumin) in a limited control program consisting of bait stations placed throughout the Island's Settlement Area and in some sections of the Permanent Park Preserve for conservation purposes (approximately 10% of the island). The LHIB also supplies Coumatetryl to residents on a pulse baiting schedule (approximately every 6 weeks) to control rats and mice and minimise the use of Brodifacoum in order to reduce the potential build up of resistance to Brodifacoum. The current rodent control program uses approximately 3 tonnes of Coumatetryl-based bait annually at a cost of around $83,000 per year but neither the rat or mouse population is being reduced to a level that reduces ecological impacts.

A range of anticoagulant toxicants including Brodifacoum baits (mostly wax blocks @ 50ppm) is currently used in the settlement area by residents to control rats and mice on their properties and inside dwellings. The LHIB has no control over this. The quantity of commercial rodenticide, (i.e. other than that provided by the Board) used by residents each year on the island is estimated at approximately 400 kg.

The present control baiting program does not adequately protect the island group's native flora and fauna. 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. Ongoing use of poison in the environment also presents a major risk to non-target species including humans, pets and livestock through continued exposure. As such, the effectiveness and long-term sustainability of the existing localised control programme, or an expanded programme, is highly questionable. Potential resistance to Brodifacoum in LHI mice is discussed in the Efficacy Module.

Further detail on the previous and current control programs is provided in the Efficacy and Safety Module.

7-1.4. THE CASE FOR ERADICATION

The 'do nothing' scenario and continuation of the current control situation on LHI are both considered unacceptable, 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 & 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 20 years of development and implementation involving more than 300 successful eradications worldwide (Howald *et al.* 2007). Systematic techniques for eradicating rodents from islands were first developed in New Zealand in the 1980s (Moors 1985; Taylor & Thomas 1989; Taylor & 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 & 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 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) (DIISE 2015). Whilst attempts at eradicating mice from offshore islands using Brodifacoum have been less successful, with a 49% success rate internationally (MacKay et al. 2007), many of these failures can be attributed to inappropriate planning or implementation. The success rate for mouse eradications on NZ islands using Pestoff 20R with 20ppm brodifacoum (the bait to be used on Lord Howe) aerially applied 1997- 2014 is 100% or 11 from 11 attempts (Broome et al, 2016).

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

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 (~4000 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 LHI Board 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 rat 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.

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 an eradication programme on the LHIG include:

- a marked increase in birds, reptiles and insects abundance – this boost in diversity 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) that have long been absent due to the predation of rats and mice, such as the LH gerygone, grey fantail 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.

The proposed eradication operation is also supported by a range of international, national and State laws, policies and strategic planning documents that effectively provide a statutory requirement for both NSW and Commonwealth governments to support the eradication of exotic rodents from LHI. The eradication of rodents from LHI is recommended in all the following documents:

- Lord Howe Island Group, World Heritage Property and Strategic Plan for Management 2000–2005 (2000).
- Biodiversity Management Plan for Lord Howe Island (DECC 2007).
- Lord Howe Island Permanent Park Preserve Plan of Management (2010).
- Predation by exotic rats on Australian offshore islands of less than 1,000 km2 (100,000 ha) (2006): a key threatening process listed under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999.
- Predation by the Ship Rat (Rattus rattus) on Lord Howe Island (2000): a key threatening process listed under the NSW Threatened Species Conservation Act 1995.
- Recovery Plan for the Lord Howe Placostylus (2001).
- Interim Recovery Actions for the Lord Howe Island Phasmid (2001).

The eradication of rodents from LHI is consistent with the:

- Australian Pest Animal Strategy – A national strategy for the management of vertebrate pest animals in Australia. Natural Resource Management Ministerial Council (2007). Commonwealth Government of Australia, Department of the Environment and Water Resources, Canberra.
- Australia's Biodiversity Conservation Strategy 2010-2020. National Biodiversity Strategy Review Task Group (2009). Consultation Draft. Australian Government, Department of the Environment, Water, Heritage and the Arts, Canberra.

7-1.5. JUSTIFICATION FOR MINOR USE

The justification of an APVMA Minor Use permit for the LHI REP is detailed below.

Unsuitability of currently registered products

Brodifacoum rodent baits currently registered in Australia are not suitable for this project chiefly because they pose a significantly greater threat to non-target wildlife than the preferred, but locally unregistered, Pestoff Rodent Bait 20R. The concentration of Brodifacoum in Pestoff 20R is 0.02g/kg or 20 parts per million, which is only 40% of the concentration of Brodifacoum in those baits registered in Australia (0.05g /kg).

Another important difference between the locally registered baits and Pestoff 20R is that the registered baits contain Bitrex, a bitter-tasting compound. Bitrex is added to the baits to deter people from eating them. There are indications that this additive may cause bait aversion in some rodents and this may have contributed to the failure of at least one island operation targeting mice. Because the project aims to eradicate rodents from the LHIG, it is imperative that all rodents eat the bait that will be dispersed over the area. Consequently, Bitrex will not be incorporated into baits used in the eradication on LHI.

The available baits are not suitable for distribution by helicopter as the wax baits clog the bucket spinner and the grain baits do not spread well. Pestoff 20R baits have been field tested in over 50 eradications.

Pestoff bait pellets come in two sizes; a 10mm diameter pellet and a 5.5 mm pellet. The 10mm baits increase the precision with which they can be dispersed from the spreader bucket because the helicopter pilot can see their line of fall much easier than if smaller baits are used.

Therefore, it is easier for the pilot to avoid dropping baits into areas excluded from aerial baiting where these excluded areas adjoin sections of the island that are to be aerially baited.

The cereal base of the pellet allows quicker environmental breakdown of the bait again reducing non target impacts. Pestoff 20R has been specifically designed for use by the manufacturer in conjunction with New Zealand Department of Conservation for aerial eradication of rodents on islands and has been used in Australia for several island rodent eradications. The rugged terrain of Lord Howe Island makes the aerial application of the bait in selected areas the only feasible option to cover the Island Group with the density of bait required to kill every rodent.

Pestoff 20R pellets have been manufactured so as to be able to withstand aerial dispersal from mechanical spreaders without excessive fragmentation. Rodent baits currently registered in Australia are registered for use in bait stations or trays; they are not registered for aerial application.

Minor Use:

The LHI REP is considered to trigger the Minor use category based on either of the following:

- Schedule 2: Limited use in a Major Non food Situation (agricultural non-crop areas, domestic and public service areas, non crop areas, bushland / native forests) or other Situation (pastures). Limited use area of 1,400 ha 2D (or 2,100 ha 3D) on Lord Howe Island only. Or
- Schedule 3: Insufficient economic return – one off pest eradication of small area only.

Unregistered product

Pestoff Rodent Bait 20R w Brodifacoum @ 20mg/kg is not currently registered in Australia (previous permits have been issued for the product and for use in eradications with aerial baiting components).

Approved active constituent

The Brodifacoum that the manufacturer of Pestoff 20R uses is currently registered for use in Australia under **Product No: 56139**.

The APVMA has granted minor-use permits (permit numbers 13966, 13536, 12498 10895, 10788, 8423) to use Pestoff 20R on a number of Australian islands. These include Montague Island in NSW, Hermite Island in WA and Macquarie Island in Tasmania.

The Minor Use Permit is for an existing active constituent in a limited use situation (a one off eradication over a relatively small area), it is appropriate to consider some consideration of fate, effects monitoring and modelling rather than extensive consideration. This means Module 7.3—Level 3 Limited Environment Assessment applies.

Both the active constituent and the end-use product are manufactured overseas and the finished product is imported fully-packaged into Australia; no further mixing or preparation of the product is required prior to its use. Accordingly, in relation to this application, potential environmental exposures, associated with the manufacture of the active constituent and product, do not require assessment.

The environmental fate and chemistry of Brodifacoum has previously been assessed by the APVMA in connection with the registration of over 70 rodenticides such as Talon and several minor use permits, therefore only limited data is provided in this application in relation to these aspects. The major focus of the application is on the Environmental Toxicology regarding the use of the bait on the LHIG. The environmental fate and chemistry of

Brodifacoum in the proposed bait product are not expected to be significantly different to that previously assessed by the APVMA. Application rates (in total, nominally 20kg bait/hectare; 0.002% Brodifacoum bait: average 0.40g active component/hectare) are low-moderate and Brodifacoum is moderately persistent in soils. Brodifacoum does not leach into ground water. While moderately persistent in the environment, the low-moderate application rate indicates that widespread environmental contamination is not expected to occur following the proposed use.

Brodifacoum is toxic to mammals, birds and fish and to a lesser extent, some reptiles. The most critical aspect in the assessment of hazard to species present on the LHIG is determining the risk of ingesting, either directly or indirectly, the poison bait. The hazards posed by Brodifacoum to mammals and birds are well established. Omnivorous, herbivorous, or granivorous species are most at risk from the direct consumption of bait (or primary poisoning); although field trials conducted on Lord Howe Island have indicated a nil to low risk of bait ingestion by most native bird species. Species that scavenge or prey on rodents have an established but variable risk of lethal and sub lethal exposure through secondary poisoning. The acute affects of Brodifacoum are the most appropriate end-point for the assessment of the environmental hazard posed by use of the product. Although non-target deaths have been documented in similar eradication programmes, extensive use of Brodifacoum to eradicate rodents from many island habitats has rarely been associated with significant long-term decline of non-target species, as with appropriate management the affected species have recovered quickly to, or exceeded, pre-eradication population levels. Significant increases in biota and native species diversity are typically associated with successful invasive-species eradications (Broome et al, 2016).

An assessment of the vertebrate species found on the island group has allowed the level of risk of primary and/or secondary poisoning to these non-target species to be estimated as well as the development of strategies to minimise non-target mortalities. Two species are considered at high risk; the Lord Howe Island Woodhen and the Lord Howe Island Currawong. Both of the species would be taken into captivity during the program. Whilst it is expected that some non-target deaths in a small number of species may occur as a result of the proposed eradication programme, these are not expected to have a significant long-term effect on the non-target populations.

Adequate data, scientific argument and mitigation procedures (such as holding in captivity the LHI Woodhen and LHI Currawong while the threat from the baiting is present) are provided to demonstrate that the proposed eradication programme is unlikely to harm non-target native animal populations. Possible exceptions are the Australian Kestrel *Falco cenchroides*), the Purple Swamphen (*Porphyrio porphyrio)*, the Pacific Black Duck (*Anas superciliosa*) and the Buff-banded Rail (*Gallirallus philippensis)*. These four species are recent colonists, and any losses in their respective populations will most likely be made good by further colonisations.

The Masked Owl (T*yto novahollandiae)* may also be affected however this species was introduced to the island in the 1920s, and is now regarded as a pest, preying on the island's endemic wildlife as well as rodents. The REP provides an opportunity to concurrently eradicate the Masked Owl.

In spite of the potential effect on species mentioned above , the proponent is satisfied that application of 0.02g/kg Brodifacoum bait as proposed would not be likely to have an unacceptable adverse effect on non target native animals or plants, or to the environment.

7-1.6. OTHER APPROVALS REQUIRED

A number of other regulatory approvals and permits will need to be obtained prior to commencement of the operation including:

- A referral to the Commonwealth Department of the Environment under the *Environment Protection and Biodiversity Conservation Act 1999*
- Civil Aviation Safety Authority approval for flight operations
- NSW Department of Planning and Environment approval under the *Environment Planning and Assessment Act* 1979 and associated approvals from various concurrence agencies including:
    - Office of Environment and Heritage - a Species Impact Statement and Threatened Species licence under Section 91 of the NSW *Threatened Species Conservation Act* 1995
    - NSW Environmental Protection Agency - permissions to aerially bait within 150 m of dwellings and public places required under the NSW *Pesticides Act 1999*
    - NSW Dept of Primary Industries (Marine Parks and Fisheries) - assessment under Division 2 of the NSW *Marine Parks Act* 1997 and *Fisheries Act 1994*

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.

7-1.7. PROTECTION OF NON-TARGET WILDLIFE AND ENVIRONMENT

The eradication will provide significant environmental benefits for the biodiversity of the Lord Howe Group. The eradication of rodents from the LHI Group is the single most effective way to protect the flora and fauna of these islands. Information on non-target species, such as conservation status, diet and tolerance to Brodifacoum, will be used to assess the risks to non-target species and to determine what, if any, mitigation measures will be used to reduce the risks posed by baiting programme.

PART 7-2: ENVIRONMENTAL EXPOSURE ASSESSMENT

This section details the bait and toxin release estimates, methods of application and expected fate in the environment of Brodifacoum during the proposed LHI REP.

Given that Brodifacoum is already a registered active constituent in Australia and has established regulatory standards, this section focuses on its use in Pestoff 20R and for the specific manner of use proposed for the LHI REP. Application methods and rates have been developed from numerous similar rodent eradication operations globally and particularly in New Zealand. Many of these eradication operations assist in forming the body of evidence on environmental fate presented below.

7-2.1. RELEASE ESTIMATION

7-2.1.1. AMOUNT OF CHEMICAL TO BE USED

The proposed treatment rate will be a nominal 12kg of Pestoff 20R pellet bait/hectare on the first application; to be followed by a second application of 8kg of bait/hectare approximately 14-21days after, weather permitting, for a total nominal treatment rate of 20 kg/ha averaged over the island.

To achieve the nominal treatment rate across the island, it is expected that the maximum bait used would be 42 tonnes of Pestoff 20R pellet baits containing 0.02g/kg (20ppm) Brodifacoum. This amount considers operational flexibility, contingency and differences in vegetation and topography across the island (i.e. the 3-Dimensional area of LHI is approximately 2,100 ha taking into account its rugged topography).

Therefore the maximum total amount of Brodifacoum used over the entire island is in the order of 840g which equates to ~ **0.40g/ha.**

7-2.1.2. MANUFACTURING PLANT (ACTIVE CONSTITUENT)

The active constituent is manufactured overseas and is imported into Australia already incorporated into the finished product. The active constituent sourced for the product is currently registered in Australia under APVMA Product Number 56139.

Therefore assessment of the extent of and potential for environmental exposure as a result of the manufacture of the active constituent is not relevant to this Module.

A Chemistry and Manufacture Module (Level 3 Limited Chemistry Assessment) will be submitted separately by the manufacturer under Commercial in Confidence.

7-2.1.3. FORMULATING PLANT (PRODUCT)

The product, Pestoff 20R, is a cereal-based bait containing 0.02g/kg Brodifacoum. Pestoff 20R pellets are made from ground wheat, glycerine, cane sugar and food flavouring. Wheat used in manufacture is ground to flour, screened to 1.5mm and heated with dry steam at a temperature of 130^{O} C for approximately 30 seconds to denature proteins required for germination. 10 mm or 5.5 mm diameter cereal pellets are made using a pellet press with a radial ring-dye and rotating internal rollers which press the loose bait pre-mix material through the radiating apertures in the ring with a pressure of approximately 10 tonnes per square centimetre, to form cylindrical pellets as the material emerges from the outside of the

die. The product is cooled to ambient temperature through a cooler/drier and then packaged and sealed to prevent post- manufacture contamination.

The active ingredient found in the bait is brodifacoum (3-[3-(4'-bromobiphenyl-4-yl)-1,2,3,4-tetrahydro-1-naphthyl]-4- hydroxycoumarin; C31H23BRO3) incorporated into bait at a level of 0.002% (20 parts per million)

It is manufactured overseas and is imported into the country as the finished product. Therefore the assessment of the extent of and potential for environmental exposure as a result of the manufacture of the finished product is not relevant to this Module. The finished product is manufactured by:

Animal Control Products Ltd
408 Heads Road
Wanganui, New Zealand

A Chemistry and Manufacture Module (Level 3 Limited Chemistry Assessment) will be submitted separately by the manufacturer under Commercial in Confidence.

7-2.1.4. USE AND APPLICATION

Baiting Protocol

The bait will be distributed at a nominal dose rate of 20 kg (12kg + 8kg) of bait (or 0.4 g of poison) per hectare. At this rate, 42 tonnes of bait (containing 840 g of Brodifacoum) will be required to cover the total island group surface area of 2,100 ha.

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 occur on offshore islands and islets close to the main island. 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, 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.

The operation is programmed to take place in winter 2017 (June-August), when the availability of natural food for rodents is low and breeding is greatly reduced or absent. 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 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.

Given the operational window, a permit is sought for at least a three year period to account for unforeseen delays beyond winter 2017.

Aerial baiting

Aerial baiting will be conducted throughout the LHI Permanent Park Preserve and other areas of the main island excluding the settlement area and identified buffer zones. In all areas baited aerially, 10 mm baits (approximately 2g 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.

The bait will be dispersed using a purpose built spreader bucket (see Figure 3) slung below a helicopter. A rotating disc throws the bait 360^{o}consistently 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 4). Application rates are adjusted to account for the 50% overlap (i.e. for the first drop 6kg/ha on each swathe with 50% overlap will be applied to achieve a 12kg/ha application rate). Each bait drop will take approximately two days to complete dependant on weather.

Figure 3: Custom built spreader bucket being prepared on LHI.

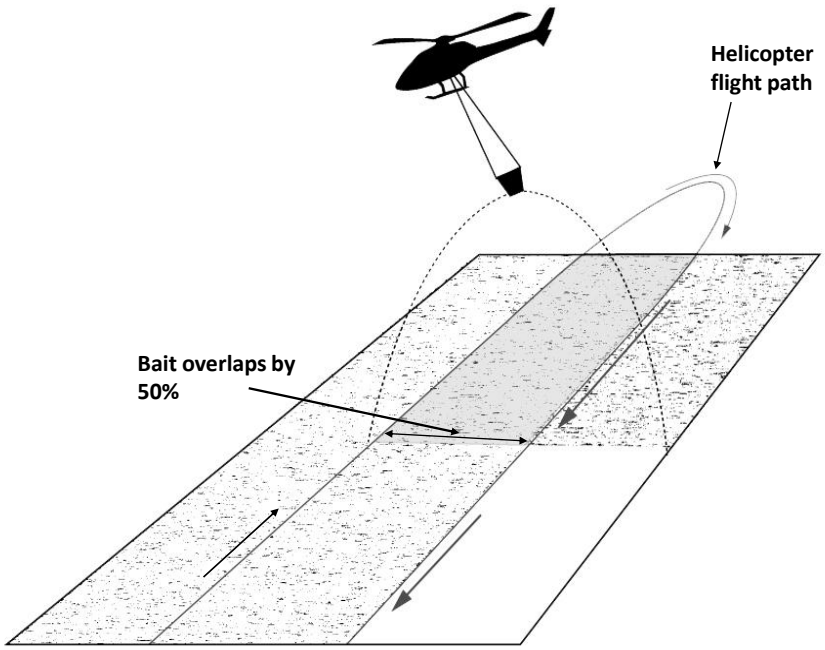

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Figure 4: Aerial Application Method

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 50m 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 180^{o}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 dose 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 turning off or removal 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 method 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 30m to dwellings. In these buffer zones bait will either be applied by hand or if agreement to the contrary is not reached, then the buffer zone will be 150 m, and will be baited by hand. This will be covered in a Property Management Plan for each property. 30m 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 after 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 technique 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 and Broughton islands in New South Wales and Hermite Island 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 (LHIB, 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 provided an opportunity to establish the correct flight configuration: air speed and settings to produce the required flow rate to achieve the on grounds 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 and operational readiness check overseen by an international eradication expert 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 (2g 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 half square metre on average) for the first application of bait and at 8kg/ha for the second application.

Provisional areas to be hand-baited are shown in (Figure 5) however this is subject to completion of individual Property Management Plans.

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 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). These 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.

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 take will provide an indication of rodent activity. Bait in these locations will not be exposed to weathering, and so any remaining bait will be removed after approximately 100 days or after mice or rats are no longer detected.

When using bait stations or trays it is important that they are set close enough together that individual rats and mice come across at least one station during their nightly movements. Rats are wide-ranging and can be eradicated using a grid spacing of 25 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.

Elimination of survivors

The settlement area and other selected areas of LHI will be monitored for the presence of rodents throughout the 100-day period of the baiting operation. Detection of surviving rodents will be evidenced by bait take from bait trays and bait stations and observations of droppings or rodent activity. Residents will be asked to report any such evidence to the project team. In addition, trained detector dogs will be deployed throughout the settlement area to find and locate any surviving rodents. In the unlikely event that rodents are detected, action will be taken to eliminate them. A Contingency Plan will be developed prior to the REP to guide selection of appropriate actions in the event that surviving rodents are detected. This could include targeted hand baiting or bait stations.

Ongoing Monitoring

Monitoring of the rodent-free status of LHI following the eradication of rats and mice will be achieved by monitoring for rodent activity at bait stations, in tracking tunnels strategically placed at stratified locations across the island and with the use of rodent detector dogs. 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.

Figure 5. Indicative Areas proposed to be hand-baited (shaded areas).

7-2.1.5. PRODUCT STORAGE

At the manufacturing plant in New Zealand, the bait will be packaged into 25kg 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 barged 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.

7-2.1.6. PRODUCT DISPOSAL

A limited amount of contingency bait will be purchased with the order in case of physical damage or weathering 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 clean up or incursion response, or 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 off in a similar manner as discarded bait pellets or they may be incinerated on LHI.

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 either be incinerated on island or transported back to the mainland for disposal at an appropriately licensed facility.

7-2.1.7. 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.

7-2.2. ENVIRONMENTAL CHEMISTRY AND FATE

7-2.2.1. PHYSIOCHEMICAL DEGRADATION

7-2.2.1.1. Hydrolysis

The Pestoff 20R bait pellets are made from 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, 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).

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

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 means that any environmental contamination would be of a sufficiently low magnitude as to not present a significant risk.

7-2.2.1.2. Photo-degradation (aqueous, soil, degradation in air)

Macleod and Saunders (2013) state Brodifacoum is thermally stable up to 50^{o}C and for 30 days in direct sunlight. It is degraded by UV light when in solution (ibid). Extensive photo-degradation is not expected to occur.

7-2.2.2. BIODEGRADATION

Brodifacoum degrades slowly in soils (pH 5.5-8) under aerobic and flooded conditions (Tomlin, 2009).

7-2.2.2.1. Soils (aerobic, anaerobic)

The Pestoff 20R bait pellets are made from 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 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 after approximately 100 days during the LHI REP.

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 6:

- Condition 1: Fresh Pellets/Pellets not discernable 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.

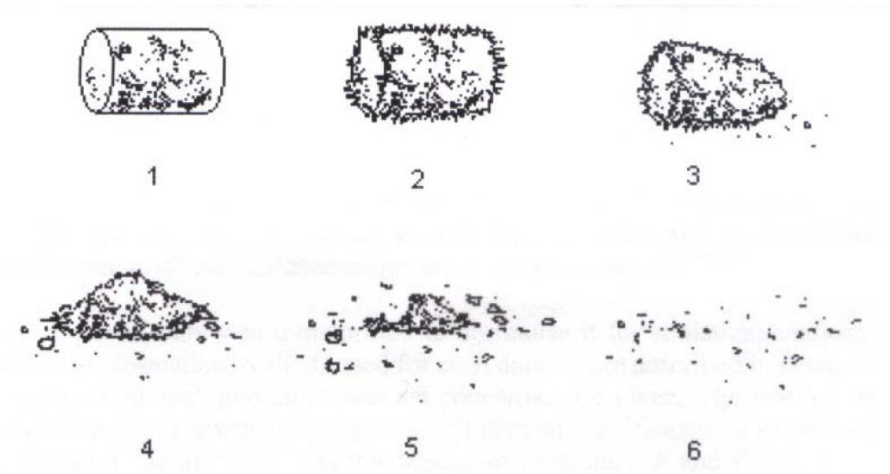

Figure 6: Illustration of typical bait condition (reproduced from Craddock, 2004)

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 7 below. All pellets had reached condition index score of 5.5 to 6 by 120 days.

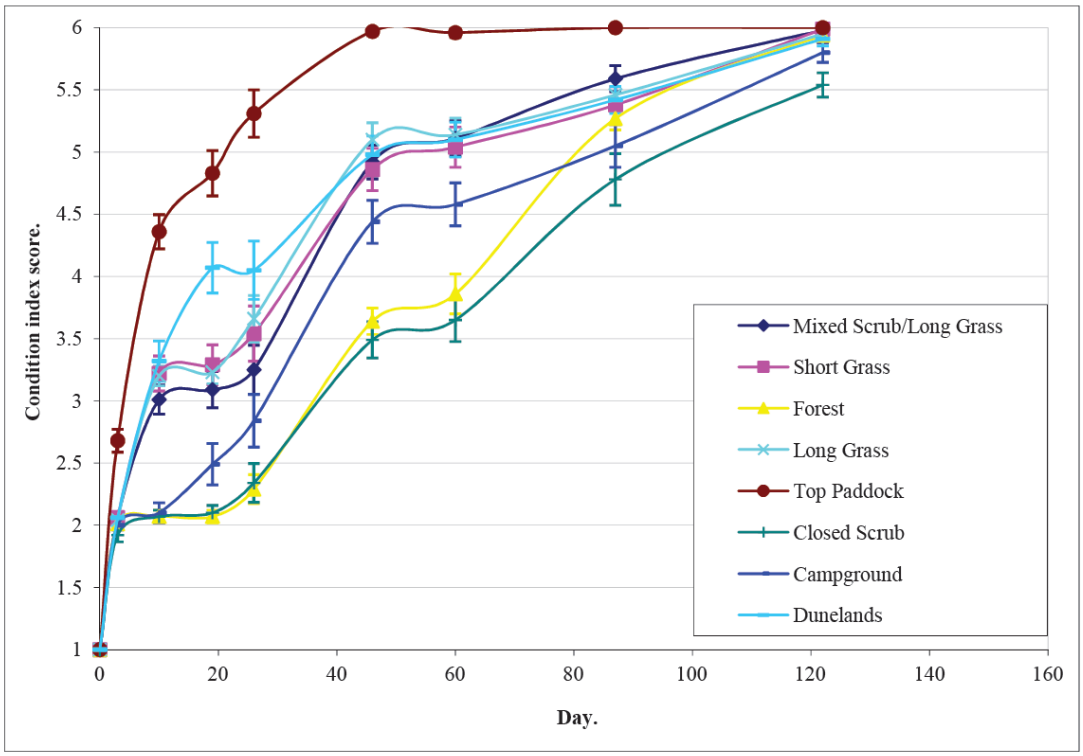

Figure 7. Bait Breakdown times of 10mm pellets (sourced from Craddock 2004)

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 (LHIB, 2007). 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 by 100 days.

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

- Trials on Great Mercury island in NZ 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 may take 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 26kg/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 & 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 at 12 kg/ha on 27 October 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 pellets at15 kg/ha on Red Mercury and Coppermine 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 low-moderate application rate of Brodifacoum for the LHI REP (0.4g / ha) and one off eradication means that any soil contamination 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 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.

7-2.2.2.2. 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.

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 30m offshore to a depth of 10m 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.

Brodifacoum has an estimated very low water solubility of <10 parts per million in fresh water at pH 7 and 20^{O}C (U.S. EPA 1998). In short, Brodifacoum is practically insoluble in water (WHO 1995). For comparison, table salt has a solubility of 1,200,000 mg/L under similar conditions. Given the non-polarity of Brodifacoum molecules, and the ionic strength of seawater the solubility of Brodifacoum in cold (~13 $^{\circ}$C) seawater is probably in the low parts per billion range (Primus *et al.* 2005); basically Brodifacoum is practically insoluble in water, particularly in cold seawater. Sea temperature around LHI in August, when the baiting is proposed to take place, will be approximately 17°C.

Note: Solubility is the determining factor for the pesticide pathway beyond the bait. 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).

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

7-2.2.2.2.1. Fresh Water

Due to the low solubility of Brodifacoum, detection of residues in fresh water after aerial and hand distribution of Pestoff 20R baits are 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 & 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 & 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 (35ha and 65ha) each received two bait drops of Pestoff 20R Brodifacoum cereal bait in September and October 2004. 15kg/ha was applied on the first drop and 8kg/ha in the second. The area (c.8ha) 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).

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. 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.

Further detail on Human Health Risk Assessment is found in the Efficacy and Safety Module.

7-2.2.2.2.2. Sea Water

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.

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 & 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 environmental contamination would be of a sufficiently low magnitude as to not present a significant risk.

Additionally significant mitigation through the use of the deflector arm on the spreader buckets, handing baiting within the Lagoon foreshore area and 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.

7-2.2.2.3. Marine Sediments

Whilst studies of breakdown in marine sediments are not presented, it is reasonable to expect that breakdown 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 20cm 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 environmental contamination would be of a sufficiently low magnitude as to not present a significant risk.

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. No marine sediment will be analysed for Brodifacoum after the LHI REP.

7-2.3. MOBILITY

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.

7-2.3.1. VOLATILITY

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

7-2.3.2. ADSORPTION/DESORPTION

As baits break down, Brodifacoum will be released to the soils where it is absorbed and degraded over time. Brodifacoum binds strongly to soil particles (Newby and White 1978 and Eason & Wickstrom, 2001).

7-2.3.3. LEACHING POTENTIAL

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.

7-2.4. FIELD DISSIPATION

Brodifacoum is expected to remain tightly bound to soil particles following the disruption of the bait matrix, where it will degrade slowly over time, being broken down by microbial activity. As the application rate is low-moderate (average 0.40g/ha Brodifacoum), long-term contamination is not expected. Because Brodifacoum is practically insoluble it is unlikely to leach into waterways or to be significantly taken up by plants. Accidental entry into waterways due to inadvertent bait placement or soil erosion is likely to result in settling of the chemical into sediments and its slow degradation. Significant concentrations of Brodifacoum in the water column are not expected. Brodifacoum does not readily enter the atmosphere.

7-2.4.1. 7-1.6.1. SOILS

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 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 environmental contamination would be of a sufficiently low magnitude as to not present a significant risk.

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.

7-2.4.2. WATER

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 & 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.

Random sampling will be conducted on water bodies on the island to monitor Brodifacoum levels after the bait drop. An option will also be available to test residents' water tanks if requested. 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. As a precaution tourists and residents will be advised not to drink from streams until laboratory testing confirms absence of detectable Brodifacoum.

7-2.4.3. 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 – 330g 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.

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.

7-2.4.4. 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.

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.

Further consideration to impact on plants is therefore not warranted in this module.

7-2.5. ACCUMULATION/METABOLISM

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.

More detail is provided below and assessment of individual species present on Lord Howe Island is detailed in Part 7-3.

7-2.5.1. BIO-ACCUMULATION IN FISH/AQUATIC ORGANISMS

Whilst Brodifacoum can bio-accumulate in fish and aquatic organisms 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 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 were collected from 3 sites. These were batched to form 9 mussel (*Mytilus edulis*) 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 & 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 0.001ppm. 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 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 & 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 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 25hours 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 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 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 & 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 & Miskelly 1999).

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. A butterfish (*Odax pullu*) sampled 9 days after the spill had Brodifacoum residues of 0.040ppm 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 <0.020ppm. 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 20ppm Brodifacoum to the Ipipiri Islands in the Bay of Islands 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 & 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 & 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 & Wegmann 2010).

Nine of ten black spot sergeant fish (*Abudefduf sordidus*) collected live following aerial bait application of Bell Labs 25w bait were found to contain residues ranging from 0.05 to 0.315 ppm (whole fish). Two applications of bait (80kg/ha and 75kg/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 tidepool 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 urchin.

Following aerial application of baits on Kaikoura Island near Great Barrier Island 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 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 0.02ppm Brodifacoum, perhaps because a toxic bait was deliberately dropped into the rock pool it was living in (Fisher et al. 2011).

Testing of liver and gut contents from two eels found dead in a Southland 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).

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.

Consideration of Brodifacoum entering the human food chain during or after the LHI REP is considered in the Efficacy and Safety module.

7-2.5.2. ACCUMULATION POTENTIAL IN SOILS

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 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 (0.4 g/ ha) for the LHI REP and one off eradication mean that the risk of bioaccumulation in soil would be of a sufficiently low magnitude as to not present a significant risk.

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.

7-2.5.3. METABOLISM IN TARGET ANIMALS

Brodifacoum is a second generation anticoagulant of the coumarin class. Its rodenticidal properties were first described in the early 1970s and it is a very potent active constituent against rats and mice, including strains resistant to warfarin and other anticoagulants

(Rennison & Hadler 1975). It has been extensively used in both rodent control and eradication operations (particularly offshore islands) worldwide including in Australia and New Zealand.

Brodifacoum, like other anticoagulant toxicants, acts by interfering with the synthesis of vitamin K-dependent clotting factors. This increases the clotting time of blood and leads to death from haemorrhaging. Symptoms manifest within 4 days post ingestion in rats and 5.5 days in mice (Broome *et al*, 2016). Average time to death of lethally exposed rats is 7 days (ibid) (range 3-14 days McLeod and Saunders 2014), and in mice 9 days (range 3-18 days ibid).

Efficacy and lethal dose for rats and mice are covered in the Efficacy and Safety Module

In sub lethal exposure, Brodifacoum is not readily metabolised and the major route of excretion of unbound compound is through the faeces (Broome *et al*, 2016). It is not rapidly broken down after death.

A proportion of any ingested dose of Brodifacoum is bound in the liver, kidney, or pancreas, where it remains in a stable form for some time and is only very slowly excreted. A European Commission study found that 10 days following a single oral dose to the rat of 0.25 mg/kg, 74.6% of the dose was retained in the tissues. The proportion of the retained dose was highest in the liver (22.8 %), followed by the pancreas (2.3 %), and then the kidney (0.8 %), heart (0.1%) and spleen (0.2 %). The remainder of the dose (approximately 50 %) was present in the carcass and skin (EC 2005c). The study also showed that for rats, elimination from the liver occurs in two phases at high doses (EC 2005c).

- Initial phase: half life ($t_{½}$) was 4 days.
- Slow terminal phase: $t_{½}$ was 128 days,

At lower doses not associated with prothrombin clotting time (PT) prolongation, $t_{½}$ was 282 – 350 days.

In mice, a study found 0.5 LD_{50} liver $t_{½}$ was 15.8 days (Vandenbroucke et al. 2008). Disappearance from serum is slow with a half-life in rats of 156 hours or longer (Bachmann & Sullivan 1983).

Other studies cited in McLeod and Saunders (2014) report half-life in rat liver between 114-130 days and mouse liver 307 days.

A literature search failed to find published or verified unpublished data relating to persistence of Brodifacoum in carcasses after death. However, it can be assumed that, like toxic bait, carcasses that have fully decomposed to skeletal remains are unlikely to contain significant Brodifacoum residues.

7-2.5.4. OTHER (E.G. BIRDS, EARTHWORMS)

7-2.5.4.1. Residue levels recorded for sub-lethally exposed animals

A number of laboratory studies have been undertaken that examined Brodifacoum residue levels in sub-lethally poisoned animals.

Laboratory Studies

Birds

Fisher (2009) sub-lethally dosed domestic chickens (*Gallus gallus*) with a solution containing 0.4mg/mL Brodifacoum at 1.25mL solution/kg of bodyweight (roughly equivalent to them eating 41g of 20ppm bait). Liver, muscle, fat, ovary, egg, plasma, dried blood spot and faecal samples were taken on days 1, 4, 7 and 14 after dosing, and tested for Brodifacoum residues. In the liver samples, the Brodifacoum concentrations remained relatively constant over the 14 days with mean values of 0.660 µg/g at day 1 and 0.617 µg/g at day 14. Brodifacoum

concentrations in muscle and fat samples were highest on day 1, both with mean concentrations of 0.062 µg/g. These declined to means of 0.028 µg/g and 0.015 µg/g respectively on day 7, and remained at this level for samples taken on day 14. Plasma samples taken on day 1 had a mean concentration of 0.215 µg/g but this declined to below the method detection limit (MDL) by day 7. The dried blood spot samples taken on day 1 had a mean Brodifacoum concentration of 0.144 µg/g which fell to below the MDL from day 4. Brodifacoum concentrations in ovaries were highest on day 1 with a mean value of 0.135 µg/g and declined to just above the MDL by day 14. Brodifacoum residues were detected in samples taken from eggs on all days. The highest concentration was 0.035 µg/g and was from a sample taken on day 14. Faecal samples taken on day one had a mean concentration of 0.17 µg/g and this had declined to below MDL by day 7.

Mammals

In a pen trial, Eason et al. (1999) examined Brodifacoum residues in primary and secondary poisoned captive pigs. When captive pigs were fed a sub-lethal dose of Pestoff® Possum Bait (0.02 g/kg Brodifacoum) at 0.57 mg/kg (an approximate LD25), the pigs had mean residues of 1.13 mg/kg in the liver, 0.05 mg/kg in muscle and 0.17 mg/L in serum, five days after dosing. Captive pigs fed the soft tissue of brushtail possums (*Trichosurus vulpecular*) poisoned with Brodifacoum were euthanised five days later and samples taken. Residues of Brodifacoum in these pigs' livers were 0.52 – 1.20 mg/kg and 0.013 – 0.094 mg/kg in their muscle tissue.

Reptiles

Under laboratory conditions, Wedding (2007) exposed rainbow **skinks** (*Lampropholis delicata*) to Brodifacoum cereal blocks (Pest-off rodent Block) for one month. Three of eight skinks euthanased immediately after the one month's exposure contained Brodifacoum residues (0.03, 0.05 and 0.13 µg/g whole body). One month after exposure ceased, two of eight skinks contained residues above the MDL (0.01 and 0.005 µg/g whole body). In a second experiment, Wedding (2007) fed rainbow skinks mealworms containing Brodifacoum. All 12 skinks fed the mealworms contained residues of between 0.006 and 0.22 µg/g (mean = 0.118 µg/g).

Witmer and Maudlin (2012) dosed a range of reptiles (turtles, snakes, lizards and iguanas) with Brodifacoum solution by oral gavage and analysed them for residues 7 days following the final exposure. Residues were found in all liver samples and most tests of other tissues apart from one iguana given a low dose which fell below the minimum levels of detection.

Captive amevia **lizards** (*Amevia amevia*) were dosed by oral gavage with Brodifacoum solution and repeat dosed a week later. Six animals received a dose of 0.084 mg/kg each time and another group of eight received a dose about ten times higher (0.79mg/kg) each time. Animals were killed and autopsied a week following the second dose and tissue analysed for residues. Liver residues were found ranging from 0.561µg/g to 1.449µg/g with a mean concentration of 0.976µg/g in the low dose group and 1.983 to 10.542µg/g (mean 6.377µg/g) in the high dose group. Residues in amevia bodies (with liver and gall bladder removed) ranged from 0.08µg/g to 0.173µg/g (mean 0.117µg/g) in the low dose group. For the high dose group they ranged from 0.267 to 2.153µg/g (mean 1.161µg/g). Four lizards died during the study but none showed signs of haemorrhage and were excluded from the analyses (Witmer and Mauldin 2012).

Invertebrates

Following exposure to soil containing 2 mg Brodifacoum/kg soil for 14 days, common garden snails *(Helix aspersa*) had Brodifacoum residues of 3.9 µg/g in the body and 1.2 µg/g in the foot tissue (Booth et al. 2003).

Captive sandhoppers contained 0.21 µg/g residues in their bodies after one week of feeding on Pestoff 20R pellets (0.02 g/kg Brodifacoum). After two weeks all the bait had been eaten and a sample of sandhoppers contained 0.19 µg/g Brodifacoum (Dowding et al. 2006).

Brooke et al (2013) studied Brodifacoum contamination 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 peaked at a mean concentration of 0.477 ug/g with one sample containing 1.075 ug/g.

In a second similar experiment using cockroaches and woodlice, Brodifacoum residues peaked at 0.262 ug/g mean concentration in cockroaches, with one sample containing 0.861 ug/g. Woodlice peaked at a mean concentration of 0.233ug/g (Brooke et al 2013). The authors speculated that Henderson rails (*Porzana atra*) would need to eat their own body weight of contaminated cockroaches to reach an estimated LD50.

Field Studies

Animals have also been sampled during a number of pest control operations to test for sub-lethal Brodifacoum residues (Table 1). The monitoring has occurred in two ways. Live animals have been sampled for brodifacoum residues during and post- aerial and bait station operations. Alternatively, brodifacoum residue samples have been taken from animals that died as a result of causes other than poisoning (e.g. natural cases, predation) following pest control operations.

Table 1. BRODIFACOUM RESIDUE LEVELS RECORDED IN SUB-LETHALLY EXPOSED ANIMALS DURING PEST CONTROL OPERATIONS IN NZ. <MDL = below method detection limit (From Broome *et al* 2016).

SPECIES	NO. OF POSITIVE SAMPLES	RANGE OF RESIDUES (mg/kg)	REFERENCE
Birds			
Australasian harrier (*Cirus approximans*)	10/11	Liver: <MDL - 0.23	Murphy et al. (1998) Fisher et al. (2011)
Australian magpie (*Gymnorhina tibicen*)	2/10	Liver: 0.08 - 0.41	Murphy et al. (1998)
Bellbird (*Anthornis melanura*)	0/1	Liver: <MDL	Murphy et al. (1998)
Blackbird (*Turdus merula*)	9/9	Liver: 0.004 – 0.81	Morgan & Wright (1996a); Murphy et al. (1998)
N.Z. Falcon (*Falco novaeseelandiae*)	0/1	Egg/embryo: <MDL	VPRD: I017
Fantail (*Rhipidura fuliginosa*)	0/1	Liver: <MDL	Murphy et al. (1998)
Kaka (*Nestor meridionalis*)	2/3	Liver: 0.01 - 0.09	VPRD: T1184, T1310
Kakariki (*Cyanoramphus sp.*)	1/1	Liver: 0.011	VPRD: 11939
Kea (*Nestor notabilis*)	1/1	Liver: 0.071	G Taylor (pers. comm.)

SPECIES	NO. OF POSITIVE SAMPLES	RANGE OF RESIDUES (mg/kg)	REFERENCE
Kereru (*Hemiphaga novaeseelandiae*)	0/5	Liver: <MDL	Eason et al. (2002)
Kiwi (brown) (*Apteryx australis*)	14/29	Liver: 0.01 – 0.69	Eason et al. (2002)
Kiwi (little spotted) (*Apteryx owenii*)	1/1	Liver: 0.01	Colbourne & Robertson (1997)
Morepork (*Ninox novaeseelandiae*)	1/1	Liver: 0.61	Murphy et al. (1998)
Robin (Black) (*Petroica traverse*)	1/1	Liver: 0.35	VPRD: T0915
Robin (N.I.) (*Petroica australis longipes*)	0/4	Liver: <MDL	Murphy et al. (1998)
Silvereye (*Zosterops lateralis*)	0/1	Liver: <MDL	VPRD: T0758
Tomtit (*Petroica macrocephala*)	0/5	Liver: <MDL	Murphy et al. (1998)
Tui (*Prosthemadera novaeseelandiae*)	0/1	Liver: <MDL	VPRD: T0755
Weka (*Gallirallus sp.*)	26/48	Liver: 0.01 – 0.95	VPRD: T0911, T1103, T1252B, T0912, T1183, 265
Whitehead (*Mohoua albicilla*)	0/5	Liver: <MDL	Murphy et al. (1998)
Eutherian Mammals			
Cat (*Felis catus*)	57/71	Liver: 0.078 – 1.84	Eason et al. (2002)
Chamois (*Rupicapra r. rupicapra*)	0/3	Liver: <MDL	G Taylor (pers. comm.)
Deer	13/52	Liver: 0.01 – 0.03	Eason et al. (2001); G. Taylor (pers. comm.)
	1/14	Muscle: 0.02	Eason et al. (2001)
Ferret (*Mustela furo*)	9/16	Liver: mean = 1.01	Murphy et al. (1998)
	25/37	Liver: 0.01 – 2.43	VPRD 24/7/02
Goat (*Capra hircus*)	2/29	Liver: 0.01	Eason et al. (2001)
Hedgehog (*Erinaceus europaeus occidentalis*)	23/46	Liver: 0.02 – 3.8	VPRD 3/09/08

SPECIES	NO. OF POSITIVE SAMPLES	RANGE OF RESIDUES (mg/kg)	REFERENCE
Mouse (*Mus musculus*)	23/54	Liver: 0.02 – 4.57	VPRD 24/7/02, Centox report T2392
Pig	61/102	Liver: 0.007 – 2.4	VPRD 3/09/08
	8/13	Muscle: 0.01 – 0.05	VPRD 3/09/08
Rabbit	12/12	Liver: 0.03 – 0.42	Rammell et al. (1984); Dowding et al. (1999)
Rats (*Rattus spp*)	83/141	Liver: 0.01 – 14.7	VPRD 3/09/08
Sheep (*Ovis aries*)	2/2	Liver: 0.03 – 0.9	VPRD: T0998
Stoat (*Mustela ermina*)	98/115	Liver 0.008 – 1.32	Eason et al. (2001)
Weasel (*Mustela nivalis vulgaris*)	15/27	Liver: mean =1.26	Murphy et al. (1998); Gillies & Pierce (1999)
	70/88	Liver: 0.01 – 2.27	VPRD 24/7/02
Marsupials			
Brushtail possum	28/35	Liver: 0.007 – 6.2	Meenken et al. (1999)
Fish			
Trout	0/2	Liver: <MDL	VPRD 24/7/02
	0/2	Muscle: <MDL	VPRD 24/7/02
	0/2	Abdominal cavity: <MDL	VPRD 24/7/02
Reptiles			
Duvaucel's gecko (*Hoplodactylus duvauceli*)	1/2	Liver: 0.007	VPRD: 11937 & 11938
Terrestrial Invertebrates			
Beetles (*Coleoptera*)	28/101	Whole body: 0.02 – 3.3	Wright & Eason (1991); Morgan et al. (1996); Ogilvie et al. (1997); Craddock (2003a); VPRD 24/7/02
Centipede (*Chilopoda*)	0/18	Whole body: <MDL	Morgan et al. (1996)

SPECIES	NO. OF POSITIVE SAMPLES	RANGE OF RESIDUES (mg/kg)	REFERENCE
Cockroaches (*Blatoidea*)	24/70	Whole bodies: 0.03 – 2.34 (24)	Morgan et al. (1996); Ogilvie et al. (1997); Booth et al. (2001); Craddock (2003a)
Insect larvae (unid.)	0/14	Whole body: <MDL	Morgan et al. (1996)
Millipede (*Diplopoda*)	0/35	Whole body: <MDL	Morgan et al. (1996)
Misc. terrestrial inverts	18/63	Whole bodies: 0.03 – 3.61	Craddock (2003a); VPRD 27/2/02
Maggots (on dead birds)	2/2	Whole bodies: 0.13 – 0.27	Brown (1997c)
Sand hopper (*Talorchestia*)	1/1	Whole bodies: 0.01	Dowding et al (2006)
Slater (*Isopoda*)	0/26	Whole body: <MDL	Morgan et al. (1996)
Slugs (*Gastropoda*)	1/6	Whole bodies: 0.12	Morgan et al. (1996)
Snail (*Gastropoda*)	0/9	Whole body: <MDL	Morgan et al. (1996)
Spider (*Araneae*)	0/34	Whole body: <MDL	Morgan et al. (1996)
Wasp (*Hymenoptera*)	0/1	Whole body: <MDL	Morgan et al. (1996)
Weta (*Orthoptera*)	28/63	Whole bodies: 0.01 – 7.47	Craddock (2003a),
Weta (cave) (*Gymnoplectron sp.*)	1/18	Whole body: 4.3 (1)	Morgan et al. (1996); Ogilvie et al. (1997)
Weta (Ground) (*Hemiandrus sp.*)	0/20	Whole body: <MDL	Morgan et al. (1996)
Weta (Ground + Cave)	6/6	Whole bodies: 0.48 – 2.3	Bowie & Ross (2006)
Weta (Tree) (*Hemideina sp.*)	0/20	Whole body: <MDL	Morgan & Wright (1996b)
Worm (*Opisthopora*)	0/23	Whole body: <MDL	Morgan et al. (1996)
Worm (pasture) (*Aporrectodea caliginosa*)	6/12	Whole body: 0.07 – 0.90 (6)	Booth et al. (2003)

Note: The information in this table was derived from direct analyses for Brodifacoum in animal tissues, from animals known or suspected to have received a sub-lethal dose of Brodifacoum. Where animals were found dead but with no detectable residues they have been excluded as it is likely that there was no prior exposure to Brodifacoum. Where the information is derived from the Vertebrate Pesticide Residue Database, a decision on whether animals had sub-lethal poisoning prior to sampling for has been based on the information submitted with the sample

7-2.5.4.2. Persistence in sub-lethally exposed animals

Brodifacoum is very persistent in the livers of most sub-lethally exposed animals, lasting at least nine months in some well documented cases. Invertebrates appear to metabolise or excrete residues rapidly at first but may retain trace amounts for several weeks. Reptiles may retain residues for longer than other species.

Birds

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).

Fisher (2009) sublethally orally dosed hens with 0.5 mg/kg brodifacoum, roughly equivalent to them eating 41g of 20ppm bait. Over the following 14 days no significant change in their normal food intake and no outward signs of anticoagulant poisoning was observed. Nine of the ten eggs collected from the birds 1, 4, 7 and 14 days after dosing had residues of brodifacoum.

Hasber et al (2015), found residues of bromadialone (also a second generation anticoagulant) in barn owl (*Tyto alba*) eggs collected from an oil palm plantation where this rodenticide was used to control rats. However no differences in egg shape, egg shell mass or thickness could be determined when compared with a non-treatment area.

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).

Mammals

A number of pen trials have been carried out to look at the persistence of Brodifacoum in sub-lethally poisoned animals.

Laas et al. (1985) reported that there were detectable residues in the liver of sheep 128 days after the animals were orally administered Brodifacoum.

Lactating ewes were dosed with 1.0 mg/kg brodifacoum and another at 0.1 mg/kg. Blood and milk samples were taken between 2 and 32 days after dosing and analysed for brodifacoum residues. Five of the 8 ewes receiving the higher dose had detectable concentrations of brodifacoum in their milk two days after dosing. Testing from 4 days post dosing and later failed to find any brodifacoum residues in milk (TbFree website accessed Dec 2015).

Brodifacoum has been shown to persist in the liver of brushtail possums for 9 months. Brushtail possums dying up to one year after a sub-lethal dose can contain residues in liver (Eason et al. 1996).

Two of six horses (*Equus caballus*) orally dosed with 0.125 mg/kg Brodifacoum had detectable levels of Brodifacoum in plasma after 9 days (Boermans et al. 1991).

Reptiles

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).

Wright's skink (*Mabuya wrightii*) were commonly found to take Brodifacoum baits from bait stations on Fregate Island in the Seychelles but no mortality was observed (Thorsen et al. 1999).

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).

Telfair's skinks were found dead after brodifacoum application on Round Island (Merton, 1987).

Invertebrates

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 baits 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 0.41ug/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 to10m 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.

7-2.5.4.3. Half life of Brodifacoum in sub lethally exposed animals

Fisher (2009) reported Brodifacoum half-life estimates for chickens as 5.3 days in muscle, 2.79 days for fat and 3.17 days for ovarian tissue. Data on the half-life of Brodifacoum in blood and liver is presented in Table 2.

Table 2. HALF LIFE OF BRODIFACOUM (from Broome *et al*, 2016)

SPECIES	BLOOD T ½ (Hours, except where specified)	LIVER T ½ (Days)	REFERENCE
Rat	156	>80	Bachmann & Sullivan (1983)
		130	Parmer et al. (1987)
Rabbit	60.8		Breckenridge et al. (1985)
Dog (*Canis familiaris*)	6 ±4 days		Woody et al. (1992)
	0.9 – 4.7 days (mean 2.4 days)		Robben et al. (1998)
Brushtail possum	20 –30 days	>252 days	Eason et al. (1996a; 1996b)
Sheep		> 250 days	Laas et al. (1985)
Human	16-36		Weitzel et al. (1990)
	24.2 days		Hollinger & Pastoor (1993)
Chicken	1.14 days (plasma)		Fisher (2009)
Mice	91.7 days (plasma)	307.4	Vandenbroucke et al. (2008)

7-2.5.4.4. Residue levels in carcasses of animals killed by Brodifacoum

The information in this section is derived from direct analyses for Brodifacoum in tissues of animals known to have received a lethal dose of Brodifacoum.

In a no-choice pen trial twelve Norway rats that ate a mean total of 0.64 mg/kg Brodifacoum over 4 days all died within 24 to 168 hours. Liver and muscle samples taken post mortem had mean residues of 1.86 µg/g and 0.16 µg/g respectively. In another no-choice trial twelve Norway rats that ate a mean Brodifacoum dose of 1.31 mg/kg over 24 hours had mean liver residues of 5.01 µg/g when euthanised 24 hours later. In a paired-choice trial twelve Norway rats ate a mean total of 6.55 mg/kg of Brodifacoum over twelve days. All rats died with times to death ranging from six to thirteen days and the Brodifacoum concentration in their livers ranging from 6.70 µg/g to 17.00 µg/g (mean = 10.70 µg/g) (Fisher 2009).

A literature search failed to find published or verified unpublished data relating to persistence of Brodifacoum in carcasses after death. However, it can be assumed that, like toxic bait, carcasses that have fully decomposed to skeletal remains are unlikely to contain significant Brodifacoum residues.

Brodifacoum residues record levels reported from animals found dead during pest control operations in New Zealand are presented in Table 3.

Table 3. TOXIC BRODIFACOUM RESIDUE LEVELS RECORDED IN CARCASSES IN NEW ZEALAND. (from Broome *et al*, 2016)

SPECIES	SAMPLE TYPE	RESIDUE RANGE (mg/kg) Sample size in brackets	REFERENCE
Birds			
Australasian harrier	Liver	0.12 – 0.66 (4)	Rammell (1984); Dowding et al. (1999)
	Muscle	0.08 – 0.11 (2)	Rammell (1984)
Australasian magpie	Liver	0.40 – 0.99 (3)	Rammell (1984); Dowding et al. (1999)
	Muscle	0.08 (1)	Rammell (1984)
Blackbird	Liver	0.56-2.1 (11)	Towns (1994); Dowding et al. (1999), McCelland (2002); Williams & Jones (2002)
Chaffinch (*Fringilla coelebs*)	Liver	0.12- 8.1 (7)	Rammell (1984); Williams et al. (1986b); Brown (1997c); Dowding et al. (1999); Williams & Jones (2002)
	Gut	0.66 (1)	Brown (1997c)
Duck (Grey) (*Anas superciliosa*)	Liver	0.91 (1)	Dowding et al. (1999)
Duck (Paradise shelduck) (*Tadorna variegata*)	Liver	0.24 – 4.0 (5)	Rammell (1984); Dowding et al. (1999)
	Muscle	<0.05 (1)	Rammell (1984)
Duck (Mallard) (*Anas platyrhynchos*)	Liver	0.29 – 1.2 (2)	Dowding et al. (1999)
Fernbird (*Bowdleria punctata*)	Liver	0.05 – 1.2 (3)	Ranum et al. (1994)

SPECIES	SAMPLE TYPE	RESIDUE RANGE (mg/kg) Sample size in brackets	REFERENCE
Gull (red billed) (*Larus novaehollandiae*)	Liver	2.3 (1)	McClelland (2001); VPRD 24/7/02
Gull (Southern black-back) (*Larus dominicanus*)	Liver	0.58 – 2.6 (11)	Rammell (1984), Dowding et al. (1999); McClelland (2001); VPRD 24/7/02
	Muscle	0.12 – 0.14	Rammell (1984)
	Fat	0.23 – 0.25	Rammell (1984)
Kaka	Liver	0.01 – 4.1 (5)	Empson & Miskelly (1999); G Taylor pers. comm. 2001; VPRD
Kakariki (*Cyanoramphus sp.*)	Liver	0.03 - 1.4 (3)	Ogilvie et al. (1997); McClelland (2002);
Kiwi (little spotted)	Liver	1.2 (1)	Robertson & Colbourne (2001)
Kiwi (North Is Brown)	Liver	0.26 -1.04 (2)	Vestena & Walker (2010); Fisher et al (2011)
Morepork (*Ninox novaeseelandiae*)	Liver	0.47 (1)	VPRD: 11697
NZ Dotterel (*Charadrius obscurus aquilonius*)	Liver	0.37-1.24 (5)	Dowding et al (2006); Vestena & Walker (2010)
Pied stilt (*Himantopus himantopus*)	Liver	0.92 (1)	Dowding et al (2006)
Robin (Stewart Island) (*Petroica australis Rakiura)*	Internal organs	0.01 – 0.28 (12)	Masuda et al. (2012)
Shag (Little) (*Phalacrocorax melanoleucos*)	Liver	0.4 (1)	Williams & Jones (2002)
House sparrow (*Passer domesticus*)	Liver	1.2 - 5.5 (4)	Towns (1993); Williams & Jones (2002)
Spotless crake (*Porzana tabuensis*)	Liver	0.04 (1)	Veitch (2002c)
Thrush (*Turdus philomelos*)	Liver	1.0 (1)	McClelland (2002)
Tui	Liver	0.32 (1)	McClelland (2002)

SPECIES	SAMPLE TYPE	RESIDUE RANGE (mg/kg) Sample size in brackets	REFERENCE
Weka	Liver	0.11 - 2.3 (7)	VPRD 24/7/02
Eutherian Mammals			
Cat	Liver	0.71-4.1 (10)	Rammell (1984); Murphy et al. (1998); Dowding et al. (1999); Williams & Jones (2002)
	Muscle	0.05 (1)	Rammell (1984)
	Fat	<0.05 (1)	Rammell (1984)
Deer	Liver	1.7 - 2.5 (2)	VPRD
Hare (*Lepus europaeus occidentalis*)	Liver	0.77 (1)	Rammell et al. (1984)
	Muscle	1.1 (1)	Rammell et al. (1984)
Pig	Liver	0.21 - 1.7 (2)	Murphy et al. (1998)
Rabbit	Liver	< 0.05 -11.7 (48)	Rammell et al. (1984); Dowding et al. (1999)
	Muscle	<0.05 - 0.79 (27)	Rammell et al. (1984)
	Fat	<0.05 – 2.1 (22)	Rammell et al. (1984)
Rat (Norway)	Liver	0.77 (1)	Williams & Jones (2002)
Rat (Kiore)	Liver	0.37-7.8 (4)	Williams & Jones (2002)
Sheep	Liver	0.48 – 3.7 (4)	Rammell (1984)
	Muscle	0.12 – 0.17 (4)	Rammell (1984)
	Fat	0.12 – 0.27 (4)	Rammell (1984)
Marsupials			
Brushtail possum	Liver	0.9 - 1.2 (3)	Meenken et al. (1999)
Reptiles			
Tuatara (*Sphenodon sp.)*	Liver	0.65 (1)	R. Stamp (pers. comms.)
Moko Skink (*Oligosoma moco*)	Internal organs	0.82 (1)	Wedding (2007)

7-2.6. MODELLING STUDIES

No modelling studies have been undertaken or are presented with this submission.

7-2.7. APPLICANT'S PROPOSED DIRECTIONS FOR STORAGE AND DISPOSAL

Bait pellets will be kept in their original bags until immediately prior to their dispersal across the LHIG. These bags will be stored in weatherproof bait pods located within a secure area, namely the grounds of the airport on Lord Howe Island. Unused Pestoff 20R is likely to be retained in case needed for clean up or incursion response, or transported back to the mainland for sale to similar project or disposal at an appropriately licensed facility. Unusable spillage will be collected and transported to the mainland for disposal. Emptied Pestoff bags may be disposed off in a similar manner as discarded bait pellets or they may be incinerated on LHI.

7-2.8. PREDICTED ENVIRONMENTAL CONCENTRATIONS

As mentioned previously, the application rate of Pestoff 20R over the LHIG group will be two applications (14- 21 days apart); 12/kg/ha and 8kg/ha giving a total application rate of 20kg/ha of Pestoff 20R pellets. For simplicity this can be considered a single application. At 20mg/kg Brodifacoum concentration this will result in application of 0.4g/ha of Brodifacoum. Each individual pellet of approximately 2g weight contains 40ug Brodifacoum. This has been used for the worst case scenario for Predicted Environmental Concentrations in Table 4 below, where pathways exist.

In the marine and aquatic environment, the dosage rate of 0.4 g/ha Brodifacoum equates to 0.4 g /1.5ML (1 ha of water 15cm deep) or 0.2ug/L in the worst case scenario. In the marine environment, this worst case scenario assumes that the entire 20kg/ha (i.e. all of the bait from coastal swaths in both bait drops) ends up in the water. This is considered highly unlikely considering Howald et al. (2005) showed that when baits were applied aerially to steep cliffs, (application rate of 15kg/ha) a mean of only 72 baits over 500 m stretch of coast (~2ha) ended up in the water. This would equate to less than 0.5% out of the approximate 15,000 baits applied over that area ended up in the sea. Using a similar percentage of bait that could bounce off the cliffs and ended up in the sea in the LHI REP situation, a more likely predicted environmental concentration in the marine environment would be in the order of 0.01ug/L.

Table 4. Predicted Environmental Concentrations

Animal group	Predicted Environmental Concentration			
	PEC_{Food}*	PEC_{Soil}^	PEC_{Water}#	$PEC_{Sediment}$^
Terrestrial Birds	0.4g/ha	0.4g/ha	Nil	Nil
Mammals	0.4g/ha	0.4g/ha	Nil	Nil
Reptiles	0.4g/ha	0.4g/ha	Nil	Nil
Invertebrates	0.4g/ha	0.4g/ha	Nil	Nil
Plants	Nil	Nil	Nil	Nil
Marine vertebrates	0.4g/ha	Nil	Nil	0.4g/ha
Marine Invertebrates	0.4g/ha	Nil	Nil	0.4g/ha
Sea Birds	Nil	Nil	Nil	Nil

- * direct consumption of pellets
- # Insoluble in water. No pathway
- ^ exposure through soil or sediment

PART 7-3: ENVIRONMENTAL EFFECTS ASSESSMENT

7-3.1. SUMMARY

Brodifacoum is highly toxic to birds, mammals and fish and to lesser extent reptiles. Brodifacoum bio-accumulates in the tissues of mammals and birds following sub-lethal exposures and has the potential to accumulate in fish. Invertebrates bio-accumulate the poison, but, in the absence of repeat feeding on Brodifacoum, rapidly excrete the compound. The risks of secondary poisoning are considered to be moderate to high for individuals of scavenging or predatory species, due to the mode of action of Brodifacoum. High levels may accumulate in organs (e.g. liver) following sub-lethal exposure, exposing non-target predators and scavengers to potentially lethal concentrations of Brodifacoum. Such non-target deaths have been documented in other eradication programmes. However, the affected species have recovered quickly to, or exceeded, pre-eradication population levels.

This section summarises recorded environmental effects of Brodifacoum on a range of species from both laboratory and field studies around the world. Studies include acute, short term and chronic.

7-3.2. BIRDS, MAMMALS AND OTHER TERRESTRIAL VERTEBRATES

7-3.2.1. ACUTE

Brodifacoum, like other anticoagulant poisons, acts by interfering with the normal synthesis of vitamin-K-dependent clotting factors in the liver of vertebrates, thereby disrupting normal blood-clotting processes. 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 (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 three to five 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. Peri-articular or intra-articular 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*). Animals experiencing prolonged toxicosis may be icteric or jaundiced. Similar clinical signs occur in humans and include haematuria (blood in urine), bleeding gums, and easy or spontaneous bruising.

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.

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 and subsequent accumulation and persistence in the liver and kidneys after absorption. All tissues that contain vitamin K-epoxide reductase (e.g. liver, kidney, and pancreas) are target organs for accumulating these poisons.

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 brushtail 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.

With Brodifacoum only a single dose is required to induce death if a sufficient quantity is ingested. LD50 data on many species is however very limited, especially reptiles and amphibians. For birds the available figures have wide variation between species. The acute toxicity of Brodifacoum to various avian and mammalian species is listed in Table 5.

A $LD_{50\ value}$ indicates the required dose likely to kill 50% of those individuals that consume the poison. The dose is expressed in milligrams of poison for every kilogram in weight of the particular species.

Table 5. ACUTE ORAL TOXICITY (LD50 mg/kg) OF BRODIFACOUM FOR A RANGE OF BIRDS and MAMMALS AND VETERBRATES (from Broome *et al*, 2016)

SPECIES	LD50 mg/kg	REFERENCES
Birds	Range: <0.75 - 20.0	
Australian harrier	10.0	Godfrey (1985)
Blackbird	>3.0	Godfrey (1985)
Chicken (*Gallus gallus*)	10.0-20.0	Godfrey (1985)
Duck (mallard)	4.6	Godfrey (1985)
Duck (Paradise shelduck)	> 20.0 (highest dose administered)	Godfrey (1985)
Goose (Canada) (*Branta Canadensis*)	<0.75	Godfrey (1985)
Gull (Southern black-backed)	< 0.75 (lowest dose administered)	Godfrey (1985)
Gull (Black-billed) (*Larus bulleri*)	< 5.0 (lowest dose administered)	Godfrey (1985)
Pheasant (ring-necked) (*Phasianus colchicus*)	10.0	Godfrey (1985)
Pukeko (*Porphyrio porphyrio*)	0.95	Godfrey (1985)
Quail (California) (*Callipepla californica*)	3.3	Godfrey (1985)
Silvereye	> 6.0 (highest dose administered)	Godfrey (1985)
Sparrow (hedge) (*Prunella modularis*)	>3.0	Godfrey (1985)

SPECIES		LD50 mg/kg	REFERENCES
Sparrow (house)		>6.0	Godfrey (1985)
Marsupial mammals		Range: 0.17 - 1.3	
Brushtail possum		0.17	Godfrey (1985)
Wallaby (Bennett's) (*Macropus rufogriseus*)		1.3	Godfrey (1985)
Eutherian mammals		Range: 0.25 to 33.0	
Cat		0.25-25	Godfrey (1985)
Dog		0.25-3.56	Godfrey (1985)
Guinea pig (*Cavio porcellus*)		2.8	WHO (1995)
Mouse (house)		0.40	Dubock & Kaukeinen (1978)
Pig		0.5 to 2	USEPA (2005)
Rabbit		0.29	Kaukeinen (1979); Godfrey (1985)
Rat (Norway)	Male	0.26	Dubock & Kaukeinen (1978)
	Female	0.22	Dubock & Kaukeinen (1978)
Rat (ship)	Male	0.73	Dubock & Kaukeinen (1978)
	Female	0.65	Dubock & Kaukeinen (1978)
Sheep		11 - 33	WHO (1995)
Vole (pine) (*Pitymys pinetorum*)		0.36	Dubock & Kaukeinen (1978)
Vole (meadow) (*Microtus pennsylvanicus*)		0.72	Dubock & Kaukeinen (1978)
Reptiles / amphibians		See below	

Reptiles

Limited published or verified unpublished LD50 data on the direct acute toxicity of Brodifacoum to reptiles was found. Reptiles are considered to be somewhat susceptible but are more tolerant than mammals and birds based on field observations and survival during experimental dosing. Some field observations are presented below.

Telfair's skinks (*Leiolopsima telfarii*) were found dead 3 to 6 weeks after eating rain-softened Talon® 20P used on Round Island, Mauritius, with residues detected in their livers (Merton 1987).

There was a 15 % mortality of the Caribbean gecko species *Sphaerodactylus macrolepis* when exposed to Talon-G (cereal pellets containing 0.02 g/kg Brodifacoum) during pen trials (Gaa 1986, cited in Garcia et al. 2002).

Adult black iguanas (*Ctenosaura pectinata*) force-fed pellets containing 25ppm brodifacoum (a dose approximately equivalent to 0.4 to 0.857 mg/kg) on Isabel Island, Mexico survived 27 days will no apparent ill effects. (Broome et al, 2016).

A range of reptile species were dosed with Brodifacoum in solution by oral gavage in a toxic residue experiment by Witmer and Mauldin (2012). The highest dose used in the experiment was 0.79mg/kg given twice, one week apart (a total dose of 1.58 mg/kg or about 3 times the LD50 of a wild caught ship rat). Test animals were then killed about 7 days following the final dose. All four Ornate wood turtles (*Rhinoclemmys pulcherrima*), all eight snakes (*Boa constrictor*), and all ten green iguana (*Iguana iguana*) survived. One of nine amevia lizards (*Amevia amevia*) was not eating well at the time of dosing and was euthanised four days after the second dose. The time between first dose and killing these reptiles for the residue testing may not have been sufficient for toxic effects to have become fatal.

7-3.2.2. SHORT-TERM

Sub-lethal effects from Brodifacoum exposure have not been proven in field studies but most studies are on mammals where higher dose groups sometimes abort their young. Brodifacoum is transferred to eggs and embryos and in one high dose study was found to transfer through the milk of mammals (sheep). Studies on birds failed to find significant effects on eggs or nestlings which could be directly attributed to Brodifacoum exposure (Broome *et al*, 2016).

Short-term sub-lethal exposure is not expected to have any significant adverse effects, though Brodifacoum may persist in tissues for several weeks to months after exposure and is only slowly eliminated from the body of most vertebrate species. 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).

<u>Birds</u>

Fisher (2009) sub lethally orally dosed hens with 0.5 mg/kg Brodifacoum, roughly equivalent to them eating 41g of 20ppm bait. Over the following 14 days no significant change in their normal food intake and no outward signs of anticoagulant poisoning were observed. Nine of the ten eggs collected from the birds 1, 4, 7 and 14 days after dosing had residues of Brodifacoum.

Hasber et al 2015, found residues of bromadialone (also a second generation anticoagulant) in barn owl (*Tyto alba*) eggs collected from an oil palm plantation where this rodenticide was used to control rats. However no differences in egg shape, egg shell mass or thickness could be determined when compared with a non-treatment area. Naim et al (2012) (cited in Hasber et al 2015), compared eggshell thickness in the same species from areas treated with Brodifacoum and found no significant differences when compared with a non-treatment area.

Naim et al (2010) compared the growth of barn owl nestlings in areas treated with Brodifacoum and a non-treatment area. All growth parameters measured were higher in the

non-treatment area than the area where Brodifacoum was used, probably because there were fewer rats, the main prey item for owls, in the treated area. However they also observed one of the two nestlings surviving in the Brodifacoum treated area had malformed primary feathers which rendered the bird flightless. No such malformations were observed either in the non-treatment area (12 birds) or in other areas using different rodent control measures (18 birds).

In pen trials, the blood clotting times of domestic chickens increased in a dose dependent response. Clotting time was elevated for up to 21 days following exposure to a single dose of 0.75 mg/kg Brodifacoum and at least 28 days when chickens were dosed with 1.5 mg/kg Brodifacoum (Bailey et al. 2002).

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).

Mammals

Godfrey (1985) reported that 48% of pregnant ewes sub-lethally dosed with 2 mg/kg Brodifacoum in the seventh week of pregnancy aborted, compared with none in the control group. In another trial, the number of abortions increased and lambing rates declined as the sub lethal dose of Brodifacoum given to pregnant ewes increased. When ewes were dosed with 2 mg/kg approximately one week before parturition, 35% of lambs died within the first three days after birth compared to 8% in the control group.

Lactating ewes were dosed with 1.0 mg/kg Brodifacoum and another at 0.1 mg/kg. Blood and milk samples were taken between 2 and 32 days after dosing and analysed for Brodifacoum residues. Five of the 8 ewes receiving the higher dose had detectable concentrations of Brodifacoum in their milk two days after dosing. Testing from 4 days post dosing and later failed to find any Brodifacoum residues in milk (Toffee website accessed Dec 2015).

Rabbits dosed with brodifacoum as part of an acute toxicity assessment (but survived) showed lassitude and anorexia, but appeared fully recovered within one month of dosing (Godfrey et al. 1981b).

Dogs dosed with brodifacoum as part of an acute toxicity assessment (but survived) showed ‘varying degrees of weakness’ through the trial but all appeared fully recovered within a month of dosing (Godfrey et al. 1981a). Munday & Thompson (2003) reported brodifacoum residues of 0.63ppm and 0.23ppm in the livers of two of three puppies that died within 6 hours of birth. Of the litter of thirteen pups, two were stillborn and another three puppies died between 6 and 48 hours after birth. Four of the six puppies that died postpartum had variable haemoptysis or epistaxis before death. The mean birth weight of the eight puppies that were born dead or died was 280 ± 107 g, compared to that of 502 ± 57 g of the 5 surviving puppies. The bitch showed no symptoms of poisoning during gestation, and the owners were confident that exposure did not occur during the last 4 weeks of gestation. As it is considered unlikely that ingestion of brodifacoum would result in fatal coagulopathy within the first 6 hours of life and a presumptive diagnosis of in utero brodifacoum toxicosis was made.

No abnormalities were detected in laboratory rats that were dosed with brodifacoum over 5 consecutive days and then survived for 21 days (World Health Organisation 1995). Laboratory rats that survived being given a continuous diet of brodifacoum for 12 weeks showed increased prothrombin time but after euthanasia showed ‘no abnormalities of major organs other than those expected of anticoagulant action’ (World Health Organisation 1995).

Four of six horses dosed with brodifacoum became anorexic and depressed, one requiring Vitamin K therapy (Boermans et al. 1991)

7-3.2.3. SPECIAL STUDIES – CHRONIC, REPRODUCTION, SIMULATED OR ACTUAL FIELD TESTING, ETC.

A number of non-target native species have been found dead following the use of Brodifacoum during pest control operations either aerial or where bait stations are used.

The risk to individual species is dependent on their tolerance levels to Brodifacoum, size eating habits and habits and exposure. Omnivorous, herbivorous and granivorous birds are most at risk from primary poisoning.

Howald *et al.* (2007) have conducted a review of programmes undertaken to eradicate invasive rodent species from islands. Data was compiled from published and grey literature as well as personal communications. Worldwide, 332 successful rodent eradications had been carried out, with rodents being eradicated from 284 Islands with a combined area of 47, 628 ha. Brodifacoum was used in 71% of the eradication campaigns and 91% of the total area treated. Application methods included bait stations, hand broadcasting and aerial broadcasting, with aerial broadcasting being responsible for 76% of the total treated area. Non-target deaths have been documented in eradication programmes. However, the affected species recovered quickly to pre-eradication population levels, or higher.

Birds

A range of native bird species have been monitored through aerial baiting eradication projects. Risks vary according to ecological niche and habitat. In general seabirds which feed at sea (eg penguins, burrowing petrels, albatross) are unaffected, scavengers, predators and opportunist generalist feeders (eg gulls, skua, ducks, weka) can be at high risk, forest dwelling insectivores (eg robins, kiwi, tits) may sometimes be at risk, and nectar feeders (eg tui, hihi) are unaffected.

Deaths recorded during aerial and hand baiting operations are described in Table 6.

Note: The information in the tables includes animals found dead, or assumed to have been lethally poisoned by the field operation from the presence of brodifacoum residues. The information has been restricted to those operations where the basic performance standards could be verified

Table 6: NON-TARGET SPECIES DEATHS REPORTED DURING AERIAL AND HANDLAYING OPERATIONS USING BRODIFACOUM (from Broome et al 2016)

SPECIES	No. OF OPERATIONS	TOTAL FOUND DEAD	No. TESTED FOR RESIDUES	No. OF POSITIVE RESIDUES	REFERENCE
Cereal aerially sown					

SPECIES	No. OF OPERATIONS	TOTAL FOUND DEAD	No. TESTED FOR RESIDUES	No. OF POSITIVE RESIDUES	REFERENCE
Australasian Harrier	6	12	2	2	Dowding et al. (1999); Griffiths (2004); Lovegrove & Richie (2005); Pestlink: 0203GRB03; Griffiths & Brown (2011); Maitland (2012)
Dotterel (NZ)	4	9	5	4	Lovegrove & Richie (2005); Dowding et al. (1999); Dowding et al (2006); Vestena & Walker (2010)
Duck (Auckland Is. teal) (*Anas a. aucklandica*)	1	7	0		Torr (2002)
Duck (brown teal) (*Anas aucklandica chlorotis*)	2	4	2	2	Veitch (2002c) Maitland (2012)
Duck (grey)	3	4	1	1	Dowding et al. (1999); Griffiths (2004); Lovegrove & Richie (2005)
Duck (grey and mallards)	2	157			DSEWPAC (2012)
Duck (paradise shelduck)	6	421	4	4	Dowding et al. (1999); Veitch (2002c); Lovegrove & Richie (2005); Vestena & Walker (2010); Griffiths & Brown (2011); Maitland (2012)
Fernbird	1	3	3	2	Ranum et al. (1994)

SPECIES	No. OF OPERATIONS	TOTAL FOUND DEAD	No. TESTED FOR RESIDUES	No. OF POSITIVE RESIDUES	REFERENCE
Giant petrel (Northern) *(Macronectes halii)*	2	693			DSEWPAC (2012)
Giant petrel (Southern) *(Macronectes giganteus)*	2	38			DSEWPAC (2012)
Gull (Southern black-back)	5	1007	9	9	Dowding et al. (1999); McClelland (2001); VPRD; Vestena & Walker (2010); Griffiths & Brown (2011); DSEWPAC (2012)
Gull (red-billed)	3	3	1	1	McClelland (2001); Lovegrove & Richie (2005); VPRD:T1535; Maitland (2012)
Kaka	1	4	3	3	Empson & Miskelly (1999)
Kakariki	4	7	5	2	Ogilvie et al. (1997); McClelland (2002); Veitch (2002c); Griffiths (2004); VPRD: T0314, I014
Kingfisher	2	3			Lovegrove & Richie (2005) Maitland (2012)
Kiwi (Brown)	2	4	2	2	Griffiths (2004); Vestena & Walker (2010); Fisher et al. (2011)
Kiwi (Little spotted)	2	3	1	1	Robertson & Colbourne (2001); Griffiths (2004)

SPECIES	No. OF OPERATIONS	TOTAL FOUND DEAD	No. TESTED FOR RESIDUES	No. OF POSITIVE RESIDUES	REFERENCE
Morepork	11	27	8	8	Ogilvie et al. (1997); Walker & Elliot (1997); Empson & Miskelly (1999); Stephenson et al. (1999); McClelland (2002); Williams & Jones (2002); Towns & Broome (2003); Griffiths (2004); VPRD; Griffiths & Brown (2011); Maitland (2012)
Pied stilt	1	3	1	1	Lovegrove & Richie (2005); Dowding et al (2006)
Plover (Spur-winged) *Vanellus miles*	2	5			Lovegrove & Richie (2005); Dowding et al (2006); Maitland (2012)
Pukeko	8	663	9	9	Ranum et al. (1994); Dowding et al. (1999); Veitch (2002c); Griffiths (2004); Lovegrove & Richie (2005); Vestena & Walker (2010); Griffiths & Brown (2011); Maitland (2012)
Robin (N.I.)	1	1	0		Stephenson et al. (1999)
Robin (Stewart Island)	1	13	13	12	Masuda at al. (2012)
Saddleback (*Philesturnus*	4	10	2	2	Stephenson et al. (1999); Veitch

SPECIES	No. OF OPERATIONS	TOTAL FOUND DEAD	No. TESTED FOR RESIDUES	No. OF POSITIVE RESIDUES	REFERENCE
carunculatus)					(2002c) ; Towns & Broome (2003)
Shag (little)	1	1	1	1	Williams & Jones (2002)
Skua (Brown) (*Catharacta skua*)	3	552	0		Torr (2002); DSEWPAC (2012)
Spotless crake	1	1	1	1	Veitch (2002c)
Tui	1	2	2	1	McClelland (2002)
Weka	1	1	0		Stephenson et al. (1999)
Cereal hand laid					
Australasian harrier	1	2	2	2	Rammell et al. (1984)
Duck (paradise shelduck)	1	1	1	1	Rammell et al. (1984)
Gull (Southern black back)	1	2	2	2	Rammell et al. (1984)

Australasian Harrier (*Circus approximans*)
Bird counts undertaken before and after the Shakespeare Open Sanctuary Eradication Project (Pestoff 20R aerially sown 31.5 kg/ha over 3 applications) showed a decline in the harrier observations. Two dead birds were recovered (Maitland 2012).

Five-minute bird counts undertaken before and after the rat eradication on Red Mercury Island (Talon® 20P pellet aerially sown at 15.5 kg/ha and some hand laying of Talon® 50WB) indicated no change in the harrier population post eradication (Robertson et al. 1993).

Raptors have been found dead after aerially applied brodifacoum in projects overseas including bald eagles (Salmon & Paul 2010), Galapagos hawks (McClelland et al 2015), owls and kestrels (Howald et al 2009) where population effects could be inferred.

Bellbird (*Anthornis melanura*)
Five minute bird counts undertaken soon after aerial poisoning with cereal pellets containing brodifacoum on Kapiti Island in 1996 did not show any significant differences in bellbird numbers when compared with baseline counts before poisoning (1991-1993) or six months after poisoning (Empson & Miskelly, 1999).

Five-minute bird counts undertaken before and after the rat eradication on Red Mercury Island (Talon® 20P pellet aerially sown at 15.5 kg/ha and some hand laying of Talon® 50WB) indicated a decline in the bellbird numbers on the island (Robertson et al. 1993).

Cuckoo (Shining) (*Chrysococcyx lucidus*)
Five-minute bird counts undertaken before and after the rat eradication on Red Mercury Island (Talon® 20P pellet aerially sown at 15.5 kg/ha and some hand laying of Talon® 50WB) indicated an increase in the shining cuckoo population after the aerial drop (Robertson et al. 1993).

Dotterel (New Zealand) (*Charadrius obscurus*)
Casual counts of dotterel on the beaches of Great Mercury Island did not change after two 8kg/ha applications of Pestoff 20R in 2014. Baits were removed from the beaches on the day of each application as a mitigation measure to protect dotterel (P. Corson pers comm.).

During the Shakespeare Open Sanctuary Eradication Project (Pest-off 20R aerially sown 31.5 kg/ha over 3 applications) beach and seaweed clearance was undertaken at Te Harui Bay prior to each bait application. All 3 pairs of resident dotterel were confirmed alive after the operation (Maitland 2012).

The same NZ dotterel precautions (bait and seaweed clearance) were taken on Motutapu Island during aerial application of 10mm Pestoff 20R baits in July 2009 with similar results although one of five banded birds was found dead after this operation. In November 2009 shortly after bait application just four territorial pairs were observed as opposed to the five pairs present in 2008. However, a number of new non-breeding birds were recorded at sites previously unoccupied. In November 2010 the number of breeding pairs had increased to eight. Five of these pairs had chicks whereas just one chick had been seen in the previous three years of monitoring on the islands. Two other dotterel banded prior to the operation were not observed in post operational surveys and the fate of these birds is unknown. The lack of information on the fate of the three birds noted above means that the effectiveness of measures instigated to reduce the risk to NZ dotterels cannot be quantified. However, clearing of seaweed did not appear to reduce sandhopper numbers because easterly storms throughout the winter period continually replenished the supply of seaweed and large areas of buried seaweed could not be removed. The clearing of bait from beaches completed immediately after each bait application appeared to be a more effective means of reducing exposure to NZ dotterel. With the number of territorial pairs of NZ dotterel on Rangitoto and Motutapu in 2011 nearly double the number present before the operation, the islands are well on their way to becoming a source rather than a sink for NZ dotterels (Griffiths & Brown 2011).

Twelve NZ dotterels were marked prior to aerial application of 10mm Pestoff 20R baits containing 20ppm brodifacoum to the Ipipiri Islands in the Bay of Islands in June 2009. Sandy beaches in the treatment area were cleared of baits immediately following each of two bait applications 20 days apart which applied a combined total average application rate of 26kg/ha over the islands. Additionally seaweed along the drift line of these beaches was also cleared to reduce the habitat for sand hoppers, a major prey item for dotterels which was known to feed on toxic baits. Despite these precautions 3 of the banded dotterels were found dead and residue analysis suggested brodifacoum contributed to their deaths. Of the remaining banded birds, two appeared to leave the area prior to bait application, six appear to have survived on the islands and one is unaccounted for. Two unbanded dotterels were found dead after the operation and appeared to have been poisoned. However in the nine months following the operation a number of extra birds have been recorded on the islands including a flock of 22 in March 2010. Eight nests were recorded over the 2009/10 summer including in previously unoccupied locations (Vestena & Walker 2010).

There was a higher than expected mortality among NZ dotterel at Tawharanui Regional Park Open Sanctuary following the aerial application of Pestoff® 20R cereal baits at 8kg/ha followed a month later by 7 kg/ha. Six of 12 NZ Dotterels known from the area probably died from brodifacoum poisoning, possibly from eating contaminated sand hoppers (Dowding et al. 2006).

All 4 pairs of NZ dotterel on Motuihe Island survived an aerial distribution of Talon® 7-20 at 8 kg/ha followed by 3.5 kg/ha 10 days later (Dowding et al. 1999).

Duck (Paradise Shelduck) (*Tadorna variegata*)
Bird counts undertaken before and after the Shakespear Open Sanctuary Eradication Project (Pestoff 20R aerially sown 31.5 kg/ha over 3 applications) showed a 90% decline in the Paradise Shelduck observations (Maitland 2012).

On Motutapu island in 2009 350 paradise shelduck were found dead, representing most of the resident population. However within one year the population had returned to close to pre-poison levels (Griffiths & Brown 2011).

Despite 32 paradise shelducks being found dead and significant declines in numbers at two of three monitoring sites following the Pestoff 20R aerial drop at Tawharanui Regional Park Open Sanctuary, the overall numbers of paradise shelducks increased. Lovegrove & Richie (2005) attributed this to immigration from areas outside the park.

Dowding et al. (1999) reported a 60% (31/52) mortality of paradise shelduck on Motuihe Island after Talon® 7-20 was aerially distributed at 8 kg/ha followed 10 days later by 3.5 kg/ha.

Fantail (*Rhipidura fulginosa*)
Fantail numbers did not change between five-minute bird counts undertaken before and after the two Pestoff 20R aerial drops at Tawharanui Regional Park Open Sanctuary in September and October 2004 (Lovegrove & Ritchie 2005).

Five-minute bird counts undertaken before and after the rat eradication on Red Mercury Island (Talon® 20P pellet aerially sown at 15.5 kg/ha and some hand laying of Talon® 50WB) indicated no change in the fantail population (Robertson et al. 1993).

Fernbirds (*Bowdleria punctata*)
Fernbirds were monitored by territory mapping and banding during an aerial operation in the Waituna Wetlands when Talon® 20P was sown at a rate of 37.5 kg/ha. 86% of the banded birds disappeared after the operation. Overall, bird numbers declined by only 50% because some birds immigrated into the treatment area following the death of the residents (Ranum et al. 1994).

Most of the fernbirds present on Codfish Island were killed during the eradication of rats from the island in 1997. In the operation, Pestoff® 20R pellets were aerially sown at 9.7 kg/ha followed, nine days later by 9.3 kg/ha over most of the island except in the prime fernbird habitat where Pestoff® 20R pellets were placed in Novacoil bait stations on a 25 x 50m grid. Very few fernbirds were recorded for the first two years after the poison operation, but by 2002 the population had built up and expanded into most of its former range (McClelland 2002).

Giant Petrels (Northern & Southern) (*Macronectes halli* & *Macronectes giganteu*)
In 2010 and again in 2011 Pestoff 20R baits were applied to Sub Antarctic Macquarie Island to eradicate rodents and rabbits. In 2010 baiting was abandoned after prolonged bad weather ruined the prospects of completing coverage of the 12800ha Island. About 10% of the island

was baited in 2010. Following this bait application (during the period June 2010 to April 2011) 306 dead Northern Giant Petrels were recovered.

In May 2011 baiting resumed and covered the whole island with 2 complete applications and partial coverage by a third giving a combined bait application rate of 24 kg/ha. Despite attempts to mitigate further non-target deaths by retrieving poisoned rabbit carcasses and burying them, a further 387 Northern Giant Petrels were found dead (during the period May 2011 to April 2012) presumably because they found rabbit carcasses the mitigation team did not. This number would have likely been higher if Rabbit Haemorrhagic Disease (RHD) was not released on the island in February 2011 causing a massive decline in rabbit populations. These numbers include all birds found, not just those that died as a result of baiting activities. It is possible some birds would have succumbed to the effects of poisoning at sea where their bodies would have not been recovered.

During the same periods 17 and 21 dead Southern Giant Petrels were recovered.
Nearly all giant petrels killed were Northern giant petrels, which is commensurate with their feeding strategy. There was also a strong imbalance of genders in the mortality with 84% of the samples tested being male, again reflecting their feeding strategy. This gender bias (approximately 30% of the mature male population of Northern giant petrels killed) will affect the number of breeding pairs that are able to form.

It is estimated that 7.6% of the Northern giant petrel population and 0.3% of the Southern giant petrel population were killed as a result of the 2010 and 2011 baiting operations (DSEWPAC 2012).

Grey warbler (*Gerygone igata*)
Five-minute bird counts undertaken before and after the rat eradication on Red Mercury Island (Talon® 20P pellet aerially sown at 15.5 kg/ha and some hand laying of Talon® 50WB) indicated a small decline in the grey warbler population following the poison drop (Robertson et al. 1993).

Grey warbler numbers did not change during five-minute bird counts undertaken before and after the two Pestoff 20R aerial drops at Tawharanui Regional Park Open Sanctuary in September and October 2004 (Lovegrove & Ritchie 2005).

Hihi (Stitchbirds) (*Notiomystis cincta*)
Hihi survival was monitored during the Mokoia (Armstrong et al. 2001) and Kapiti (Empson & Miskelly 1999) Island rat eradications. On Mokoia Island, mark-recapture data analysis showed that the poison drop (Talon® 7-20 at 10 kg/ha) had no or negligible effect on hihi survival (Armstrong et al. 2001).

Empson & Miskelly (1999) reported there was no evidence of hihi being killed during the Kapiti Island operation (Talon® 7-20 at 9.0 kg/ha and 5.1 kg/ha), and survival rates increased after the poison drop, possibly due to the removal of the Norway rats.

Kaka (*Nestor meridonalis***)**
4 out of 20 (20%) of radio-tagged kaka died during the rat eradication (Talon® 7-20 at 9.0 kg/ha followed by 5.1 kg/ha 25 days later) on Kapiti Island (Empson & Miskelly 1999).
All 5 kaka monitored by radio telemetry on Whatupuke Island survived an aerial poison drop of Talon® 20P at 12 kg/ha with some follow up hand laying. Additionally, no reduction in kaka numbers was detected during five-minute bird counts one month after the operation compared with counts one month before the operation (Pierce & Moorhouse 1994).
No obvious change in the number of kaka present (6 birds including one with a radio-transmitter) on Nukuwaiata Island occurred when Talon® 7-20 was sown at 11 kg/ha (Brown 1997a).

Five-minute bird counts undertaken before and after the rat eradication on Red Mercury Island (Talon® 20P pellet aerially sown at 15.5 kg/ha and some hand laying of Talon® 50WB) indicated no change in the kaka population on the island (Robertson et al. 1993).

Kakariki (*Cyanoramphus novaezelandiae*)
In winter 2013 a non-toxic bait trial using Pestoff 20R baits with pyranine biomarker was conducted over 6ha of Antipodes Island by handspreading the bait at a rate of 16kg/ha. Both Antipodes parakeets (*Cyanoramphus unicolor*) and Reischek's parakeet (*Cyanoramphus hochstetteri*) were observed in the baited area. Some of these were caught and inspected for signs of feeding on the bait. None of the 18 Antipodes parakeets and 17 Reischek's parakeets captured showed any sign of pyranine marking. There were no observations of either species showing interest in the bait despite them being observed walking over the baits (Elliot et al 2015).

Kakariki were abundant on Macauley Island in the Kermadecs when kiore were eradicated in 2006 using Pestoff 20R baits applied aerially in two applications totally an average of 13.5kg/ha (Pestlink 0708WAR22). . Kakariki were surveyed immediately before the bait was dropped and a follow up expedition in August 2006 found no evidence of any non-target affect on them. About six kakariki were observed near the loading site where bait was available to them on the ground and they showed no interest in it (R. Griffiths pers comm. DOCDM-115910).

Five-minute bird counts conducted prior to and post the rat eradication on Red Mercury Island (Talon® 20P pellet aerially sown at 15.5 kg/ha and some hand laying of Talon® 50WB) indicated that red-crowned kakariki were not affected by the operation (Robertson et al. 1993)

Five-minute bird counts on Kapiti Island pre and post the rat eradication in 1996 (aerial application of Talon® 7-20 at 9.0 kg/ha followed by 5.1 kg/ha, 25 days later) showed no significant difference in red-crowned kakariki (Empson & Miskelly 1999).

Kereru (*Hemiphaga novaeseelandiae*)
There were no significant differences in counts of kereru along transects in Shakespear Open Sanctuary during the multispecies pest eradication that took place in 2011 using aerially applied Pestoff 20R bait (Maitland 2012)

Kereru numbers increased significantly in the five-minute bird counts undertaken after the two Pestoff 20R aerial drops at Tawharanui Regional Park Open Sanctuary in September and October 2004 (Lovegrove & Ritchie 2005).

Distance sampling monitoring of forest birds including kereru during the Hauturu kiore eradication using Pestoff 20R baits aerially applied in winter 2004 could detect no changes in populations three months after the first bait application (R. Griffiths pers comm. OLDDM-147458).

Five-minute bird counts on Kapiti Island pre and post the rat eradication in 1996 (aerial application of Talon® 7-20 at 9.0 kg/ha followed by 5.1 kg/ha, 25 days later) showed no significant difference in kereru numbers (Empson & Miskelly 1999).

Five-minute bird counts conducted prior to and post the rat eradication on Red Mercury Island (Talon® 20P pellet aerially sown at 15.5 kg/ha and some hand laying of Talon® 50WB) indicated that kereru were not affected by the operation (Robertson et al. 1993)

There are no records of dead kereru with brodifacoum residues following rodent eradication operations despite them having been exposed to aerially broadcast baits on at least 8 island eradication projects (VPRD in Broome et al, 2016)

Kingfisher (*Halcyon sancta*)
There were no significant differences in counts of kingfisher along transects in Shakespear Open Sanctuary during the multispecies pest eradication that took place in 2011 using aerially applied Pestoff 20R bait (Maitland 2012)

Five-minute bird counts undertaken before and after the rat eradication at Tawharanui Regional Park open sanctuary (Pestoff 20R aerially sown) indicated a significant decline in kingfisher numbers (Lovegrove & Ritchie 2005).

Five-minute bird counts undertaken before and after the rat eradication on Red Mercury Island (Talon® 20P pellet aerially sown at 15.5 kg/ha and some hand laying of Talon® 50WB) indicated an increase in the kingfisher population on the island (Robertson et al. 1993).

Kiwi (Little spotted) (*Apteryx owenii*)
Little Spotted kiwi were monitored through the Kapiti Island rat eradication (Talon® 7-20 at 9.0 kg/ha followed by 5.1 kg/ha 25 days later) using 50 banded birds, 10 of which also had radio-transmitters (Robertson & Colbourne 2001). Two of the 10 birds with radio-transmitters died (a mortality rate of 20%) within a month of the poison drops, One of these birds tested positive for brodifacoum residues. Six months after the eradication, 46 of the banded birds were still alive. Robertson & Colbourne (2001) estimated that in the worst-case, poison induced mortality was 8% (3-19%). They concluded that the short term effect of operation on little spotted kiwi was small and the removal of the rats would increase long term survival rates.

Robertson et al. (1993) reported that on Red Mercury Island all nine Little Spotted kiwi with radio transmitters were still alive 1 month after the 1992 rat eradication operation (Talon® 20P pellet aerially sown at 15.5 kg/ha and some hand laying of Talon® 50WB). The authors expected the Little Spotted kiwi population to continue growing from the 11 pairs estimated in September 1992, as the absence of rats should improve the availability of invertebrate prey.

The Little Spotted kiwi population on Tiritiri Matangi Island was not seriously affected by the aerial application of Talon® 20P at 10 kg/ha (Eason et al. 2002).

Kiwi (North Island Brown) (*Apteryx mantelli*)
Brown kiwi were exposed to Pestoff 20R baits during the Hauturu kiore eradication in winter 2004. Two kiwi were found dead following the bait application and one was later confirmed to contain brodifacoum residues. Long term monitoring of kiwi call counts could detect no differences after the operation (R Griffiths pers comm. OLDDM-147458).

Two brown kiwi were found dead following aerially applied Pestoff 20R on Motuarohia Island as part of Project Island Song in 2009. One was confirmd 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 & Walker 2010).

Kokako (Callaeas cinerea)
There was an 85% (11/13, including 3 with radio-transmitters) survival rate among the kokako monitored during the rat eradication (Talon® 7-20 at 9.0 kg/ha followed by 5.1 kg/ha 25 days later) on Kapiti Island (Empson & Miskelly 1999).

Mohua (Yellowhead) (*Mohua ochrocephala*)
Five-minute bird counts of mohua on Ulva Island showed no indication of effects from the aerial application of 14 kg/ha Pestoff 20R bait to eradicate rats in August 2011 (Masuda & Jamieson 2012).

Morepork (*Ninox novaeseelandiae*)

Three of 14 (21%) radio tagged morepork died in the 51 days after Talon® 7-20 was aerially applied at 10 kg/ha over Mokoia Island (Stephenson et al. 1999).

On Kapiti Island, morepork call rates dropped from 15.6 calls/hr pre- to 11.9 calls/hr post- rat eradication (Talon® 7-20 at 9.0 kg/ha and 5.1 kg/ha). This change was not statistically significant (Empson & Miskelly 1999).

Moreporks decreased after the aerial distribution of Talon® 20P at 10 kg/ha on Tiritiri Matangi Island, 1993, but it is not known whether this was induced by poisoning or the removal of their major food item, rats (Eason et al. 2002).

There was no evidence of a detrimental effect on the morepork population Red Mercury Island (Robertson et al. 1993) after aerial distribution of Talon® 20P to eradicate kiore.

Morepork call counts did not change significantly after the Pestoff 20R aerial drops at Tawharanui Regional Park Open Sanctuary in September/October 2004 (Lovegrove & Ritchie 2005).

During the Shakespeare Open Sanctuary Eradication Project morepork call counts were recorded pre and post bait application at four sites. Only one of the sites showed a significant decline in call numbers and three morepork carcasses were recovered from the vicinity of that count site. There was no significant change in the number of morepork calls at any of the four control sites outside the treatment area. Morepork were observed breeding successfully within the treatment area the summer following bait application (Maitland 2012).

Oystercatcher (Variable) (*Haematopus unicolor*)
Dowding et al. (1999) reported no mortality in 7 pairs of variable oystercatcher on Motuihe Island when Talon® 7-20 was spread aerially at 8 kg/ha and then 3.5 kg/ha in 1997.

All nine colour banded variable oystercatchers resident at Tawharunui at the time Pestoff® 20R cereal baits were spread in two aerial applications of 8kg/ha and 7 kg/ha, survived (Dowding et al. 2006).

NZ Pipit (*Anthus novaeseelandiae*)
In 2013 mice established on Maud Island and an eradication using aerially applied Pestoff 20R baits containing 0.02g/kg brodifacoum was undertaken in the winter of 2014. Counts of pipits before and following bait application showed a decline, although the sample size is low (5 pair and 1 individual pre, 4 individuals post) and birds were not banded. (Bartlett and Chateris 2014, in Broome et al , 2016).

In winter 2013 a non-toxic bait trial using Pestoff 20R baits with pyranine biomarker was conducted over 6ha of Antipodes Island by hand-spreading the bait at a rate of 16kg/ha. Antipodes pipits (*Anthus novaeseelandiae steindachneri*) were observed in the baited area. Bird droppings were collected and later analysed for DNA to identify the species and inspected for signs of pyranine dye. Of the 52 droppings identified as coming from pipits, 12 (23%) showed signs of dye. Observations of pipits interacting with baits showed little interest in the bait despite them being observed walking over the baits. However there was one observation of a bird eating fragments of bait (Elliot et al 2015in Broome et al, 2016).

Plover (Spur winged) (*Vanellus miles*)
Bird counts undertaken before and after the Shakespear Open Sanctuary Eradication Project (Pest-off 20R aerially sown 31.5 kg/ha over 3 applications) showed a 70% decline in the plover observations (Maitland 2012).

Pukeko (*Porphyrio porphyrio*)

Bird counts undertaken before and after the Shakespear Open Sanctuary Eradication Project (Pest-off 20R aerially sown 31.5 kg/ha over 3 applications) showed a 96% decline in the pukeko observations (Maitland 2012).

On Motutapu island in 2009 over 400 pukeko were found dead, representing most of the resident population. However within one year the pukeko population had returned to close to pre-poison levels (Griffiths & Brown 2011).

Lovegrove & Richie (2005) estimated pukeko numbers declined by 80% after Pestoff 20R was aerial sown in Tawharanui Regional Park open sanctuary.

Over 90% of pukeko on Tiritiri Matangi Island were killed following the aerial distribution of Talon® 20P at 10 kg/ha (Veitch 2002c).

Dowding et al. (1999) reported that on Motuihe Island, 49% (48/98) of pukeko died following the aerial sowing of Talon® 7-20 (8 kg/ha followed 10 days later by 3.5 kg/ha).

Robins (*Petroica australis*)
Based on mark-recapture data analysis, Armstrong & Ewen (2001) estimated there was 10 - 12.5 % mortality of North Island robins on Tiritiri Matangi Island following the use of Talon® 20P at 10 kg/ha. It was estimated that this mortality resulted in a one year lag in the robin population's growth but had no long-term effect on the viability of the population.

On Kapiti Island, banded North Island robins were monitored at two study sites during the 1996 rat eradication (Talon® 7-20 at 9.0 kg/ha followed by 5.1 kg/ha 25 days later) (Empson & Miskelly 1999). Survival rates of 35% and 74% were recorded. However, these survival rates are likely to be an underestimate of overall robin survival because the study sites were adjacent to public tracks where the birds were habituated to sampling novel foods. Analysis of data from one site showed that 60% of the robins adjacent to tracks survived compared to 100% of those away from tracks. In the year following the operation there was improved robin nesting success.

Following the re-establishment of a rat population on Ulva Island in late December 2010, and subsequent aerial application of brodifacoum (Pestoff 20R at 14 kg/ha) in August 2011, Masuda & Jamieson (2012) surveyed Stewart Island robins (*Petroica australis rakiura*) to determine what effect the rats and the poison operation had on the population. They reported a population decline of 31.5% following the rat re-invasion and brodifacoum application, with the majority of the decline taking place immediately after the poison drop. They however projected that the population would recover to 89% of its original size by the 2012/2013 breeding season.

Brown (1997c) monitored radio-tagged and banded South Island Robins in a 20 ha study site at Station Creek, Maruia where Talon® 20P was hand broadcast at 3 kg/ha, in October 1996. The minimum estimate of the robin's survival was 52.2% (95% CI = 31 - 75%).

On Nukuwaiata Island, 14/20 (70%) banded South Island robins survived Talon® 7-20 sown at 11 kg/ha (Walker & Elliott 1997).

Saddleback (*Philesturnus carunculatus*)
Population changes of saddlebacks were monitored for 8 months post rat and rabbit eradication on Stanley Island (Talon® 20P aerially distributed at 17kg/ha and Talon® 50 WB hand-laying at 1 kg/ha), by following banded birds during and after application, and with 5 minute bird counts. 41 of 43 banded birds were located post rat eradication. Saddleback mortality due to poisoning was <5% and may have been as low as 1%. This mortality was not sufficient to result in an increase in the annual overall mortality (Towns et al. 1993).

At a study site on Tiritiri Matangi, about 21% of the banded North Island saddlebacks died following the rat eradication using Talon® 20P at 10 kg/ha. Post rat eradication counts showed that this mortality was not detrimental to the saddleback population in the medium term (Veitch 2002c).

Davidson & Armstrong (2002) estimated that saddleback mortality immediately after the aerial application of Talon® 7-20 at 10 kg/ha on Mokoia Island was 45% for adults and 35% for juveniles. This mortality probably set population growth back by 1-2 years, but fecundity appeared to be unaffected when density effects were considered.

Five-minute bird counts undertaken before and after the rat eradication on Red Mercury Island (Talon® 20P pellet aerially sown at 15.5 kg/ha and some hand laying of Talon® 50WB) indicated saddleback population was unaffected by the poison drop (Robertson et al. 1993).

While saddleback were not monitored during the rat eradication on Kapiti Island (Talon® 7-20 at 9.0 kg/ha and 5.1 kg/ha), they had highly successful breeding season after the rat eradication, with the number of pairs increasing by 120% (Empson & Miskelly 1999).

Silvereye (*Zosterops lateralis***)**
Silvereye numbers did not change between five-minute bird counts undertaken before and after the two Pestoff 20R aerial drops at Tawharanui Regional Park Open Sanctuary in September and October 2004 (Lovegrove & Ritchie 2005).

Silvereye numbers did not change between five-minute bird counts undertaken before and after aerial application of Talon7-20 cereal baits containing 20ppm brodifacoum on Kapiti Island in 1996 (Empson & Miskelly 1999).

Five-minute bird counts undertaken before and after the rat eradication on Red Mercury Island (Talon® 20P pellet aerially sown at 15.5 kg/ha and some hand laying of Talon® 50WB) indicated the silvereye population increased post eradication (Robertson et al. 1993).

Skua (Brown) (*Stercorarius/ Catharacta lonnbergi*)
In 2010 and again in 2011 Pestoff 20R baits were applied to Sub Antarctic Macquarie Island to eradicate rodents and rabbits. In 2010 baiting was abandoned after prolonged bad weather ruined the prospects of completing coverage of the 12800ha island. About 10% of the island was baited in 2010. Following this bait application (during the period June 2010 to April 2011) 230 dead skua were recovered.
In May 2011 baiting resumed and covered the whole island with 2 complete applications and partial coverage by a third giving a combined bait application rate of 24 kg/ha. Despite attempts to mitigate further non-target deaths by retrieving poisoned rabbit carcasses and burying them, a further 282 skua were found dead (during the period May 2011 to April 2012) as they were better able to locate carcasses. This number would have likely been higher if Rabbit Haemorrhagic Disease (RHD) was not released on the island in February 2011 causing a massive decline in rabbit populations. These numbers include any dead birds found, not just those that died as a result of baiting activities, but some birds would have succumbed to the effects of poisoning at sea where their bodies would have not been recovered. It is estimated that there were 1030 breeding pairs of skua on Macquarie Island during the 2010/11 breeding season and the skua census taken in the 2011/12 summer confirmed a lower number of breeding birds, with a 40% drop in some study areas. (DSEWPAC 2012).

Approximately two thirds of the Enderby and Rose Island skua population died when two applications (18 days apart) of Wanganui #7 pellets were aerially sown at 5 kg/ha (10kg/ha in areas with high rabbit numbers), in 1993. One year later the population had not recovered, but by 2001 the population had recovered to near pre-poisoning levels (Torr 2002).

Tomtit (*Petroica macrocephala*)
Five-minute bird counts conducted prior to and post the rat eradication on Kapiti Island suggested that tomtit were not affected by the aerial application of Talon® 7-20 at 9.0 kg/ha followed, 25 days later, by 5.1 kg/ha (Empson & Miskelly 1999).

Tui (*Prosthermadera novaeseelandiae*)
Tui increased significantly in the five-minute bird counts undertaken after the two Pestoff 20R aerial drops at Tawharanui Regional Park Open Sanctuary in September and October 2004 (Lovegrove & Ritchie 2005).

Weka (*Gallirallus australis*)
All 15 banded western weka and more than 98% of the unbanded weka were killed on Nukuwaiata Island, following the use of Talon® 7-20 at 11 kg/ha in 1993 (Brown 1997a).

Empson & Miskelly (1999) reported that following the aerial distribution of Talon® 7-20 on Kapiti Island (9.0 kg/ha followed by 5.1 kg/ha 25 days later), mean weka call rates dropped significantly. Three months after the operation, weka were still less conspicuous than prior to the operation.

Weka were exposed to Pestoff 20R in July 2006 on Taukihepa Island where they had been introduced in the early 20th century. Plans to follow up poisoning by-kill of weka with hunting to eradicate them from the island were abandoned due to a higher than expected survival of weka post poisoning. (P. McClelland pers comm.).

Whitehead (*Mohoua albicilla*)
Five-minute bird counts conducted prior to and post the rat eradication on Kapiti Island suggested that whiteheads were less conspicuous following the aerial application of Talon® 7-20 at 9.0 kg/ha followed by 5.1 kg/ha 25 days later (Empson & Miskelly 1999).

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 including birds. Invertebrates, however, tend not to bio-accumulate Brodifacoum during one-off bait drops used in eradications; instead it passes through them reasonably quickly. Consequently, in those instances where ingestion occurs, affected birds tend to receive sub-lethal doses. Notwithstanding, occasional instances of secondary poisoning of birds have been reported in eradications using Brodifacoum (Dowding *et al.* 2006). These have occurred when birds have fed heavily on contaminated invertebrates, e.g., New Zealand Dotterels feeding on beach invertebrates that were feeding on Brodifacoum baits that these invertebrates had cached.

Small birds, such as silvereyes, sparrows and blackbirds, are considered more resistant to Brodifacoum than some larger birds, such as gulls and geese, although some large birds (e.g., Australasian Harriers) are also considered to be relatively resistant. Nevertheless, despite these distinctions, a variety of both large and small birds have been found dead from primary poisoning after the field use of Brodifacoum. However, to date there has been little evidence of any deleterious long-term effects of Brodifacoum exposure on bird populations in eradication operations. There have been no detectable declines in populations of silvereyes, kingfishers, plovers, or swallows following baiting operations involving Brodifacoum. In New Zealand, breeding success and survival of Kaka (a parrot), robins, Brown Kiwi, Kukupa (the New Zealand Wood Pigeon) and Kokako (Wattled-crow) have all been observed to increase after Brodifacoum use. Tawny Owl populations in Great Britain have been in decline since the early 1970s and this decline may have been accelerated since the introduction of second-generation anticoagulant rodenticides (SGARs), such as Brodifacoum, in the 1980s. Comparison of liver residues of SGARs of Tawny Owl populations in 1990-1993 and 2003-2005 demonstrated that the extent of exposure (% birds exposed, magnitude of residues) had not altered over time which, coupled with lack of evidence of any large-scale

mortality, indicated that there was little evidence for a role of SGARs in the decline of Tawny Owl populations in Britain over time.

Reptiles

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. This 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).

Several other studies show substantial increases in the abundance of reptiles since the removal of rodents. For example, the number of skinks on Korapuki Island in New Zealand increased 30 fold within 5 years of rats being removed (Towns 1994).

Two months after Talon® 20P was applied aerially at 17.5 kg/ha and Talon® 50 WB hand-laid at 1 kg/ha on Stanley Island, lizard pitfall capture rates were 29% higher than the previous best (Towns et al. 1993).

Three months prior to the aerial application of Pestoff Rodent Bait 20R at 12 kg/ha and 7 kg/ha on Taranga Island, 22 tuatara were captured and identified with PIT tags. In the 9 months following the bait application 50% of the marked tuatara were recaptured at least once. This recapture rate is similar to those observed in monitoring studies. A further 27 unmarked tuatara were also captured during this time (Mickelson 2012).

On Selvagem Grande Island in the eastern Atlantic, Pestoff 20R baits were hand laid in small piles on a 12.5m grid and placed in tube type bait stations targeting rabbits and mice. The project also followed up with some hand broadcast baiting using Pestoff 20R and Brodifacoum wax blocks in areas where mice persisted. The abundance of the gecko *Tarentola bischoffi* was monitored through the operation and for three years following. No change in abundance was detected immediately following the baiting but populations had increased significantly after three years (Olivera et al. 2010).

Brown (1997a) reported that the spotted skink (Oligosoma lineoocellatum) population on Nukuwaiata Island increased by 67% over the two years following the aerial application of Aerial Talon® 7-20 at 11 kg/ha to remove rat and weka.

Mammals

During the 1998 Codfish Island rat eradication (Pestoff® 20R aerially sown at 9.7 kg/ha followed, nine days later by 9.3 kg/ha and Pestoff® 20R in Novacoil bait stations on a 25 x 50m grid in key fernbird habitat), the wild bat population was monitored using radio tracking and video monitoring of roosts. Bats were also held in captivity on the island during the poison drop. There were no observable losses in either the wild population or the released captive bats, and the poison drop had no effect at a population level (McClelland 2002).

Apart from studies involving the deliberate administration of anti-coagulants to livestock so as to poison vampire bats (e.g., Thompson *et al*. 1972), there is little published information on the possible effects that baiting with Brodifacoum may have on bats. Daniel and Williams

(1984) attribute the death of a short-tailed bat to its consumption of a cyanide bait, and Eason and Spur (1995) suggest that short-tailed bats may feed on cereal-based pellets, thereby putting them at risk of primary poisoning.

Death of a number of short tailed bats in Pureora Forest Park, near Benneydale in NZ was attributed to a likely consumption of diphacinone used in a rodent control program. However, the Lesser Short-tailed Bat *Mystacina tuberculata* of New Zealand forages by walking on all fours on forest floors in search of insects, fruit, nectar and pollen (Science Alert 2009). It is not a typical bat, being one of only two world-wide bat species so adapted for walking so as to forage on the ground (Science Alert 2009).

7-3.3. NON-TARGET INVERTEBRATES (TERRESTRIAL)

Brodifacoum is not expected to have significant effects on invertebrates as they have different blood clotting systems to mammals and birds. While most studies of molluscs indicate a lack of impact of Brodifacoum (Booth *et al.* 2003; Bowie & Ross 2006), a study conducted in Mauritius reported mortality in two snail species after reports of snails consuming toxic baits (Gerlach & 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 & Ross 2006).

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, several orders of magnitude higher than proposed in this eradication proposal (Booth *et al.* 2003). 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. Non-target insects and millipedes in the Seychelles Islands consumed Brodifacoum bait with no apparent adverse effects. While some studies of molluscs indicate a lack of impact of Brodifacoum (Booth *et al.* 2003), a study conducted in the Seychelles indicated mortality in three snail species after reports of snails consuming toxic baits (Gerlach and Florens 2000). Eason and Wickstrom (2001) also cite a personal communication from David Merton suggesting that Brodifacoum may be toxic to molluscs.

7-3.3.1. PREDATORS

No studies are provided.

7-3.3.2. PARASITES

No studies are provided.

7-3.3.3. BEES

Not applicable as manner of use of products containing Brodifacoum makes exposure to honeybees very unlikely.

7-3.3.4. EARTHWORMS AND SOIL INVERTEBRATES

Molluscs

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 & 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 a *A. fulica* eating approximately 0.2 g of 0.02 g/kg Brodifacoum bait.

Gerlach & 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 & 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.

Annelids

Booth et al. (2003) used introduced pasture earthworms (*Aporrectodea calignosa*) as a model for native earthworms in pen trials. Brodifacoum was toxic to the worms at 500 μg (micrograms of poison per gram of soil). These concentrations are equivalent to 25 kg of 0.02 g/kg Brodifacoum bait being distributed into 1 kg of soil which is several orders of magnitude higher than the likely levels of Brodifacoum that would be found in soil directly below the bait at the application rate proposed for the LHIG REP. It is extremely unlikely these concentrations would occur in the field. Baits (pellet size 10 mm) are distributed at about 0.6 baits per square metre, so most soil would not have any Brodifacoum residues at all.

Arthropods

Craddock (2003) used locusts to model **weta** in pen trials. No toxic effects could be determined following exposure to Pestoff possum baits containing 0.02 g/kg Brodifacoum for six weeks. An undescribed species of **weevil** colonised a bag of toxic bait during this experiment and were able to reproduce from an estimated population of 20 to about 1500 individuals over a period of 2 months living solely on Brodifacoum bait.

Booth et al. (2001) orally dosed **large-tree weta** with up to 62.5 µg/g Brodifacoum. No mortality was observed over 3 weeks. Bowie and Ross (2006) allowed three adult **cave weta** (*Pleioplectron simplex*) and five ground weta (*Hemiandrus spp*) held in captivity, to feed freely for 60 days on Talon 50WB® wax baits containing 0.05 mg/kg Brodifacoum. Mortality observed over the study period was not significantly different between treatment and non-treatment groups, 4 of 8 died in the treatment group and 2 of 7 in the non-treatment group fed non-toxic cereal baits.

Bowie and Ross (2006) compared the mortality of **carabid beetles** (*Laemostenus companatus*) held in captivity and allowed to feed freely for 40 days on Talon 50WB® wax baits containing 0.05 mg/kg Brodifacoum. No mortality was observed over the study period in treatment or non-treatment groups.

No effect was found on ground weta (*Hemiandrus* spp) and cave mortality observed over the study period was not significantly different between treatment and non-treatment groups. The mean weight of surviving weta in both groups declined over the period but the difference in weight loss between groups was not significant (Bowie & Ross 2006)

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.

Wetapunga (*Deinacrida heteracantha*) counts doubled over five years following the eradication of kiore on Hauturu Island in 2004 using aerially applied Pestoff 20R baits (Green et al 2011).

Large-headed tree weta numbers on Nukuwaiata Island increased by 50% in the first year after the aerial application of Aerial Talon® 7-20 at 11 kg/ha. By the second year the weta numbers had increased 80% (Booth et al. 2001)

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).

Invertebrates monitored on Kapiti Island using pitfall trapping a year before and four years after a rat eradication using aerially applied cereal pellets containing 20ppm Brodifacoum. Invertebrate species richness was found to decline gradually in the years following the eradication, although no immediate effect attributable to toxicant induced mortality could be determined for the groups studied (Sinclair et al 2005). The authors suggest an increase in insectivorous birds and seasonal variations confounding results could explain the changes observed.

Green (2002) studied invertebrate populations using pitfall trapping on Tiritiri Matangi Island for three months before and five years after rat eradication using aerially applied Brodifacoum baits. He found capture rates of several large (>10mm) species increased during the study, including ground weta and prowling spiders.

There are indications that molluscs outside of New Zealand may be susceptible to Brodifacoum. Gerlach & 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 in 72 hours. This is equivalent to a *P. silhouettanus* eating between 0.5 and 10 g of 0.02 g/kg Brodifacoum bait or between 0.2 and 4g of 0.05 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 a *A. fulica* eating approximately 0.2 g of 0.02 g/kg Brodifacoum bait or 0.8 g of 0.05 g/kg Brodifacoum bait. However, published studies of other species of

molluscs indicate a lack of impact of Brodifacoum (Booth *et al.* 2003) although there are anecdotal reports of mollusc fatalities due to Brodifacoum (Eason and Wickstrom (2001).

Gerlach & 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.

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.

Observations of baits in the field during non toxic bait trials conducted on LHI in 2013 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 (LHIB, 2007).

7-3.3.5. SOIL MICRO-ORGANISMS

No information is available. Brodifacoum is unlikely to have significant adverse effects on soil micro-organisms (low-moderate application rates are not expected to have any adverse effects.)

During the eradication of rats on Little Barrier Island in 2004, soil samples were collected from directly under decaying Pestoff 20R baits. Samples were taken 56 and 153 days after the aerial bait drop. Those in grassland areas had residues of 0.2 μg/g 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.

7-3.3.6. OTHER

No other information is available.

7-3.4. NON-TARGET VEGETATION

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. No further consideration of Brodifacoum impact on plants is considered warranted in this module.

7-3.4.1. RESULTS FROM LABORATORY TESTS

A literature search failed to find published or verified unpublished data regarding plant uptake or persistence.

Brodifacoum is not herbicidal, and due to its poor solubility in water it is not likely to be significantly taken up by the roots of plants. It is not expected to have any adverse effects on vegetation.

7-3.4.2. OBSERVATIONS FROM FIELD TRIALS/EFFICACY TESTS

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).

7-3.5. NON TARGET AQUATIC ORGANISMS (FRESHWATER AND MARINE)

7-3.5.1. ACUTE (FISH, MICROCRUSTACEAN, ALGAE)

Lethal Concentration (LC), referring to the concentration of a chemical in a medium such as air or water, is the measure of the toxicity of that chemical to a particular test subject. Typically it is defined as LC_{50} for exposure for a certain amount of time; the 50 indicating the concentration likely to kill 50% of those organisms exposed to it.

LETHAL CONCENTRATIONS (LC50 mg/L) OF BRODIFACOUM FOR A RANGE OF FISH AND AQUATIC INVERTEBRATES (from Broome et al, 2016)

SPECIES	LC50 mg/L	REFERENCES
Fish	Range: 0.02 - >10.0 mg/L	
Bluegill sunfish (*Lepomis macrochirus*)	0.12 (96-hour LC50)	USEPA (2005)
	0.165 (96-hour LC50)	Eason & Wickstrom (2001)
Crucian Carp (*Carassius carassius*)	>10.0 (24 hour LC50)	USEPA (2005)
	>10.0 (48 hour LC50)	USEPA (2005)
	1.0 (72 hour LC50)	USEPA (2005)
	1.0 (96 hour LC50)	USEPA (2005)
	1.0 (7 day LC50)	USEPA (2005)
	1.0 (14 day LC50)	USEPA (2005)
	0.1 (21 day LC50)	USEPA (2005)
Common carp (*Cyprina carpio*)	>10.0 (24 hour LC50)	USEPA (2005)
	>10.0 (48 hour LC50)	USEPA (2005)
	1 (72 hour LC50)	USEPA (2005)
	1 (96 hour LC50)	USEPA (2005)
Cyprinid (*Leucaspius delineatus*)	>10.0 (24 hour LC50)	USEPA (2005)
	>10.0 (48 hour LC50)	USEPA (2005)
	1.0 (72 hour LC50)	USEPA (2005)
	1.0 (96 hour LC50)	USEPA (2005)

SPECIES	LC50 mg/L	REFERENCES
	1.0 (7 day LC50)	USEPA (2005)
	0.1 (14 day LC50)	USEPA (2005)
	0.1 (21 day LC50)	USEPA (2005)
Rainbow trout (*Oncorhynchus mykiss*)	0.155 (24-hour LC50)	Eason & Wickstrom (2001)
	0.051 (96 hour LC50)	Eason & Wickstrom (2001)
	0.02 (96 hour LC50)	USEPA (2005)
	0.025 (96 hour LC50)	USEPA (2005)
	0.04 (96 hour LC50)	(Anonymous 2009)
Tench (*Tinca tinca*)	>10.0 (24 hour LC50)	USEPA (2005)
	>10.0 (48 hour LC50)	USEPA (2005)
	1.0 (72 hour LC50)	USEPA (2005)
	1.0 (96 hour LC50)	USEPA (2005)
	1.0 (7 day LC50)	USEPA (2005)
	0.1 (14 day LC50)	USEPA (2005)
	0.1 (21 day LC50)	USEPA (2005)
Aquatic Invertebrates	Range: 0.34 - >10.0 mg/L	
Daphnia (*Daphnia magna*) 1st instar	1.0 (24 hour LC50)	Eason & Wickstrom (2001)
	0.34 (48 hour LC50)	Eason & Wickstrom (2001)
Adult	0.98 (48 hour LC50)	USEPA (2005)
Tubificid worm (*Tubifex tubifex*)	>10.0 (24 hr LC50)	USEPA (2005)
	>10.0 (48 hr LC50)	USEPA (2005)
	>10.0 (72 hr LC50)	USEPA (2005)
	1.0 (96 hr LC50)	USEPA (2005)
Mosquito larvae (*Aedes aegypti*)	8.23 (24hr LC50)	Jung & Moon (2011)

Brodifacoum is considered to be toxic to aquatic organisms, but at concentrations in their environment many orders of magnitude greater than those that could be associated with the small amount of bait that may be deposited in the sea as the result of rodent baiting operations conducted on nearby land. In the marine and aquatic environment the dosage rate of 0.4 g/ha

Brodifacoum for the LHI REP equates to 0.4 g /1.5ML (1 ha of water 15cm deep) or 0.2ug/L which is orders of magnitude below the LC_{50} for the most sensitive species above.

Howald et al. (2005) showed that when baits were applied aerially to steep cliffs, (application rate of 15kg/ha) a mean of only 72 baits over 500 m stretch of coast (~2ha) ended up in the water. This would equate to less than 0.5% out of the approximate 15,000 baits applied over that area ended up in the sea.

Using a similar percentage of bait that bounced off the cliffs and ended up in the sea in the LHI REP situation, a more likely predicted environmental concentration in the marine environment would be in the order of 0.01ug/L.

7-3.5.2. SHORT-TERM (SUB-CHRONIC)

No short-term studies are presented, but a log P_{OW}: 8.5 indicate potential for bioaccumulation in fish species (appreciable bio-accumulation potential is to be expected as log P_{OW} >3).

7-3.5.3. SPECIAL STUDIES – CHRONIC, SEDIMENT, SIMULATED OR ACTUAL FIELD TESTING

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 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 were collected from 3 sites. These were batched to form 9 mussel (*Mytilus edulis*) 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 & 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 0.001ppm. 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 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 & 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 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 25hours 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 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 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 & 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 & Miskelly 1999).

Two of 5 pipi (*Paphies australis*) samples taken within 72 hours of aerial application of baits containing 20ppm Brodifacoum to the Ipipiri Islands in the Bay of Islands 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 & 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 & 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 & Wegmann 2010).

Nine of ten black spot sergeant fish (*Abudefduf sordidus*) collected live following aerial bait application of Bell Labs 25w bait were found to contain residues ranging from 0.05 to 0.315 ppm (whole fish). Two applications of bait (80kg/ha and 75kg/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 tidepool 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 urchin.

Following aerial application of baits on Kaikoura Island near Great Barrier Island 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 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 0.02ppm Brodifacoum, perhaps because a toxic bait was deliberately dropped into the rock pool it was living in (Fisher et al. 2011).

Testing of liver and gut contents from two eels found dead in a Southland 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).

The most dramatic demonstration of the relatively innocuous effects of Brodifacoum in the marine environment comes from an accidental discharge of 18 tonnes of Brodifacoum bait (20 mg/kg Brodifacoum)from a truck accident in an area that includes wave-exposed rock reefs, headlands and beaches located on the South Island of New Zealand in 2001 (Primus *et al.* 2005). The bait in this incident was a cereal-based pellet formulated with a water-soluble green dye and contained 20 parts per million (ppm) Brodifacoum so it is identical to that proposed for LHI. This truck accident resulted in 18 tonnes of bait containing 360 g of Brodifacoum entering the sea at a point source. Bait entering the water quickly began to soften and disintegrate; and a cloudy green plume developed because of the release of dye and particulates from the baits. The plume covered an area of 100 m wide by 300-700 m long, and persisted for approximately 24 hours (Primus *et al.* 2005).

A monitoring programme was commenced immediately, and was initially undertaken by the local agency of the environment department and then by the New Zealand Ministry of Health. Samples were taken shortly after the spill and then at regular intervals over the following 21 months. Water and sediment samples were collected by divers from locations at the spill site and up to 400 metres north and south of it. Water samples were collected on each of the two days following the spill, at 10 and 11 days, and at one month and six weeks afterwards; and sediment samples were collected at two, nine and 14 days after the accident. Marine invertebrates sampled included abalone, spiny rock-lobster, sea urchins, limpets, mussels and starfish; and fish sampled included herring, butterfish and scorpion fish. Of the marine samples tested, Brodifacoum was only found to persist in abalone, limpets and mussels, consequently these organisms were collected over a nine-month period. Tissue samples of any dead animals observed in the area were also analysed.

The maximum acceptable concentration of Brodifacoum in food for human consumption in New Zealand is 0.001 parts per million (i.e., 1 part per billion) (New Zealand Maximum Residue Limit (MRL) of the Agricultural Compounds Mandatory Food Standard 1999 as amended June 2001); the method of detection limit (MDL) adopted to analyse the spill samples was set below this limit at 0.02 parts per billion (ppb).

Measurable concentrations of Brodifacoum were detected in the water column at the immediate spill location within 36 hours of the spill, but these residues declined to below detectable concentrations (< 0.020 ppb) within three days (Primus *et al.* 2005). Brodifacoum has an estimated very low water solubility of <10 ppm at pH 7 at 20^{O}C (US EPA 1998). Given the non-polarity of Brodifacoum molecules, and the ionic strength of seawater at 12-14 ^{O}C (the average temperature of the ocean at the time of the spill) the solubility was probably in the low ppb range, therefore a significant portion of the Brodifacoum is likely to have remained as particulate matter adsorbed to bait particles or other organic material (Primus *et al.* 2005).

One of seven sediment samples collected one day after the spill was positive for Brodifacoum (0.060 ppm). Other sediment samples collected at day 9 after the spill were below the MDL, as were seaweed samples collected 64 and 91 days after the spill. A single starfish collected at day 16 had residues <0.020 ppm, as did 13 crayfish and one crab sampled between eight and 14 days after the spill at the point source. A butterfish sampled nine days after the spill had residues of 0.040 ppm in the liver and 0.020 ppm in the gut, although muscle tissue was below MDL. Residues in other fish sampled between days 14 and 16 were all less than 0.020 ppm. Two seals, two Black-backed Gulls and a cormorant were found dead in the area following the spill but necropsies found no sign of anticoagulant toxicity, and no tissues sampled from carcasses contained detectable Brodifacoum.

A butterfish (*Odax pullu*) sampled 9 days after the spill had Brodifacoum residues of 0.040ppm 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 <0.020ppm. 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.

Primus *et al.* (2005) concluded that initial high environmental Brodifacoum concentrations in the immediate locality of the spill site were probably sufficient to cause mortality of some invertebrates, particularly abalone, and fish. The greatest exposure of marine invertebrates occurred within 100 metres of the spill location, but only minor exposure was observed in the 100-300 metre range from the spill location.

The above study by Primus *et al.* (2005) dealt with the effect of 18 tonnes of bait entering the sea at a single point, and it represents a worst-case scenario. Other studies have examined the fate of baits, either toxic or non-toxic, that enter the sea in line with normal aerial baiting operations where bait is dispersed from a hopper slung beneath a helicopter.

In 2001 a programme was instigated to eradicate the introduced Ship Rat from the three islets that comprise Anacapa Island, in the United States of America. The steepness and ruggedness of the three islets dictated the need for the aerial application of the bait which was cereal pellets containing Brodifacoum at 25 ppm (Howald *et al.* 2005). Aerial baiting with Brodifacoum was seen as the only alternative that "offered a reasonable probability of eradicating rats and that any negative impacts would be short-term and not significant to native populations" (Howald *et al.* 2005).

The cliff faces were treated with the hopper fitted with a deflector that spread bait to one side only, preventing significant bait spread into the marine ecosystem. Bait was broadcast at 15 kg per hectare.

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 (Howald *et al.* 2005). 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. No Brodifacoum residues were detected in water samples collected (at 24 and 48 hours post-drop). Mussels and crabs were also sampled at days 15 and 30 post-application, as were tide-pool sculpins, a carnivorous fish species of the Cottidae family, at 15, 30 and 90 day post-application. No Brodifacoum was detected in any of these samples.

Two baiting applications using Brodifacoum-laced cereal pellets, the first drop at 9 kg/ha, the second one at 5.1 kg/ha, have also been undertaken on Kapiti Island, a rugged 1,965 ha island off the coast of New Zealand (Empson and Miskelly 1999). To determine the effect such baiting might have on the marine environment, the Department of Conservation monitored reef fish populations around Kapiti Island. Monitoring took place at three sites which could potentially have been affected by accidental application of poison baits to the near-shore sub-tidal environment due to the steepness of the nearby land (Cole and Singleton 1996). Two species were chosen for sampling: the Spotty *Notolabrus celidotus*; and Blue Cod *Parapercis colias* which is a bottom-dweller and predator of reef fish assemblages. Spotties are known to scavenge on a wide variety of food types, and were expected to feed on baits if any fell into the sea (Empson and Miskelly 1999). Cole and Singleton (1996) concluded: …"*The surveys provide no evidence that the fish densities had been affected by the poison application. Initial and final survey densities of both species at all three sites were similar, and our incidental observations of other fish species did not suggest any alterations in the density of those species either. Further, in the more than 20 diver hours spent underwater in the study sites, we observed no dead or moribund organisms, nor any changes to the benthic assemblages suggestive of poison entering food webs*."

Aquarium trials were also used to assess the risk to three marine fish species found in the waters off Kapiti (Empson and Miskelly 1999).The fish selected were Blue Cod, Spotty and Variable Triplefin (*Forsterygion varium*). Fish were held in experimental fish tanks for 24 hours without food then assigned to the following treatments:

- Treatment 1: fish were held solitarily, exposed to a single non-toxic bait for one hour before being transferred to specific communal holding tanks for 23-31 days;
- Treatment 2: fish were held solitarily, exposed to a single toxic bait for one hour before being transferred to specific communal holding tanks for 23-31 days;
- Treatment 3: fish were held in groups of four or five, exposed to three non-toxic baits for one hour before being transferred to specific communal holding tanks for 23-31 days; and
- Treatment 4: fish were held in groups of four or five, exposed to three toxic baits for one hour before being transferred to specific communal holding tanks for 23-31 days.

Once transferred to the communal holding tanks the fish were fed mussel flesh. At the end of the trial the fish were killed and examined internally for signs of Brodifacoum poisoning, and livers from 15 were analysed for the presence of Brodifacoum.

None of the three species of fish tested in the various trials showed much interest in the bait but all readily consumed the mussel flesh upon transfer to the holding tanks. However, of the 60 fish tested, two had ingested enough bait to kill them while two others that were examined at the end of the trial were found to have clinical signs of Brodifacoum poisoning. Neither of these latter two fish had been observed to eat toxic baits so it is assumed that they had absorbed Brodifacoum through their skin or gills. Such absorption in the wild is unlikely as "the toxin would be quickly and considerably diluted" (Empson and Miskelly 1999). The results indicated that populations of three of the commonest fish species around Kapiti Island were unlikely to be significantly affected by the poisoning operations (Empson and Miskelly 1999) as only a small proportion of the fish that encountered the bait consumed it; and those that died from absorbing the poison through their skin or gills, did so because they were exposed to concentrations of Brodifacoum far in excess to that which may result from bait inadvertently entering the sea during the baiting of the adjacent land.

Aerial baiting with Brodifacoum in cereal pellets conducted in the Gulf of Mexico on two islands also did not result in harm to marine life (Samaniego-Herrera *et al*. 2009). As with the Anacapa Island baiting of cliffs, a lateral deflector was installed on the bucket to narrow the

angle of bait dispersion and minimise the amount of bait spread into the ocean (Samaniego-Herrera *et al.* 2009). The application rate on one island was 24.4 kg/ha, and on the second it averaged 17.6 kg/ha (note the significant difference between these rates and the proposed application rates for LHI of 12 and 8 kg/ha).

One of the pre-baiting trials conducted on the islands involved the deliberate dispersal of non-toxic bait into the marine environment. The observation of how fish reacted to cereal baits was confined to waters that were immediately adjacent to the islands as it was thought unlikely that bait would land in water more than 10 m offshore (Samaniego-Herrera *et al.* 2009). Seven underwater observation sessions were conducted. At each session a diver was stationed 3-5 metres from shore and made observations along the water column down to 15 m deep. He recorded the species present and their reaction to non-toxic bait pellets that were thrown into the ocean. Reactions were categorised as: a) no consumption (pellet ignored); b) inspection but not consumption; and c) consumption. The only reactions recorded for all of the 23 species from 11 families observed were those involving "no consumption". Only one individual *Ophioblennius steindachneri* from more than a dozen co-specifics took a bait but it spat it out (Samaniego-Herrera *et al.* 2009).

It appears that the deflector was successful in minimising the number of bait pellets broadcast into the ocean because, following the baiting application, no traces of pellets were found at the intertidal and sub littoral zones of each island. No signs of poison-caused death were found in marine species, and marine invertebrates and fish communities did not appear to be negatively affected by the low amount of bait that may have fallen into the water (Samaniego-Herrera *et al.* 2009-).

Tests were also conducted on Lehua Island in Hawaii in 2004 in order to address the question of whether fish would eat bait pellets (U.S. Fish and Wildlife Service and Hawai'i Department of Land and Natural Resources 2008). While nine of the 21 species routinely inspected bait pellets in the water, none of the nearshore fish species that were observed actually consumed the bait. Results are presented in Appendix 4.

PART 7-4: RISK ASSESSMENT

7-4.1. SUMMARY

This section assesses the risk to non target species on the LHIG from the proposed LHI REP, considering the fate in the environment and environmental exposure discussed in the previous sections. The risk to non-target species during an eradication programme will be 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.

Whilst many species of birds are found on the island group, the vast majority of species are considered to be at low risk of primary or secondary poisoning following use of Brodifacoum bait as they show no interest in the baits, or feed at sea and hence unlikely to consume baits or will not be present during the baiting programme.

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 (LHIB, 2007). These baits contained a fluorescent dye that glowed under ultraviolet light.

Eleven species of birds were examined during the study: Lord Howe Woodhen, Lord Howe Island Currawong, Lord Howe Island Silvereye, Lord Howe Island Golden Whistler, Emerald Ground-dove, Purple Swamphen, Buff-banded Rail, Sacred Kingfisher, Australain Magpie lark, Common Blackbird and pacific Black Duck-Mallard hybrid. Woodhen, Buff-banded Rail, Common Blackbird and the duck all produced fluorescing faecal samples, indicating that they had consumed bait. Woodhen and ducks were also observed feeding directly on baits. All other birds showed no indication of having consumed bait, either directly or indirectly through their prey. Although currawongs did not consume baits they are vulnerable to secondary poisoning when feeding on dead or dying rodents that have taken baits.

Emerald Ground-doves presented with baits consumed red baits and brown baits, but completely ignored green baits. This finding accords with the view that colouring the bait green affords protection for many bird species.

Native species such as the Lord Howe Woodhen, Purple Swamphen, Black Duck and Buff-banded Rail, and exotic species such as the Common Blackbird and the Mallard are considered to be at risk of primary poisoning, while the Australian Kestrel, Masked Owl and Lord Howe Currawong are at risk of secondary poisoning as they may feed on dying or dead rodents. To mitigate the threat posed by the baiting, a large proportion of the population of the endemic woodhen and currawong will be housed in aviaries during the baiting and for several months after baiting to ensure that Brodifacoum residues have diminished to a level that would no longer pose a threat to free-ranging woodhen or currawong.

No attempt will be made to protect exotic species or the Masked Owl. This owl was introduced to LHI in the 1920s in an attempt to control rodents. The LHI Masked Owl were until recently believed to be the Tasmanian subspecies (*Tyto novaehollandiae castanops*), however genetic testing has found significant divergence of the LHI population with *T. n. castanops*, suggesting hybridisation with the mainland subspecies (*T. n. novaehollandiae*) (Hogan Et al 2013). This hybridisation and loss of genetic integrity would exclude translocation of the LHI Masked Owl to Tasmania. A recent study has shown that rodents currently provide the Masked Owl's main prey base on the Island, supplemented by occasional predation on native birds. During the rodent eradication it is expected that some

owls are likely to succumb to secondary Brodifacoum poisoning by ingestion of poisoned rodents. To avoid any remaining owls switching to a diet comprised solely of native species in the absence of rodents, it is proposed to eradicate the remaining owls via hunting or trapping before, during and after the baiting program.

A small number of deaths among the Australian Kestrel, Purple Swamphen, Black Duck and Buff-banded Rail populations are possible. Although unfortunate, these losses are deemed an acceptable cost in eradicating rodents, which are a major threat to at least 13 bird species, two reptiles, three invertebrates, 51 flowering and non-flowering plants and 12 vegetation communities (DECC, 2007). The four aforementioned native bird species at risk are nationally common and relatively recent arrivals to the LHIG. Anny losses are likely to be offset increased reproductive output of survivors following the removal of rats and mice and possibly immigration. Rodent eradication is the single most effective action that can be taken to conserve LHI's wildlife.

During the trial conducted on LHI, some ants, slugs, cockroaches and snails (not Placostylus) were observed feeding on baits (LHIB, 2007). For each of these groups only a small proportion of individuals had consumed bait; consequently it is unlikely that any of the birds on LHI will consume contaminated invertebrates exclusively to the point where there is a risk of secondary poisoning from insects.

The only known native mammal present on Lord Howe Island is the Large Forest Bat (*Vespadelus darlingtoni*). It is considered to be at minimal risk of either primary or secondary poisoning.

The only two native reptiles on the island the LHI skink (Cyclodina lichenigera) and LHI gecko (Christinus guentheri) are currently heavily predated by rodents. Both species occur on the main island and on many offshore islets around LHI as well as on Norfolk Island. These species are considered to be at low risk of primary or secondary poisoning, and are likely to substantially increase in abundance following the removal of rodents.

Brodifacoum is not expected to have significant effects on invertebrates including the *Threatened* Lord Howe Placostylus or Flax Snail as they have different blood clotting systems to mammals and birds. During trials conducted on LHI, some ants, slugs, cockroaches and snails (not Placostylus) were observed feeding on baits (LHIB, 2007). For each of these groups only a small proportion of individuals had consumed bait.

Marine species (including pelagic feeding sea birds) are not considered to be at risk from primary or secondary poisoning given the low-moderate application rate of Brodifacoum (0.4 g/ ha) for the LHI REP, rapid bait breakdown, low solubility, high dilution factor in the marine environment, and one off eradication. Some individual fish may directly consume pellets that accidentally enter the marine environment however it is considered unlikely that they will receive a lethal dose. Bioaccumulation in local marine species would be of a sufficiently low magnitude as to not present a significant risk. Similarly marine species are not considered at risk of poisoning through water contamination given the very low concentrations of Brodifacoum (0.2ug/L) likely to enter the marine environment and very low solubility. The risk will be further mitigated through the use of deflector buckets, handing baiting within the Lagoon foreshore area and baiting above the high water mark to minimise bait entry into the water. Therefore detailed assessment of marine species is not warranted in this Module.

7-4.2. TERRESTRIAL VERTEBRATES (WILD)

The Lord Howe Group was recognised as being of World Heritage importance in part due to the number of endemic species it contains. Although most of this endemism relates to plant and invertebrate species, there are, nonetheless, four endemic vertebrate species or sub-

species currently on LHI. In addition to these endemic vertebrate fauna, there have been over 150 other protected vertebrate species recorded for the LHIG. Some of these species were present before LHI was settled in 1833, others have since colonised the island group and some species have been introduced. Species of chief concern in this document will be those listed in the *Threatened Species Conservation Act 1995* (the TSC Act) or the *Environmental Protection and Biodiversity Conservation Act 1999* (the EPBC Act); the former being NSW state legislation, the latter an act of the Commonwealth of Australia.

The relevance of the proposed rodent eradication to most of the local native bird species not listed in either of the aforementioned acts but covered by the *National Parks and Wildlife Act 1974* and the *Lord Howe Island Act 1953* will also be outlined (Appendix 1). Omissions, however, will be made concerning introduced native species such as the Grass Skink (*Lampropholis delicata),* Eastern Snake-necked Tortoise *(Chelodina longicollis)* and Bleating Tree Frog (*Litoria dentata*), none of which is regarded as *Endangered* or *Vulnerable*. Possible effects of the rodent eradication on exotic species such as the Common Blackbird are also not considered in any great detail.

Vertebrates on the LHIG include three freshwater fish species, four terrestrial reptiles (including two introduced species), one amphibian (introduced), one bat, 20 resident landbirds (introduced and exotic species), 12 regularly visiting migratory shorebirds, 14 breeding and three regularly visiting seabirds, and more than 100 vagrant bird species (Hutton 1991; McAllan *et al*. 2004). one

7-4.2.1. RISKS TO BIRDS

The most obvious fauna component of the LHIG is the bird life. The LHIG is a major seabird breeding location, possibly having more species breeding in higher numbers than anywhere else in Australia (DECC, 2007). Nine endemic landbirds (species or sub-species) have become extinct since people settled on LHI (Hutton *et al.* 2007).

Many records for bird species on the LHIG refer to species that rarely visit the island group, and such visits typically involve only a small number of individuals. These are considered vagrants, rare or irregular visitors. This includes more than 40 of the *Migratory* and/or *Marine* bird species listed in the EPBC Act that have been recorded for the LHIG. 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 risk by the proposed action.

In most cases the low overall number of individuals involved, their diet or the small possibility that they will be in the vicinity during the baiting operation strongly suggest that these species will not be significantly harmed by the eradication. Information on these species is contained in Appendix 2a. There are 19 regular visitors to the LHIG that are listed in the EPBC Act, Twelve of these will not be in the area when the eradication is proposed to take place so, consequently, they will not be harmed by the baiting. These 12 are also listed in Appendix 2a.

The *Migratory, Vulnerable* or *Endangered* bird species that are residents or regular visitors to the LHIG at the time of the proposed baiting are outlined in Appendix 2b and dealt with in detail below. Exotic or introduced bird species at risk include ducks (mostly hybrids of the native Pacific Black Duck (*Anas superciliosa*) and the exotic Mallard (*A. platyrhynchos*)), feral Pigeon or Rock Dove (*Columba livia*), domesticated Chicken (*Gallus gallus domesticus*), Common Blackbird (*Turdus merula)* and Masked Owl. No action will be taken to mitigate the potential effects of poisoning on these species.

Bar-tailed Godwit *Limosa lapponica*
Listed as *Marine Species* and *Migratory Wetland Species* under the EPBC Act.

The Bar-tailed Godwit is a trans-equatorial migratory shore-bird that breeds in Siberia and Alaska during the northern summer before flying to Australia and New Zealand (Lane 1987). It feeds and rests on sandy beaches and mudflats (Lane 1987). The godwit's diet consists of crustaceans, molluscs, worms, insects and some plant material so risk of primary poisoning is considered low. The main aggregations of godwits in Australia occur at two sites in Western Australia where over 99,000 birds have been counted (Lane 1987). Nationwide, the population is estimated to be 165,000 (Watkins 1993). At 5,050, the number of godwits visiting New South Wales is relatively small (Lane 1987). Only a very small number of godwits (20-50 birds – LHIB records) visit LHI over summer, and most of these leave before the beginning of winter. Some young non-breeding birds (<5) may over-winter on LHI.

Dotterels *Charadrius obscurus* in New Zealand have succumbed to secondary poisoning following rodent eradication using Brodifacoum (Dowding *et al*. 2006). The poisoning was probably the result of the dotterels eating crustaceans, mostly sandhoppers (*Talorchestia* sp.), that had been feeding on the poison baits that they had cached. These crustaceans congregated under beachcast seaweed, where they were found by the dotterels. As such, it is possible that those very few godwits that over-winter on LHI are also potentially at risk of secondary poisoning if they eat crustaceans, such as sandhoppers, that have fed heavily on pellets although the risk is considered very low.

Mitigation of the Proposed Rodent Eradication

Baits will be distributed above the Mean High Water mark where ever possible to minimise baits on beaches. Due to this mitigation measure and the low number (approximately five or less) of Bar-tailed Godwits likely be on LHI in June - August, the proposed eradication programme will not result in significant harm to the species. If ill birds are observed, they can be caught and treated with vitamin K.

Brown (or Common) Noddy *Anous stolidus*

Listed as a *Migratory* and *Marine* species under the EPBC Act.

This species has a world-wide distribution, except for the west coast of South America (Hutton 1991). It breeds on numerous islands in the tropics and sub-tropics (ibid). The LHIG is one of its most southerly breeding locations (Hutton 1991). Breeding sites here are North Head, Mt Eliza, Malabar, Blinky Beach, King Point, Mutton Bird Point, Mutton Bird Island, the Admiralty Islands and Balls Pyramid as well as several other smaller off-shore islands (DECC 2007). The population size on the LHIG is somewhere between 100 and 10,000 pairs (Hutton 1991). Although present mainly from August (Hutton 1991) or September (McAllan *et al*. 2004) to May, Brown Noddies have been seen on the LHIG in all months (NSWBA cited in McAllan *et al.* 2004). Noddies leave their roosting sites early in the day to go to sea where they surface-skim the surface for fish and small crustaceans (Hutton 1991). They return to land late in the day (ibid). Egg laying commences in October.

Risk Posed by the Proposed Rodent Baiting

Because the birds feed at sea and given the low risk of bioaccumulation in the marine environment, the population is not at risk of primary or secondary poisoning.

Flesh-footed Shearwater *Ardenna carneipes*

Listed as *Vulnerable* under the TSC Act.
Listed as *Migratory* and *Marine* under the EPBC 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 late August (Hutton 1991) or 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.

The species is subject to predation by rodents on LHI.

Risk Posed by the Proposed Rodent Baiting
Because the birds feed at sea and given the low risk of bioaccumulation in the marine environment, the population is not at risk of primary or secondary poisoning.

Mitigation of the Proposed Rodent Eradication
No mitigation is required.

Grey Ternlet *Procelsterna cerulea*
Listed as *Vulnerable* under the TSC Act
Listed as *Marine Species* under the EPBC 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 believed to be absent from the other islands in the LHIG) (DECCW 2009);

Risk Posed by the Proposed Rodent Baiting
Because the birds feed at sea and given the low risk of bioaccumulation in the marine environment, the population is not at risk of primary or secondary poisoning.

Mitigation of the Proposed Rodent Eradication
No mitigation is required.

Little Shearwater *Puffinus assimilis*
Listed as *Vulnerable* under the TSC Act
Listed as *Marine Species under* the EPBC Act.

In the Southern Hemisphere the distribution of the Little Shearwater in the Southern Hemisphere is from the mid South Pacific Ocean, around the southern coastline of Australia, across the Indian and South 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.

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 rats at the nesting grounds (DEC 2005);

Risk Posed by the Proposed Rodent Baiting
Because the birds feed at sea and given the low risk of bioaccumulation in the marine environment, the population is not at risk of primary or secondary poisoning.

Mitigation of the Proposed Rodent Eradication
No mitigation is required.

Lord Howe Island Currawong *Strepera graculina crissalis*
Listed as Vulnerable under both the EPBC and TSC acts.

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 (DECC 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 Office of Environment and Heritage 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 (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).

Mitigation of the Proposed Rodent Eradication
The proposed rodent eradication poses a significant threat to currawongs. 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 approximately October, 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 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 significant risk.

The stability displayed in the present population size and the presence of non-breeding currawongs during the breeding season (a result of a lack of availability of unoccupied breeding territories), indicate that LHI is at carrying capacity for currawongs. If so, the potential death of a sizeable proportion of the at-large (i.e., non-captive) currawong population from poisoning due to the proposed rodent eradication 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 rats and mice 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 currawongs (e.g., forest fruits, seeds, invertebrates, reptiles and small birds).

The captive facility will be located on LHI and will be managed by a highly experienced aviculturist most likely 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. One critical lesson learnt from this trial was how currawongs reacted to being confined with or near other currawongs during the breeding season.

As stated above, approximately 50-60% of the currawong population will be placed into captivity during the eradication. Holding currawongs 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 affect the entire population, and given that currawongs are long-lived, such disruption is not expected to result in long-term harm to the population. On the contrary, the eradication of rodents will lead to an increase in the overall feed supply available to the currawongs.

Lord Howe Island Golden Whistler *Pachycephala pectoralis contempta*
This sub-species, endemic to LHI, is listed as *Vulnerable* in the TSC Act.

It 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).

Risk Posed by the Proposed Rodent Baiting
The diet of the whistler is comprised of invertebrates. It was not observed to eat non toxic pellets so it is not considered at risk of primary poisoning. It may be exposed to Brodifacoum by eating insects that have fed on pellets but few, if any, whistlers are expected to 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 presently Brodifacoum baits are widely and frequently used.

Mitigation of the Proposed Rodent Eradication

No mitigation is required.

Lord Howe Island Silvereye *Zosterops lateralis tephropleura*
This sub-species, endemic to LHI, is listed as *Vulnerable* under the TSC Act (DECC 2007). It is widely distributed on the main island, occurring in all habitats except open fields. Its diet consists of insects, fruit and nectar (*ibid*).

Breeding season: from spring to summer.
Population size: 100 – 1,000 pairs (Fullagar *et al*. 1974).

Risk Posed by the Proposed Rodent Baiting
The silvereye is considered to be at low risk given that it eats mainly fruit, seeds and insects. Local non toxic bait trial studies found no evidence that this sub-species consumed baits although Eason and Spur (1995) state that the New Zealand silvereye would probably eat cereal-based baits if encountered. Results from rodent eradications in New Zealand suggest 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. If there is an initial decline then it will be followed by a marked increase in populations due to the removal of rodents and corresponding reduction in predation pressure, and increase in invertebrate food resources.

Mitigation of the Proposed Rodent Eradication
No mitigation is required.

Lord Howe Woodhen *Gallirallus sylvestris*
Listed on Schedule 1 of the TSC Act as an *Endangered* species.
List as V*ulnerable* under EPBC Act.

The Lord Howe Woodhen is a flightless bird endemic to LHI.
The population estimate in 1997 was 220-230 individuals and 71-74 breeding pairs (NPWS 2002). The population of woodhen has remained relatively static over the last ten years (DECC 2007), and may have reached carrying capacity at least in the lowlands, (NPWS 2002). 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.

Habitat
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 (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 (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.

Risk Posed by the Proposed Rodent Baiting

This species is at risk of both primary and secondary poisoning. 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.

Mitigation of the Proposed Rodent Eradication

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. 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. 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 most likely from Taronga Zoo. Woodhen have previously been successfully held in captivity (Lourie-Fraser 1985; 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.

Woodhen 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 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 (Lourie-Fraser 1985). The full or partial loss of one breeding season is unlikely to have a significant effect on the population particualry 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.

Masked Booby (Tasman Sea) *Sula dactylatra*

Listed as *Vulnerable* under the TSC Act.

Listed as both *Marine* and *Migratory* in the EPBC 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 2009a). Population size for this sub-species was estimated as, 600-900 pairs on the LHIG, 300 pairs on Norfolk Island, and <100 pairs for the Kermadec Islands (ibid). However, Garnett and Crowley (2000) suggest the LHI population to be only 500 individuals which is in line with the estimate by Priddel (1996) of 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). 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 2009a). Nests are built on the surface in high open areas. The species is impacted by predation of eggs and young by rodents (DEC 2005).

Risk Posed by the Proposed Rodent Baiting
Because the birds feed at sea and given the low risk of bioaccumulation in the marine environment, the population is not at risk of primary or secondary poisoning.

Mitigation of the Proposed Rodent Eradication
No mitigation is required.

Masked Owl Tyto novaehollandiae
Listed as *Vulnerable* under the TSC Act. Introduced to LHIG

Masked Owls were introduced to LHI in the 1920s in an attempt to control rats. It is estimated that currently there are between 10 and 100 pairs present on LHI (DECC 2007). Although the species is classified as *Vulnerable* under the TSC Act, the LHI owls are regarded as pests on LHI. Masked Owls primarily consume rodents but have been recorded eating a number of bird species on LHI including the woodhen, terns, Little and Wedge-tailed shearwaters, and Black-winged and Providence petrels.

The LHI Masked Owl were until recently believed to be the Tasmanian supspecies (*T. n. castanops*), however genetic testing has found significant divergence of the LHI population with *T. n. castanops*, suggesting hybridisation with the Mainland race (*T. n. novaehollandiae*) (Horgan, *et al* 2013). This hybridisation and loss of genetic integrity prohibits translocation of the LHI Masked Owl to Tasmania or mainland NSW.

A recent study has shown that rodents currently provide the Masked Owl's main prey base 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 comprised solely of 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.

Risk Posed by the Proposed Rodent Baiting
A large proportion of the local owl population will likely succumb to secondary poisoning as a result of the proposed rodent eradication.

Mitigation of the Proposed Rodent Eradication
No mitigation is proposed. To the contrary, the survivors are likely to be targeted for extermination or translocation to safeguard the woodhen population.

Pacific Golden Plover *Pluvialis fulva*
Listed as both *Marine* and *Migratory* in the EPBC Act.

The breeding grounds of the Pacific Golden Plover are found in western Canada and northern Siberia (Lane 1987). In August they commence migrating through Asia to spend the non-breeding months in locations that include India, Africa, China, Australia and various Pacific islands (ibid). A small number, arrive on LHI in September and leave in April, although some, less than 10, may over-winter. They feed on insects, molluscs, crustaceans and some plant material (Hutton 1991).

Risk Posed by the Proposed Rodent Baiting
Those few plovers that over-winter on LHI may be at risk of primary poisoning from consumption of bait pellets and secondary poisoning from eating beach invertebrates however this is considered unlikely.

Mitigation of the Proposed Rodent Eradication

Baits will be distributed above the Mean High Water mark where ever possible to minimise baits on beaches. Due to this mitigation measure and the low number of birds present during the proposed baiting it is unlikely that the baiting will significantly affect the species.

Providence Petrel *Pterodroma solandri*
Listed as *Vulnerable* under the TSC Act.
Listed as both *Marine* and *Migratory* in the EPBC 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 and their associated slopes, 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 Phillip 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. Their diet consists of fish and squid.

Providence Petrels construct nests in burrows. Rodents have been documented to prey on Providence petrels on LHI.

Risk Posed by the Proposed Rodent Baiting

It is very unlikely that their diet of squid and fish caught offshore of LHI will lead to secondary poisoning of petrels.

Mitigation of the Proposed Rodent Eradication
No mitigation is proposed.

Red-tailed Tropicbird *Phaethon rubricauda*
Listed as *Vulnerable* under the TSC Act.
Listed as a *Marine Species* and *Migratory* under the EPBC 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).

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 this species.

Mitigation of the Proposed Rodent Eradication
None required.

Ruddy Turnstone *Arenaria interpres*
The Ruddy Turnstone is a *Migratory* and *Marine* species as listed in the EPBC Act.

Approximately 14,000 turnstones migrate to Australia from Siberia and Alaska during their non-breeding season (Watkins 1993). A small number of turnstones begin to arrive on LHI in September; most leave by April. A few (10 – 20 birds) remain to over winter (Hutton 1991). They eat crustaceans, molluscs and worms sheltering under organic debris such as seaweed (Hutton 1991). Turnstones will also eat carrion.

Risk Posed by the Proposed Rodent Baiting
A baiting programme conducted in New Zealand using Brodifacoum in cereal baits possibly resulted in a large proportion (> 50%) of a local dotterel population being killed through secondary poisoning (Dowding *et al*. 2006).The dotterels had fed on beach crustaceans which in turn had been feeding on cached poison baits. Normally, secondary poisoning of invertebrate-eating birds is unlikely because it is rare for a significant proportion of the invertebrates that may be eaten by a particular bird to contain Brodifacoum (Craddock 2003). In addition it is usual for the Brodifacoum ingested by invertebrates feeding on baits not to be retained for long because it is soon excreted. However, in the New Zealand case, the dotterels were feeding on a relatively concentrated source of prey that were routinely eating poisoned baits.

Those few turnstones that over-winter on LHI are at risk of secondary poisoning from eating beach invertebrates or scavenging dead rodents.

Mitigation of the Proposed Rodent Eradication
Baits will be distributed above the Mean High Water mark where ever possible to minimise baits on beaches. Due to this mitigation measure and the low number of birds present during the proposed baiting it is unlikely that the baiting will significantly affect the species.

Sooty Tern *Onychoprion fuscata*
Listed as *Marine species* under the EPBC Act and Vulnerable under 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 estimated that the breeding population on the LHIG was up to one million pairs. Other major breeding sites for the Sooty Tern in Australia is at Norfolk Island, which has an estimated 40,000 to 70,000 pairs (Higgins and Davies 1996) and Great Barrier Reef islands. 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 (Hutton 1991).

Sooty terns are known to be impacted by predation of eggs and chicks by rats on the LHIG.

Risk Posed by the Proposed Rodent Baiting
Sooty Terns are not susceptible to poisoning by the rodent eradication because, in winter, they only feed at sea.

Mitigation of the Proposed Rodent Eradication
None required.

Wedge-tailed Shearwater *Ardenna pacifica*
Listed as *Migratory* and *Marine* under the EPBC Act.

This species is widely distributed in the Pacific and Indian oceans. It breeds on islands throughout its distribution. Australian breeding locations are Lord Howe Island (Blackburn Island, Roach Island, Balls Pyramid, Mutton Bird Point, Signal Point, along the lagoon foreshore and beneath Mount Eliza), various Great Barrier Reef islands, on over 30 islands in NSW, with large colonies on Montague, Muttonbird and Broughton islands and on many islands of mid-western and south-western WA.

An estimated 10,000 – 100,000 pairs nest on LHI (Hutton 1991). Nests are in burrows under vegetation on the surface . Adults start to arrive on LHI in late August to commence breeding (Hutton 1991), but the majority of the population arrive during September and October (McAllan *et al.* 2004). Wedge-tailed Shearwater diet is made up of small fish and squid caught in deepwater. The species is known to be predated by rodents on the LHIG.

Risk Posed by the Proposed Rodent Baiting
As this species feeds away from the island over deep water and will most likely be absent during the REP, it is not at risk from primary or secondary poisoning.

Mitigation of the Proposed Rodent Eradication
None proposed.

Whimbrel *Numenius phaeopus*
The EPBC Act lists this species as *Migratory and Marine*.

Whimbrels are seen on LHI from September to April in small numbers (Hutton 1991; McAllan *et al*. 2004), probably less than 20 (compared to the 10,000 that annually visit Australia – Watkins 1993). One or two may stay throughout winter (Hutton 1991). Whimbrels forage in local paddocks for insects and seeds (Hutton 1991). They are also seen on rocky seashores at low tide feeding mostly on worms, molluscs, and crustaceans (ibid). Reptiles and tern chicks are also included in their diet.

Risk Posed by the Proposed Rodent Baiting
Birds feeding on beaches may be at risk of primary poisoning through consumption of baits and secondary poisoning through consumption of invertebrates however this is considered unlikely.

Mitigation of the Proposed Rodent Eradication

Baits will be distributed above the Mean High Water mark where ever possible to minimise baits on beaches. Due to this mitigation measure and the low number of birds present during the proposed baiting it is unlikely that the baiting will significantly affect the species. If ill birds are observed, they can be caught and treated with vitamin K.

White Tern *Gygis alba*
Listed as *Vulnerable* under the TSC Act
Listed as *Marine species* under the EPBC 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 in press) 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.

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.

7-4.2.2. RISKS TO MAMMALS

Large Forest Bat *Vespadelus darlingtoni*
Not listed in either the TSC Act or the EPBC Act.

LHI once had two species of bat, the Large Forest Bat and an endemic bat species, the Lord Howe Island Long-eared Bat *Nyctophilus howensis*. The latter species is now regarded as *Extinct*, possibly wiped out by introduced predators (DEWHA 2009b).

The Large Forest Bat is a common species. Apart from occurring on LHI, it is widely distributed from the New South Wales-Queensland border, along the coast and Great Dividing Range of New South Wales, throughout most of Victoria and on to the south-east corner of South Australia as well as Tasmania (Hoye 1995). This species is capable of foraging for small insects on mild nights during winter, a season when most other bats are hibernating (Hoye 1995).

Risk Posed by the Proposed Rodent Baiting
The Large Forest Bat is entirely insectivorous, taking its prey on the wing. It may be at risk of secondary poisoning if some of the insects it eats have fed on cereal baits within a month or so (Hoare and Hare 2006) but this risk is small at the population level.

Physical inspection of the mouths and anus of 21 bats captured during the non toxic bait trial on LHI in 2007 (LHIB, 2007) showed no evidence of pyranine fluorescence. It is therefore unlikely that the proposed baiting will be harmful to the forest bat of LHI. To the contrary, it is expected that the removal of rodents will result in increased populations of bats through a reduction in food competition with rodents.

Mitigation of the Proposed Rodent Eradication
As the risk to the island population is minor, no mitigation is proposed.

7-4.2.3. RISKS TO REPTILES

Excluding recently introduced reptile species, there are two species of native terrestrial reptiles 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. These species are considered to be at low risk of poisoning, and are likely to increase in abundance substantially following the removal of rodents (Towns and Daugherty 1994, Hoare et al. 2006).= as they are heavily predated by rodents currently.

The Lord Howe Island Gecko *Christinus guentheri*
Listed as *Vulnerable* under the TSC Act.
Listed as *Vulnerable* in the EPBC Act.

Distribution and Ecology
This gecko 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). Predation by rodents are a key threat (DECC, 2007).

Risk Posed by the Proposed Rodent Baiting

There is little published information on the interactions between reptiles and Brodifacoum worldwide, however reptiles are considered to be more tolerant than mammals and birds based on field observations and survival during experimental dosing (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).

There was a 15 % mortality of the Caribbean gecko species Sphaerodactylus macrolepis when exposed to Talon-G (cereal pellets containing 0.02 g/kg Brodifacoum) during pen trials (Gaa 1986, cited in Garcia et al. 2002).

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. Firstly, the number of invertebrates that will have fed on Brodifacoum baits before being consumed by the gecko will 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)). Secondly, baiting will take place in winter when reptiles may be relatively inactive.

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).

Mitigation of the Proposed Rodent Eradication

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.
Listed as *Vulnerable* under the EPBC Act.

Distribution and Ecology

This skink is restricted to Norfolk Island and the LHIG. 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).

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.

It feeds on beetles, spiders, ants and other invertebrates amongst the leaf litter (DECC 2007). Predation by rodents are a key threat (DECC, 2007).

Risk Posed by the Proposed Rodent Baiting

In general, the risk of primary poisoning in reptiles appears to be 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 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. 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).

Insectivores such as this skink risk ingesting Brodifacoum if they feed on invertebrates that have themselves fed on Brodifacoum-laced baits. However the risk of secondary poisoning for this skink is low because:

- baiting will take place in winter when reptiles may be either hibernating, or relatively inactive. Therefore few if any skinks will be feeding at the time when invertebrates may be carrying Brodifacoum; and
- the proportion of invertebrates that will have fed on Brodifacoum baits will be small so even if skinks are foraging at this time then most of the potential prey that they will encounter will not be poisoned (Morgan *et al.* 1996);

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).

Mitigation of the Proposed Rodent Eradication

No mitigation is proposed as baiting is very unlikely to pose a significant threat to the Lord Howe Island Skink.

7-4.3. RISKS TO INVERTEBRATES

The LHIG is characterised by a large number of terrestrial invertebrate species, many of which are found nowhere else in the world (DECC 2007). More than 1,600 species have been recorded, including 464 beetles, 183 spiders, 157 land and freshwater snails, 27 ants and 21 earthworms (ibid). Since the settlement of LHI at least one endemic ant species and ten endemic beetle species may have become extinct; and six endemic ants, nine endemic spiders and 38 endemic beetles are at risk of extinction (Cassis *et al*. 2003 cited in DECC 2007). Other invertebrates thought to be extinct or at risk include several snails, a cockroach, earthworm and a stick-insect (DECC 2007). Predation by rodents is regarded as a significant threat to many of the invertebrates on Lord Howe Island (DECC 2007).

Brodifacoum is generally perceived to lack insecticidal properties and is not expected to have significant effects on most invertebrates as they have different blood-clotting systems compared to vertebrates. Introduced slugs and snails used as analogues for native snail species in experiments suggest NZ terrestrial molluscs are not susceptible to Brodifacoum poisoning. However studies undertaken outside NZ have sometimes identified a risk. Worms and arthropods have shown no evidence of vulnerability to Brodifacoum poisoning. Therefore assessment of impacts to all invertebrates on the LHIG is not considered warranted for this permit application. This section focuses only on listed threatened species.

Research was conducted in 2009 to assess the vulnerability of the endangered LH Placostylus to Brodifacoum baits (Wilkinson *et al.* unpubl. data). 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. In the unlikely event of any incidental mortality occurring during the eradication, evidence from other eradications suggests that this will be more than offset by the benefits that accrue to invertebrate populations from the removal of predation pressure by rodents.

There are also four species of critically endangered land snails on LHI: Masters' charopid land snail, Mount Lidgbird charopid land snail, Whitelegge's land snail and *Gudeoconcha sophiae magnifica*. All these species 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, however, for these species the threats associated with not removing rodents exceed the potential risk associated with an eradication operation.

Lord Howe Placostylus *Placostylus bivaricosus*
Listed as *Endangered* under the TSC Act.
Listed as *Endangered* under the EPBC 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 (NPWS 2001).

Three recent sub-species of the Lord Howe Placostylus are recognised:

1) *P. b. 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 (NPWS 2001).
2) *P. b. 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 (NPWS 2001).
3) *P. b. 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 (NPWS 2001).

Habitat
Observations of Placostylus in the 19th Century indicate that this snail prefers shady, damp situations, preferably on scrubby calcarenite hillsides (Brazier 1889 cited in NPWS 2001). Ponder and Chapman (1999, cited in NPWS 2001) 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 made in evergreen closed forests dominated by either Kentia Palm *Howea fosteriana* or *Greybark Drypetes australasica/Blackbutt Cryptocarya triplinervis* association (or ecotones between the two) (NPWS 2001).

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 (NPWS 2001). Eggs are laid in the soil under leaf litter. Fallen dead leaves from broadleaf trees are thought to be its food source (NPWS 2001).

The Ship Rat is a significant threat to the Placostylus, being a major predator of the species (NPWS 2001).

Risk Posed by the Proposed Rodent Baiting
Internationally, there are at least three species of snail that may have been killed by Brodifacoum baits (Booth *et al.* 2001) and dead slugs have also been found in bait stations primed with Brodifacoum baits (Bowie and Ross 2006).

To evaluate the risk posed by the baiting to the snail, lab-acclimated Placostylus were exposed to non-toxic baits (containing the biomarker pyranine that fluoresces under ultra violet light) along with natural food in a cafeteria-like choice trial. They fed exclusively on natural food, with no fluorescing faecal samples detected. When animals were only offered toxic baits under laboratory conditions, no mortalities resulted from the exposure to Brodifacoum (Wilkinson and Hutton, 2013). These findings suggest that the probability of a significant proportion of the species consuming and dying from toxic baits in the wild is extremely unlikely.

Mitigation of the Proposed Rodent Eradication
No mitigation proposed.

Magnificent Helicariond Land Snail *Gudeoconcha sophiae magnifica*
Listed as *Critically Endangered* under the EPBC Act and 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.

The key threat to this snail is likely to be predation by introduced rats (Beeton 2008a). Predation by the introduced Common Blackbird is also thought likely (ibid).

Population estimate
It appears that this 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, and 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).

Risk Posed by the Proposed Rodent Baiting
Snails of at least three species are known to be sensitive to Brodifacoum (Booth *et al.* 2001) although laboratory tests conducted on other species indicated that other species of snails are not susceptible to Brodifacoum baits (Booth *et al.* 2003), including *Placostylus bivaricosus*.

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 alive 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. Rats are regarded as a significant threat to this snail (Beeton 2008a) and are possibly driving this species towards extinction, if they have not done so already. The eradication of rodents from LHI may place *G. s. magnifica* at risk of poisoning, but this possibility must be weighed up against the almost certainty that predation by rats will result in the extinction of this snail.

Masters' Charopid Land Snail *Mystivagor mastersi*
Listed as *Critically Endangered* under the EPBC Act and TSC Act.

This snail, endemic to LHI, is only known from a few sites, including the summit of 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).

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, with only 17 specimens being collected by the Australian Museum in 140 years (Beeton 2008b). Although there is insufficient quantitative data available to prove that the snail population has declined, it is possible that it has, due initially to pigs and goats, then later to predation by the introduced rat (Beeton 2008b). The size of the current population is unknown.

The key threat to this snail is predation by introduced rats (Beeton 2008b).

Risk Posed by the Proposed Rodent Baiting

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. 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 17 Masters' Charopid Land Snails have been found since 1869 (Beeton 2008b). None of these 17 was alive when collected so, therefore, it is very unlikely any could now be found to take into captivity. Rats are regarded as a significant threat to this snail (Beeton 2008b) and are possibly driving this species towards extinction, if they have not done so already. The eradication of rodents from LHI may place Masters' Charopid Land Snail at risk of poisoning, but this possibility must be weighed up against the almost certainty that predation by rats will result in the extinction of this snail.

Mount Lidgbird Charopid Land Snail *Pseudocharopa lidgbirdi*

Listed as *Critically Endangered* under the EPBC Act and 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 Erskine's 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, no live specimens have been found since 1979 (Beeton 2008c). 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 unknown.

The key threat to this snail is predation by introduced rats (Beeton 2008c).

Risk Posed by the Proposed Rodent Baiting

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 six Mount Lidgbird Charopid Snails have been found since 1981 (Beeton 2008c). None of these six was alive when collected so, therefore, it is very unlikely any could now be found to take into captivity. Rats pose a significant threat to this snail (Beeton 2008c) and, unless eradicated, they may drive this species towards extinction, if they have not already done so.

Whitelegge's Land Snail *Pseudocharopa whiteleggei*
Listed as *Critically Endangered* under the EPBC Act and 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 34 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 relatively uncommon. Furthermore, in spite of increased survey effort, only two specimens have been found since 1971 compared to 32 before 1920. This suggests a significant decline in snail abundance (Beeton 2008d).

The key threat to this snail is predation by introduced rats (Beeton 2008d).

Risk Posed by the Proposed Rodent Baiting
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.

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 two specimens, one of which was living, 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.

Lord Howe Island Earthworm *Pericryptodrilus nanus*
Listed as *Endangered* 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 2008a).

Predation by rodents (DEC 2005) is a threat to the species.

Risk Posed by the Proposed Rodent Baiting
As the ecology of this species is mostly unknown, there is little data available to indicate whether this particular worm is at risk of Brodifacoum poisoning. However, limited studies of the effect of Brodifacoum on the common pasture worm (*Aporrectodea calignosa*) indicate that a very high concentration of Brodifacoum is required to kill worms. The concentration of Brodifacoum in soil required to cause mortality in pasture earthworms (500 micrograms of poison per gram of soil) is around 1000 times higher than the likely levels of Brodifacoum that would be found in soil directly

below the bait at the application rate proposed for the LHIG. Baits (pellet size 10 mm) are distributed at about one bait per 2 m^2, so most soil would not have any Brodifacoum residues at all.

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*
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 2008b) (although the 1930s is given as the last decade that it was collected from LHI by the Museum – DECC 2007). 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.

The key threat to this cockroach is predation by introduced rats, however mice may also prey on juveniles of this species (DECC 2007).

Risk Posed by the Proposed Rodent-Baiting
Brodifacoum is not expected to have significant effects on most invertebrates as they have different blood-clotting systems compared to vertebrates. 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. On Lady Alice Island, cockroaches were collected in the days and weeks after aerial baiting and tested for Brodifacoum; none was detected. However similar testing done after the aerial application of Brodifacoum on Coppermine Island detected Brodifacoum residue in some cockroaches (G.R.G. Wright cited in Booth *et al.* 2001).

Although cockroach species will eat Brodifacoum-laced baits, there have been no reported instances of such consumption causing death. The removal of rodents will benefit the Lord Howe Island Wood-feeding Cockroach by eliminating the major threat to its existence, and so pave the way for its re-establishment on LHI.

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

7-4.4. RISKS TO AQUATIC AND MARINE SPECIES

The solubility of Brodifacoum in water is less than 10 parts per million at pH 7 and 20°C (US EPA 1998). Solubility is the maximum equilibrium amount of solute (in this case Brodifacoum) that can dissolve per amount of solvent under specified conditions (in this case fresh water at pH 7 and 20°C). Given the non-polarity of Brodifacoum molecules, and the ionic strength of seawater the solubility of Brodifacoum in cold (~13 °C) seawater is probably in the low parts per billion range (Primus *et al.* 2005); basically Brodifacoum is practically insoluble in water, particularly in cold seawater. Sea

temperature around LHI in August, when the baiting is proposed to take place, will be approximately 17˚C.

As Brodifacoum is poorly soluble in water contamination of streams and other water bodies after the aerial application of bait is extremely unlikely. The insolubility of Brodifacoum coupled with its propensity to bind strongly to soils means that it cannot easily be washed into the marine environment. Only the erosion of soil itself would see any Brodifacoum reaching water, and even then Brodifacoum would remain absorbed in organic material and settle out in the sediment. In studies, less than 2% of Brodifacoum added to soil leached more than 2 cm in any of the four soil types tested (WHO 1995). Where baits are dropped directly into fresh or salt water, the poison will bind to organic matter in the sediment with no effect on water quality. Brodifacoum baits have been used on islands in at least three marine reserves (Tuhua, Kermadec, Ulva/Te wharawhara and Kapiti) and a marine park (Hauraki Gulf) without any incidents or measurable effects.

Any baits entering streams or other water bodies on LHI will sink and disintegrate, usually within a few hours, depending on turbulence or rate of flow. The minute amount of Brodifacoum in the bait (20 parts per million) settles in the sediment where it binds to organic material and breaks down. Although we can be certain that Brodifacoum will not contaminate water bodies it is considered highly unlikely.

THE AQUATIC HABITAT

The three species of freshwater fish found on Lord Howe Island are the Long-finned Eel *Anguilla reinhardtii,* Short-finned Eel *A. australis,* and Common Jollytail *Galaxias maculatus.*

Long-finned Eel *Anguilla reinhardtii*

Not listed in the TSC Act or in the EPBC Act.

Distribution and Ecology

This freshwater fish is found along the entire coastal margin of eastern Australia from Cape York to Tasmania. It is also found in New Caledonia and New Zealand (Australian Museum 2009a).

Adults leave their freshwater habitat to migrate to the sea near New Caledonia to breed. Developing eels stay a year at sea before returning to freshwater streams where they spend a number of years before maturing.

They are carnivorous, feeding on water invertebrates, frogs and other eels.

Risk Posed by the Proposed Rodent Baiting

The proposed baiting poses little risk to the eels of LHI. Although it is likely that very small quantities of baits will enter the streams on the island, there is little chance that Brodifacoum will contaminate these waterways because Brodifacoum is practically insoluble in water (WHO 1995). When the pellets breakdown their Brodifacoum content will bind with organic material in the sediment, effectively immobilising it. Primary poisoning from direct ingestion of bait is also considered unlikely given the application rate. Secondary poisoning through consumption of dead rodents that enter the water course may be possible but is considered unlikely.

Mitigation of the Proposed Rodent Eradication

No mitigation is proposed as baiting is very unlikely to pose a significant threat to the eels on Lord Howe Island.

Short-finned Eel *Anguilla australis*

Not listed in the TSC Act or in the EPBC Act.

Distribution and Ecology
This freshwater fish is also found along the coastal margin of south-eastern Australia, as well as in New Zealand, Norfolk Island, New Caledonia, Tahiti and Fiji (Murray Darling Basin Commission 2009).

Adults leave their freshwater habitat to migrate to their spawning grounds in the Coral Sea near New Caledonia to breed. Developing eels stay a year at sea before returning to freshwater streams where they spend a number of years before maturing.

They are carnivorous, feeding on water invertebrates, frogs and other eels.

Risk Posed by the Proposed Rodent Baiting
The proposed baiting poses little risk to the eels of LHI. Although it is likely that very small quantities of baits will enter the streams on the island, there is little chance that Brodifacoum will contaminate these waterways because Brodifacoum is practically insoluble in water (WHO 1995). When the pellets breakdown their Brodifacoum content will bind with organic material in the sediment, effectively immobilising it. Primary poisoning from direct ingestion of bait is also considered unlikely given the application rate. Secondary poisoning through consumption of dead rodents that enter the water course may be possible but is considered unlikely.

Mitigation of the Proposed Rodent Eradication
No mitigation is proposed as baiting is very unlikely to pose a significant threat to the eels on Lord Howe Island.

Common Jollytail *Galaxias maculatus*
Not listed in the TSC Act or in the EPBC Act.

Distribution and Ecology
As well as being present on LHI, this freshwater fish is found in coastal streams in eastern and western mainland Australia, Tasmania, New Zealand, Chatham Islands, Chile, Argentina and the Falkland Islands (Australian Museum 2009b).

Adults spawn in river estuaries in autumn, and then die. The larvae swim out to sea where they overwinter before returning to freshwater. Jollytails reach maturity at one year of age and most will spawn at this age although some females may delay maturity until the second or third year.

They are carnivorous, feeding on water invertebrates.

Risk Posed by the Proposed Rodent Baiting
The proposed baiting poses little or no risk to the jollytails of LHI. The breeding cycle of this fish is such that none, or only a few, will be present on LHI during the time of baiting as the adults that spawned in autumn would have already died, and their offspring will be at sea until spring or summer.

Although it is likely that very small quantities of baits will enter the streams on the island, there is little chance that Brodifacoum will contaminate these waterways because Brodifacoum is practically insoluble in water (WHO 1995). When the pellets breakdown their Brodifacoum content will bind with organic material in the sediment, effectively immobilising it. Primary poisoning from direct ingestion of bait is also considered unlikely given the application rate.

Mitigation of the Proposed Rodent Eradication
No mitigation is proposed as baiting will not pose a significant threat to the jollytails of Lord Howe Island.

THE MARINE HABITAT

The accidental spillage of 360g of Brodifacoum into the sea in New Zealand from a single-point discharge of 18 tonnes of bait was not associated with any long-term adverse effects on the marine environment (see Section 7-2.3.3). This incident represents an extreme example of Brodifacoum contamination. Although 18 tonnes of bait, almost half the total proposed to be applied to the whole of the LHIG, was deposited into the sea at one point, the overall effect was small and localised (Primus *et al.* 2005). There were no report of damage to the surrounding reefs (Primus *et al*. 2005), and what effect there was on the local marine life was limited in extent and transient (*ibid*). Although it is possible that, as a consequence of the aerial baiting of the LHG, some pellets will land in the ocean, the number of such pellets will be small. In an aerial baiting programme conducted on a U.S. island where baits were dispersed at a higher application rate then that proposed for the LHG, the average number of pellets landing per 500 metres of coastline was only 72 (Howald *et a*l. 2005). If nine million pellets deposited at one point resulted in a limited and transient effect on the marine environment within a 100 metres of the spill-site (Primus *et al.* 2005) then, intuitively, 14 pellets in 100 metres (Howald *et al.* 2005) would have negligible effect on the marine environment of LHI.

Other baiting operations using similar methods to the one proposed for LHI have not caused harm to marine organisms (Howald *et al.* 2005; Samaniego-Herrera *et al.* 2009), even though the bait application rates in those operations were up to double that proposed for LHI, and the bait more concentrated (i.e. 50ppm compared to 25 ppm on LHI).

The use of a deflector arm on the spreader bucket will direct bait onto land but a small number of pellets are likely to bounce off steep cliff faces into the sea (Samaniego-Herrera *et al.* 2009). It is possible that some fish will eat these pellets before they decompose, which may be only about 15 minutes if there is wave action, and slighter longer if there is not (Empson and Miskelly 1999). It is thus possible that a few individuals may consume enough bait to receive a fatal dose but, in other island eradications, mortality has been rare and nowhere has the species been adversely affected (Cole and Singleton 1996; Empson and Miskelly 1999; Howald *et al.* 2005; Samaniego-Herrera *et al.* 2009).

In the lagoon on LHI, where wave action is not as great, disintegration may take longer. Consequently, additional care will be taken to prevent bait entering the lagoon. This will be done by aerial baiting with specialised equipment that limits the spread of bait or by hand-broadcasting of bait along the shoreline of the lagoon where necessary.

Apart from direct ingestion of Brodifacoum in baits it is also possible for marine organisms to absorb Brodifacoum through their gills or skin (Empson and Miskelly 1999). However, the dilution factor of a few baits in the sea off LHI will be so great that it will nullify any such a risk. Lethal Concentration (LC) is the measure of the susceptibility of marine organisms to poisons. Typically it is defined as LC_{50} for exposure for a certain amount of time; the 50 indicating the concentration required to probably kill 50% of those organisms exposed to it. The reported LC_{50} (96 hours) values available for Brodifacoum and fish range from 0.051 mg/L to 0.165 mg/L depending on species; for daphnia, which is a small aquatic crustacean, the LC_{50} (48 hours) value is 0.34 mg/L.

Marine invertebrates

Since brodifacoum is practically insoluble in water (WHO 1995), marine invertebrates could not be exposed to significant amounts of dissolved brodifacoum as a result of a few bait pellets that may fall into the sea; not only is the potential source of contamination miniscule, but the dilution factor is extremely large.

Because many marine invertebrates scavenge or graze on items on the sea bottom or in intertidal areas, it is possible that a few may pick up bait pellets or pellet fragments prior to the pellets breaking down in the water. Breakdown of a pellet would likely take only a few minutes, especially if the water is rough (Empson and Miskelly 1999). However, evidence against the existence of a significant dietary-

exposure pathway for invertebrates comes from field sampling of marine invertebrates following an actual rodenticide application (Howald et al. 2005) where no brodifacoum was detected in invertebrate species. Sampling undertaken after a spill of 18 tonnes of 0.002% (20 ppm) brodifacoum bait in New Zealand in 2001 (Primus et al. 2005,) also demonstrated that even when extremely large amounts of brodifacoum enter the sea, the effect on the marine environment is transient and localised. Therefore baiting of the Lord Howe Island Group poses negligible risk to local marine invertebrates.

Corals

The rodent eradication will not pose a risk to coral because:

1) the pellets and most pellet fragments are too big for the filter-feeding coral polyps to eat;
2) the solubility of brodifacoum in water is poor and the amount of rodenticide in pellets (20 ppm) is low to begin with, thus the risk of corals absorbing dissolved brodifacoum is negligible; and
3) there is no known physiological mechanism by which vertebrate anticoagulants can affect invertebrates.

Fish

If in sufficient quantity, it is possible for fish to absorb brodifacoum through their gills or skin (Empson and Miskelly 1999). However, the proposed baiting of the LHIG is likely to result in only a small number of baits landing in the sea. Because i) brodifacoum is practically insoluble in water, ii) the total amount of brodifacoum is minute, and iii) the dilution factor is great, the risk of fish absorbing brodifacoum is negligible.

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 Marine invertebrates (above).

Marine mammals

There is no realistic pathway by which marine mammals can be significantly exposed to rodenticide at the LHIG as a result of the proposed aerial baiting with Pestoff® 20R (see Appendix 3). 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.

In summary, the proposed baiting of LHI does not pose a threat to the marine life (Cetaceans, seals, turtles, fish or invertebrates, including coral) or the conservation values of the Lord Howe Island Marine Park 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;
- Brodifacoum in practically insoluble, particularly in cold seawater (Primus *et al.* 2005) such as will be found off LHI in August, therefore extremely little Brodifacoum will dissolve out from the baits and remain suspended in the water. This, coupled with the significant dilution factor, will mean that the amount of Brodifacoum assimilated into the marine environment will be many orders of magnitude lower than the concentrations known to be toxic to fish (Empson 1996); and
- Baiting other islands using similar methods, although sometimes using significantly more bait, has not resulted in adverse effects on the marine environment.

Appendix 3 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.

7-4.5. MITIGATION SUMMARY

Measures used to mitigate potential environmental harm are summarised below:

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. 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.

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.

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 180^{o} 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.

Captive housing
A large proportion of the population of the woodhen and currawongs will be taken into captivity as they are at significant risk 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 to ensure birds are not released at a time which may put them at risk. Woodhen and currawongs are highly susceptible to poisoning; the former from eating baits and poisoned rodents, the latter from preying on poisoned rodents. 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%. Protocols for capturing and housing birds have been established as a result of a trial or rehearsal using a small number of birds undertaken in 2013. A bird-specialist veterinarian will be on site during capture and release operations.

An experienced aviculturist from Taronga Zoo has designed the holding facilities which will be sited on LHI. The designer has benefited from knowledge gained from previous examples of facilities built to house woodhens both at Taronga Zoo and on LHI. An aviculturist will be employed to manage the holding facility for the period that the birds are held.

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.
- 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.
- 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 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.
- Monitoring for ill and dead non target species. Ill individuals will be treated with Vitamin K where possible. Carcasses of rodents and non target species will be collected if found.
- Analysis of milk samples post baiting.

PART 7-5: REFERENCES

Alifano A, Wegmann A 2010. The ecotoxicology and palatability of two rodenticide products: Field-based assessment at Palmyra Atoll. Island Conservation report prepared for the Palmyra Atoll Rainforest Restoration Project. 51 p.

Angel, A., Wanless, R. and Cooper, J. 2009. Review of impacts of the introduced house mouse on islands in the Southern Ocean: are mice equivalent to rats? *Biological Invasions* **11**, 1743-1754.

Armstrong DP, Ewen JG 2001. Estimating impacts of poison operations using mark-recapture analysis and population viability analysis: an example with New Zealand robins (Petroica australis). New *Zealand Journal of Ecology* **25**: 29-38.

Armstrong DP, Perrott JK, Castro I 2001. Estimating impacts of poison operations using mark-recapture analysis: hihi (*Notiomystis cincta*) on Mokoia Island. *New Zealand Journal of Ecology* **25**: 49-54.

Athens, J. 2009. Rattus exulans and the catastrophic disappearance of Hawaiis native lowland forest. *Biological Invasions* **11.** 1489-1501.

Auld, T.D., Hutton, I., Ooi, M.K.J. and Denham, A.J. 2010 Disruption of recruitment in two endemic palms on Lord Howe Island by invasive rats. *Biological Invasions* **12**, 3351-3361

Australian Museum (2009a). Wildlife of Sydney – Fact File – Longfinned Eel. http://faunanet.gov.au/wos/factfile.cfm?Fact_ID=390

Australian Museum (2009b). Common Jollytail, *Galaxias maculatus* (Jenyns, 1842). http://www.australianmuseum.net.au/Common-Jollytail-Galaxias-maculatus-Jenyns

Australian Museum (2010). Australian Fur Seal. http:/www.australianmuseum.net.au/Australian-Fur-Seal.

Bachmann KJ, Sullivan TJ 1983. Dispositional and pharmacodynamic characteristics of brodifacoum in warfarin-sensitive rats. *Pharmacology* **27:** 281-288.

Bailey C, Fisher P, Eason CT 2002. Assessing anticoagulant resistance in rats and coagulation effects in birds using small-volume blood samples. *Science for Conservation* **249**. Department of Conservation, Wellington, N.Z. 22 p.

Beesley, P.L., Ross, G.J.B., Wells, A. (eds) (1998). Mollusca: The Southern Synthesis. Fauna of Australia. Vol 5, Part A. CSIRO Publishing: Melbourne.

Beeton, R.J.S. (2008a). *Gudeoconcha sophiae magnifica* ms (a snail) Listing Advice: Advice to the Minister for the Environment, Water, Heritage and the Arts from the Threatened Species Scientific Committee on Amendment to the list of Threatened Species under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Threatened Species Scientific Committee, Canberra.

Beeton, R.J.S. (2008b). *Mystivagor mastersi* (Masters' Charopid Land Snail) Listing Advice: Advice to the Minister for the Environment, Water, Heritage and the Arts from the Threatened Species Scientific Committee on Amendment to the list of Threatened Species under the *Environment*

Protection and Biodiversity Conservation Act 1999 (EPBC Act). Threatened Species Scientific Committee, Canberra.

Beeton, R.J.S. (2008c). *Pseudocharopa lidgbirdi* (Mount Lidgbird Charopid Snail) Listing Advice: Advice to the Minister for the Environment, Water, Heritage and the Arts from the Threatened Species Scientific Committee on Amendment to the list of Threatened Species under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Threatened Species Scientific Committee, Canberra.

Beeton, R.J.S. (2008d). *Pseudocharopa whiteleggei* (Whitelegge's Land Snail) Listing Advice: Advice to the Minister for the Environment, Water, Heritage and the Arts from the Threatened Species Scientific Committee on Amendment to the list of Threatened Species under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Threatened Species Scientific Committee, Canberra.

Bester, A.J., Priddel, D., Klomp, N.I., Carlile, N., O'Neill, L. (2007). Reproductive success of the Providence Petrel *Pterodroma solandri* on Lord Howe Island. *Australia Marine Ornithology* **35 (1),** 21-28.

Billing, J. (1999). The management of introduced rodents on Lord Howe Island. Unpublished report. Lord Howe Island Board, Lord Howe Island.

Black, K., Swearer, S. and Symonds, G. (2007). Understanding larval dispersal and the inter-connected wave and wind-driven circulation at Lord Howe Island: numerical modelling, empirical observations, and model validation. Draft Report prepared for the NSW Parks and Wildlife Service. ASR Limited; Marine Consulting and Research, Raglan, New Zealand.

Boermans HJ, Johnstone I, Black WD, Murphy M 1991. Clinical signs, laboratory changes and toxicokinetics of brodifacoum in the horse. *Canadian Journal of Veterinary Research* **55**: 21-27.

Booth, L.H., Eason, C.T. and Spur, E.B. (2001). Literature review of the acute toxicity and persistence of Brodifacoum to invertebrates. Pp. 1-9 in *Department of Conservation 2001: Literature Review of the Acute Toxicity and Persistence of Brodifacoum to Invertebrates and Studies of Residue Risks to Wildlife and People* (eds J. Jasperse and L. Clelland). Department of Conservation, Wellington.

Booth, L.H., Fisher, P., Heppelthwaite, V. and Eason, C.T. (2003). Toxicity and residues of Brodifacoum in snails and earthworms. DOC Science Internal Series, No. 143. Department of Conservation, Wellington, New Zealand.

Bowie, M.H. and Ross, J.G. (2006). Identification of weta foraging on Brodifacoum bait and the risk of secondary poisoning for birds on Quail Island, Canterbury, New Zealand. *New Zealand Journal of Ecology* **30**, 219-228.

Brooke MdL, Cuthbert RJ, Mateo R, Taggart MA 2011. An experimental test of the toxicity of cereal pellets containing brodifacoum to the snails of Henderson Island, South Pacific. *Wildlife Research* **38**: 34-38.

Brooke MdL, Cuthbert RJ, Harrison, G Gordon, Taggart MJ 2013. Persistence of brodifacoum in cockroach and woodlice: Implications for secondary poisoning during rodent eradications. *Ecotoxicology and Environmental Safety* **97** 183-188.

Broome, K.G.; Fairweather, A.A.C.; Fisher, P. 2016: Brodifacoum Pesticide Information Review.

Version 2016/1. Unpublished report docdm-25436, Department of Conservation, Hamilton, NZ. 137p

Brown, D. A. (1997a). Chetwode Island kiore and weka eradication project. *Ecological Management* **5**, 11-20.

Brown, K. P. (1997b). Impact of brodifacoum poisoning operations on South Island robins Petroica australis australis in a New Zealand Nothofagus forest. *Bird Conservation International* **7**, 399-407.

Brown, D., Wylie, M. and McClelland, P. (2006). Assessment of environmental effects for the eradication of: Ship Rats (*Rattus rattus*) from Taukihepa, Pukeweka and Solomon (Rerewhakaupoko) Islands; and Kiore (*Rattus exulans*) from Big Moggy (Mokonui) Island. Unpublished Report. Department of Conservation, New Zealand.

Buckelew S, Howald G, MacLean S, Byrd V, Daniel L, Ebbert S, Meeks W 2009. Rat Island Habitat Restoration Project: Operational Report. Report to USFWS. Island Conservation., Santa Cruz, CA. 44 p.

Carlile, N. and Priddel, D. (2015). Establishment and growth of the White Tern Gygis alba population on Lord Howe Island, Australia. *Marine Ornithology* **43**, 113-118.

Carlile, N and Priddel, D. (2007) Population size and distribution of the Lord Howe Currawong Strepera *graculina crissalis.* Report prepared for the Lord Howe Island Board by the Department of Environment and Conservation (NSW).

Carlile, N. (2015). *Monitoring, evaluating and reporting the biodiversity benefits of eradicating exotic rodents from Lord Howe Island*. Unpublished report for the LHIB. Office of Environment and Heritage, NSW

Christmas, E. (1995). Interactions between Duvaucel's Gecko (*Hoplodactylus duvaucelii*) and Kiore (*Rattus exulans*). MSc. Thesis (unpublished thesis), Department of Zoology, University of Otago, Dunedin, New Zealand. Cited in Hoare, J.M. and Hare, K.M. (2006). The impact of Brodifacoum on non-target wildlife: gaps in knowledge. *New Zealand Journal of Ecology* **30**(2), 157-167.

Cole, R.G. and Singleton, R.J. (1996). Monitoring of reef fish populations at Kapiti Island during aerial poisoning for rats 1996. Unpublished report prepared for Wellington Conservancy, Department of Conservation, Wellington. National Institute of Water and Atmospheric Research, Nelson, New Zealand.

Cogger, H. G. (1971). The reptiles of Lord Howe Island. *Proceedings of the Linnean Society of New South Wales* **96**, 23-38

Craddock, P. 2003. Aspects of the Ecology of Forest Invertebrates and the Use of Brodifacoum. PhD Thesis University of Auckland.

Craddock, P. (2004). Environmental breakdown of Pest-Off poison bait (20ppm Brodifacoum) at Täwharanui Regional Park, North of Auckland. Unpublished report prepared for Northern Regional Parks, Auckland Regional Council. Entomologica Consulting, Auckland.

Cuthbert, R. and Hilton, G. (2004). Introduced house mice Mus musculus: a significant predator of threatened and endemic birds on Gough Island, South Atlantic Ocean? *Biological Conservation* **117**, 483-489.

Daniel, M.J. and Williams, G.R. (1984). A survey of the distribution, seasonal activity and roost sites of New Zealand bats. *New Zealand Journal of Ecology* **7**: 9-25.

Day, T.D. (2004). Withholding period from pasture for sheep exposed to hand-broadcast Pestoff 20R Rodent Bait. Report prepared as part of a code of practice for the aerial application of Pestoff 20R Rodent bait on mainland New Zealand (unpublished). XcluderTM Pest Proof Fencing Company, Cambridge, New Zealand. 13pp

DEC (2005). NSW Threatened Species Factsheets.
http://www.threatenedspecies.environment.nsw.gov.au/tsprofile.....
Date accessed 31/8/2009.

DECC (2007) Lord Howe Island Biodiversity Management Plan. Department of Environment and Climate Change, Hurstville.

DECCW (2009). Grey Ternlet: profile. NSW Threatened Species Factsheets.
http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/profile.aspx?id=10670

DEWHA (2009a). Species Profile and Threat Database. Department of Environment, Water, Heritage and the Arts, the Australian Government, Canberra.
http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_

DEWHA (2009b). The Action Plan for Australian Bats – Recovery Outlines. Department of Environment, Water, Heritage and the Arts, the Australian Government, Canberra.
www.environment.gov.au/biodiversity/threatened/publications/actions/bats/7.html Accessed 28/9/9

DIISE 2015: Database for Island Invasive Species Eradications accessed December 2015: http://diise.islandconservation.org

Dowding, J.E., Lovegrove, T.G., Ritchie, J., Kast, S.N. and Puckett, M. (2006). Mortality of northern New Zealand dotterels (*Charadrius obscurus aquilonius*) following an aerial poisoning operation. *Notornis* **53**, 235-259.

Dowding JE, Murphy EC, Veitch CR 1999. Brodifacoum residues in target and non-target species following an aerial poisoning operation on Motuihe Island, Hauraki Gulf, New Zealand. *New Zealand Journal of Ecology* **23**: 207-214.

DSEWPAC 2012. Non-target species mitigation for the Macquarie Island Pest Eradication Project. Final report Department of Sustainability, Environment, Water, Population and Communities, Canberra. Australia. 87 p.

Eason, C.T. and Spurr, E.B. (1995). Review of the toxicity and impacts of Brodifacoum on non-target wildlife in New Zealand. *New Zealand Journal of Zoology* **23**, 371-379.

Eason CT, Wright GR, Meikle L, Elder P 1996. The persistence and secondary poisoning risks of sodium monofluoroacetate (1080), brodifacoum, and cholecalciferol in possums. *Proceedings of the Vertebrate Pest Conference* **17:** 54-58.

Eason C, Wickstrom M 2001. Vertebrate Pesticide Toxicology Manual (Poisons). Department of Conservation, PO Box 10-420, Wellington, New Zealand. 122 p.

Eason C, Milne L, Potts M, Morriss G, Wright G, Sutherland O 1999. Secondary and tertiary poisoning risks associated with brodifacoum. *New Zealand Journal of Ecology* **23**: 219-224.

Eason CT, Murphy EC, Wright GRG, Spurr EB 2002. Assessment of risks of brodifacoum to non-target birds and mammals in New Zealand. *Ecotoxicology* **11**: 35-48.

EC. (2005). Competent Authority Report Brodifacoum (PT14). Doc1.3, Document II-A. Effects Assessment for the active substance Brodifacoum. European Commission.

Empson, R.A. (1996). Application for resource consent application of anticoagulant toxic baits for rat eradication (Kapiti Island): Background information and assessment of effects. Unpublished report. Department of Conservation, Wellington, New Zealand.

Empson, R.A. and Miskelly, C.A. (1999). The risks, costs and benefits of using Brodifacoum to eradicate rats from Kapiti Island, New Zealand. *New Zealand Journal of Ecology* **23**(2), 241–254.

Environment Australia (2002). Lord Howe Island Marine Park (Commonwealth Waters) Management Plan. 2002, Environment Australia, Canberra

Fisher, P. (2013). Environmental residues of anticoagulants used for pest animal control. Landcare Research New Zealand.

Fisher P, Funnell E, Fairweather A, Brown LE, Campion M. (2012). Accidental discharge of brodifacoum baits into a freshwater lake: A case study. *Bulletin of Environmental Contamination and Toxicology* **88**: 226-228.

Fisher P, Griffiths R, Speedy C, Broome KG 2011. Environmental monitoring for brodifacoum residues after aerial application of baits for rodent eradication. In: Veitch CR, Clout MN, Towns DR eds. Island Invasives: Eradication and Management. *Proceedings of the International Conference on Island Invasives*, IUCN, Gland, Switzerland, Auckland, New Zealand. Pp. 300-304.

Fisher PM 2009. Residual concentrations and persistence of the anticoagulant rodenticides brodifaocum and diphacinone in fauna. Unpublished PhD thesis. Lincoln University, Lincoln, NZ. 155 p.

Freeman, A.B., Hickling, G.J., and Bannock, C.A. 1996. Response of the skink *Oligosoma maccanni* (Reptilia : Lacertilia) to two vertebrate pest-control baits. *Wildlife Research* **23,** 511-516.

Fullagar, P.J., McKean, J.L. and van Tets, G.F. (1974). Appendix F. Report on the birds. In *Environmental Survey of Lord Howe Island: A Report to the Lord Howe Island Board*. (eds H.F. Recher and S.S. Clark). New South Wales Government Printer.

Garcia MA, Diez CE, Alvarez AO 2002. The eradication of Rattus rattus from Monito Island, West Indies. In: Veitch CR, Clout MN eds. *Turning the tide: the eradication of invasive species*, IUCN SSC Invasive Species Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. Pp. 116-119.

Garnett, S. and Crowley, G.M. (2000). The action plan for Australian birds 2000. Environment Australia, Canberra.

Gerlach, J. and Florens, V. (2000). Considering molluscs in rodent eradication projects. *Tentacle - The Newsletter of the IUCN/SSC Mollusc Specialist Group* **9**, 7-8.

Gillespie, J. (1993). Avian husbandry notes; guidelines; the Lord Howe Island Woodhen *Tricholimnas sylvestris*. Taronga Zoo, Sydney.

Godfrey MER 1985. Non-target and secondary poisoning hazards of 'second generation'

anticoagulants. *Acta Zoologica Fennica* **173**: 209-212.

Green C 2002: Recovery of invertebrate populations on Tirtiri Matangi Island New Zealand following eradication of Pacific rats (*Rattus exulans*). In: Veitch CR, Clout MN eds. Turning the tide: the eradication of invasive species, IUCN SSC Invasive Species Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. Pp. 407.

Green C J, Gibbs G W, Barrett P A 2011: Wetapunga (Deinacrida heteracantha) population changes following Pacific rat (Rattus exulans) eradication on Little Barrier Island. In: Veitch CR, Clout MN, Towns DR eds. Island Invasives: Eradication and Management. *Proceedings of the International Conference on Island Invasives*, IUCN, Gland, Switzerland, Auckland, New Zealand. Pp. 305-308

Griffiths R 2004. Little Barrier Island Kiore Eradication Monitoring Report. Unpublished, Hamro-100283 Warkworth Area Office, Department of Conservation, Warkworth

Griffiths R, Brown P 2011. The Rangitoto and Motutapu Pest Eradication Post Operational and Monitoring Report. Unpublished, Docdm-693971 Auckland Area Office, Department of Conservation, Auckland

Groombridge, B. (1992). Global biodiversity: status of the earth's living resources: a report. Report prepared for the World Conservation Monitoring Centre, British Museum (Natural History), and International Union for Conservation of Nature and Natural Resources. Chapman and Hall, London.

Harden, B. (2001). Recent trends in the number of woodhen recorded during surveys. Unpublished report to the Lord Howe Island Board. NSW National Parks and Wildlife Service, Armidale.

Harden, R.H. and Robertshaw, J.D. (1988). Lord Howe Island woodhen census, 1987. Unpublished report to the NSW National Parks and Wildlife Service, Sydney.

Hasber S, Hafidzi M.D, Noor H H, Dzolkhifli O, Azhar K, Cik M.R.Z.A. 2015: The effects of rodenticide residues deposited in eggs of Tyto alba to eggshell thickness. *Sains Malaysiana* **44** (4): 559-564.

Higgins, P.J. and Davies, S.J.J.F. (1996) Handbook of Australian, New Zealand and Antarctic Birds. Volume 3: snipes to pigeon. Melbourne, Oxford University Press.

Higgins, P.J., Peter, J.M. and Cowling, S.J. (2006). Handbook of Australian, New Zealand and Antarctic Birds. Volume 7: boatbill to starlings. Oxford University Press, Melbourne.

Hindwood, K.A. (1940). The birds of Lord Howe Island. *Emu* **40**, 1-86.

Hoare, J.M. and Hare, K.M. (2006). The impact of Brodifacoum on non-target wildlife: gaps in knowledge. *New Zealand Journal of Ecology* **30**(2), 157-167.

Holdaway, R. N., Hawke, D. J., Hyatt, O. M. and Wood, G. C. (2007). Stable isotopic (15N, 13C) analysis of wood in trees growing in past and present colonies of burrow-nesting seabirds in New Zealand. I. 15N in two species of conifer (Podocarpaceae) from a mainland colony of Westland petrels (Procellaria westlandica), Punakaiki, South Island. *Journal of the Royal Society of New Zealand* **37**, 75-84.

Horgan, F.,Campbell, C. Harrison, K., Milledge, D., and Cooke, R. 2013. Molecular data contradicts historical records and cautions translocation of the Lord Howe Island masked owl. *Biological Conservation* **159** 313-320

Howald GR, Mineau P, Elliott JE, Cheng KM 1999. Brodifacoum poisoning of avian scavengers during rat control on a seabird colony. *Ecotoxicology* **8**: 431-447.

Howald,G.,Donlan,C.J.,Faulkner,K.R.,Ortega,S.,Gellerman,H.,Croll,D.A.,Tershy, B.R., 2010. Eradication of black rats Rattus rattus from Anacapa Island.*Oryx* **44** (01),30–40.

Howald, G., Donlan, C.J., Galvan, J.P., Russell, J.C., Parkes, J., Samaniego, A., Wang, Y., Veitch, D., Genovesi, P., Pascal, M., Saunders, A. and Tershy, B. (2007). Invasive rodent eradication on islands. *Conservation Biology* **21**, 1258-1268.

Howald, G.R., Faulkner, K.R., Tershy, B., Keitt, B., Gellerman, H., Creel, E.M., Grinnell, M., Ortega, S.T. and Croll, D.A. (2005). Eradication of Black Rats from Anacapa Island: biological and social considerations. In *Proceedings of the Sixth California Islands Symposium.* (eds D. K. Garcelon and C. A. Schwemm). National Park Service Technical Publication CHIS-05-01, Institute for Wildlife Studies, Arcata, California.

Howald, G., Donlan, C. J., Galvan, J. P., Russell, J. C., Parkes, J., Samaniego, A., Wang, Y., Veitch, D., Genovesi, P., Pascal, M., Saunders, A. and Tershy, B. (2007). Invasive rodent eradication on islands. *Conservation Biology* **21**, 1258-1268.

Hoye, G.A. 1995. "Large Forest Bat *Vespadelus darlingtoni"* in The Mammals of Australia (ed. R. Strahan) Reed Books, Chatswood.

Hull, A.F.B. (1910). The birds of Lord Howe and Norfolk Islands. *Proceedings of the Linnean Society of New South Wales* **34**(4), 636-693.

Hutton, I. (1991). Birds of Lord Howe Island: Past and Present. Ian Hutton, Coffs Harbour.

Hutton, I. (1998). The Australian Geographic Book of Lord Howe Island. Australian Geographic, Terrey Hills.

Hutton, I. (2007). Investigation into captive breeding and surveys of *Placostylus bivaricosus* on Lord Howe Island. Unpublished report prepared for the Lord Howe Island Board.

Hutton, I., Parkes, J.P., and Sinclair, A.R.E. 2007. Reassembling island ecosystems: the case of Lord Howe Island. *Animal Conservation* **10**(1), 22-29.

Jones, A. G., Chown, S. L., Ryan, P. G., Gremmen, N. J. M. and Gaston, K. J. (2003). A review of conservation threats on Gough Island: a case study for terrestrial conservation in the Southern Oceans. *Biological Conservation* **113**, 75-87.

Jones, H. P., Tershy, B. R., Zavaleta, E. S., Croll, D. A., Keitt, B. S., Finkelstein, M. E. and Howald, G. R. (2008). Severity of the effects of invasive rats on seabirds: a global review. *Conservation Biology* **22**, 16-26.

Knight, B.J. (1987). A population survey of the Lord Howe Island Currawong. *Australian Birds* **21** (1), 28-29.

Laas FY, Forss DA, Godfrey MER 1985. Retention of brodifacoum in sheep and excretion in faeces. *New Zealand Journal of Agricultural Research* **28**: 357-359.

Lane, B.A. (1987). Shorebirds in Australia. Royal Australasian Ornithologists Union, Melbourne.

Lavoie, C., Donlan, C. J., Campbell, K., Cruz, F. and Carrion, V. G. (2007). Geographic tools for eradication programmes of insular non-native mammals. *Biological Invasions* **9**, 139-148.

Lourie-Fraser, G. (1985). Successful woodhen project - a brief overview. *Australian Aviculture* **November**, 255-271.

Lovegrove TG, Ritchie J 2005. Impacts of the aerial application of brodifacoum baits in September and October 2004 on bird populations at Tawharanui Regional Park. Auckland Regional Council, Auckland, NZ. 14 p.

LHIB (2007). Report on non-toxic bait trials Lord Howe Island – August 2007. Unpublished report for the Lord Howe Island Board.

Macleod, L. and Saunders, G. (2013). Pesticides used in the Management of Vertebrate Pests in Australia: A Review. NSW Department of Primary Industries, Orange.

Maitland MJ 2012. Shakespear Open Sanctuary animal pest eradication monitoring report #1. Auckland Council, Auckland, New Zealand. 69 p.

MacKay, J. W. B., Russell, J. C. and Murphy, E. C. (2007). Eradicating house mice from islands: successes, failures and the way forward. In 'Managing Vertebrate Invasive Species: *Proceedings of an International Symposium* '. Eds G. W. Witmer, W. C. Pitt and K. A. Fagerstone. pp. 64-66. (USDA/Aphis/WS, National Wildlife Research Center: Fort Collins.)

Marchant, S. and Higgins, P.J. (1993). Handbook of Australian, New Zealand and Antarctic Birds. Volume 2: raptors to lapwings. Oxford University Press, Melbourne.

Marris, J. W. M. (2000). The beetle (Coleoptera) fauna of the Antipodes Islands, with comments on the impact of mice: and an annotated checklist of the insect and arachnid fauna. *Journal of the Royal Society of New Zealand* **30**, 169-195.

Masuda BM, Fisher P, Beaven B 2015. Residue profiles of brodifacoum in coastal marine species following an island rodent eradication. *Ecotoxicology and Environmental Safety* **113**: 1-8

Masuda BM, Jamieson IG 2012. The impact of a rat invasion and subsequent aerial brodifacoum poisoning operation on survival of a marked population of Stewart Island Robins and on other endemic birds species on Ulva Island. Technical report University of Otago, Dunedin, NZ. 12 p.

Mayr, E. and Greenway, J.C. (1962). Check-list of birds of the world. Volume 15. Museum of Comparative Zoology, Cambridge.

McAllan, I.A.W., Curtis, B.R., Hutton, I. & Cooper, R.M. (2004). The birds of the Lord Howe Island Group: a review of records. *Australian Filed Ornithology* **21**.

McFarland, D.C. (1994). Notes on the Lord Howe Island Currawong *Strepera graculina crissalis. Australian Bird Watcher* **15**, 310-313.

McClelland P 2002. Eradication of rats from Codfish, Putauhinu and Raratoka Islands. In: Veitch CR, Clout MN eds. *Turning the tide: the eradication of invasive species, IUCN SSC Invasive Species Specialist Group*. IUCN, Gland, Switzerland and Cambridge, UK. Pp. 173-181.

McClelland, Broome, Mineau, Springer 2015: A review of rodent eradication projects on the Galapagos Islands focused on the Rabida(2010) and Pinzon (2012) operations. Island Conservation unpublished internal report.

Merton, D. (1987). Eradication of rabbits from Round Island, Mauritius: a conservation success story. *Dodo* **24**, 19-43.

Merton, D., Climo, G., Laboudallon, V., Robert, S. and Mander, C. (2002). Alien mammal eradication and quarantine on inhabited islands in the Seychelles. Pp. 182-198 In *Turning the Tide:*

the Eradication of Invasive Species (eds C. R. Veitch and M. N. Clout). IUCN; Gland, Switzerland.

Moore Jr, H. E. (1966). Palm hunting around the world. IV Lord Howe Island. *Principes* **10**, 12-21.

Moors, P. J. (1985). Eradication campaign against *Rattus norvegicus* on the Noises Islands, New Zealand, using brodifacoum and 1080. In ' Conservation of Island Birds: Case Studies for the Management of Threatened Island Species. Technical Publication No. 3'. pp. 143-155. (International Council for Bird Preservation: Cambridge.)

Morgan DR, Wright GR, Ogilvie SC 1996. Assessment of the environmental impact of brodifacoum during rodent eradication operations in New Zealand. In: Timm RM, Crabb AC eds., University of California, Davis, USA. Pp. 213-218.

Meyer, J-Y and Butaud, J-F. 2009. The impacts of rats on the endangered native flora of French Polynesia (Pacific Islands): drivers of plant extinction or coup de grace species? *Biological Invasions* **11,** 1569-1585.

Mickelson L 2012. Taranga Trip Report March 2012 Monitoring report. Victoria University of Wellington, Wellington, NZ. 3 p.

Miller, B. and Mullette, K.J. (1985). Rehabilitation of an endangered Australian bird: the Lord Howe Island Woodhen (Sclater). *Biological Conservation* **34**, 55-95.

Morgan, D.R. (1993). Lab report to the Department of Conservation on assays of samples from Coppermine and Red Mercury islands. Unpublished report. Landcare Research, Hamilton.

Morgan, D.R. and Wright, G.R. (1996). Environmental effects of rodent Talon® baiting. Part 1: Monitoring for toxic residues. Science for Conservation: 38. Dept. of Conservation, Wellington, New Zealand.

Morgan, D.R., Wright, G.R., Ogilvie, S.C., Pierce, R. and Thompson, P. (1996). Assessment of the environmental impact of Brodifacoum during rodent eradication operations in New Zealand. Pp. 213-218 in *Proceedings of the Seventeenth Vertebrate Pest Control Conference* (eds R.M. Timm and A.C. Crabb). Davis, California.

Murray Darling Basin Commission (2009). Native Fish Factsheets – Short-finned Eel. http://www.mdbc.gov.au/subs/fish-info/native_info/shortfinnedEel.html

Nevill, J. (2004). Eco-tourism as a source of funding to control invasive species: The case of the Seychelles. *International Journal of Island Affairs*. **February,** 99 – 102.

Newby, S. and White, B.G. (1978).Brodifacoum: Adsorption and desorption in soils measured under laboratory conditions. Haslemere, Surrey, Imperial Chemical Industries Ltd. Plant Protection Division (Report No. TMJ 1764B.

Newman, D. G. (1994). Effects of a mouse, Mus musculus, eradication programme and habitat change on a lizard population on Mana Island, New Zealand, with special reference to McGregor's skink, Cyclodina macgregori. *New Zealand Journal of Zoology* **21**, 443-456.

North, S.G., Bullock, D.J., Dulloo, M.E. (1994). Changes in vegetation and reptile populations on Round Island, Mauritius, following eradication of rabbits. *Biological Conservation* **67**, 21-28.

NPWS (1999). Threatened Species Information Sheet: Sooty Tern. NSW National Parks and Wildlife Service, Hurstville.

NPWS (2001). *Lord Howe Island Placostylus* Placostylus bivaricosus *(Gaskoin, 1855) Recovery Plan*. NSW National Parks and Wildlife Service, Hurstville.

NPWS (2002). *Recovery Plan for the Lord Howe Woodhen* Gallirallus sylvestris. NSW National Parks and Wildlife Service, Hurstville.

NSW Scientific Committee (2008a). *Pericryptodrilus nanus* **(An** Earthworm) – Endangered Species Listing.
http://www.environment.nsw.gov.au/determinations/PericryptodrilusNanus
Date accessed 4/11/2009.

NSW Scientific Committee (2008b). Lord Howe Island Wood-feeding Cockroach – Endangered Species Listing
http://www.environment.nsw.gov.au/determinations/PanesthiaLata
Date accessed 4/11/2009.

Ogilvie, S.C., Pierce, R.J., Wright, G.R.G., Booth, L.H. and Eason, C.T. (1997). Brodifacoum residue analysis in water, soil, invertebrates, and birds after rat eradication on Lady Alice Island. *New Zealand Journal of Ecology* **21**, 195-197.

Olivera P, Menezes D, Trout R, Buckle A, Geraldes P, Jesus J 2010. Successful eradication of the European rabbit (Oryctolagus cuniculus) and house mouse (Mus musculus) from the island of Selvagem Grande (Macaronesian archipelago), in the Eastern Atlantic. *Integrative Zoology* **5**: 70-83.

Parkes, J., Ruscoe, W., Fisher, P. and Thomas, B. (2004). Benefits, constraints, risks and costs of rodent control options on Lord Howe Island. Unpublished report to the Lord Howe Island Board. Landcare Research, Lincoln, New Zealand.

Pickard, J. (1982). Catastrophic disturbance and vegetation on Little Slope, Lord Howe Island. *Australian Journal of Ecology* **7**, 161-170.

Pickard, J. (1983). Vegetation of Lord Howe Island. *Cunninghamii* **1,** 133-265.

Pitt WC, Berentsen AR, Volker SF, Eisemann JD 2012. Palmyra Rainforest Restoration Project: Monitoring Results for the Application of Broadcast of Brodifacoum 25W. USDA, APHIS, National Wildlife Research Center, Hilo Hawaii.

Pitt WC, Berentsen AR, Shiels AB, Volker SF, Eisemann JD, Wegmann AS, Howald GR 2015. Non-target species mortality and the measurement of brodifacoum rodenticide residues after a rat (Rattus rattus) eradication on Palmyra Atoll, tropical Pacific. *Biological Conservation* **185**.

Ponder, W.F. (1997). Conservation status, threats and habitat requirements of Australian terrestrial and freshwater mollusca. *Memoirs of the Museum of Victoria* **56**, 421-430.

Ponder, W. and Chapman, R. (1999). Survey of the Land Snail *Placostylus bivaricosus* on Lord Howe Island. Unpublished report to the NSW National Parks and Wildlife Service.

Priddel, D. (1996). The status of seabirds in New South Wales. Pp. 201-208 in *The status of Australia's seabirds: proceedings of the National Seabird Workshop, Canberra 1-2 November 1993.* (eds G.J.B. Ross, K. Weaver and J.C. Grieg.). Biodiversity Group, Environment Australia, Canberra.

Priddel, D., Carlile, N., Humphrey, M., Fellenberg, S. and Hiscox, D. (2003). Rediscovery of the 'extinct' Lord Howe Island stick-insect (*Dryococelus australis* (Montrouzier)) (Phasmatodea) and

recommendations for its conservation. *Biodiversity and Conservation* **12**, 1391-1403.

Primus, T., Wright, G. and Fisher, P. (2005). Accidental discharge of Brodifacoum baits in a tidal marine environment: a case study. *Bulletin of Environmental Contamination and Toxicology* **74**, 913–919.

Pringle, J.D. (1987). Shorebirds of Australia. Angus and Robertson, North Ryde.

Rance, B. (2001). Titi Islands expedition, March 2001. Unpublished Report RI 6418. Department of Conservation, Invercargill.

Ranum A, Dawson N, Elliott G 1994. The effect of brodifacoum on South Island Fernbirds (Bowdleria punctata punctata) in the Waituna Wetlands Scientific Reserve. 16 p.

Rennison BD, Hadler MR 1975. Field trials of difenacoum against warfarin-resistant infestations of Rattus norvegicus. *Journal of Hygiene* **74**: 449-455.

Robertson HA, Colbourne RM 2001. Survival of little spotted kiwi exposed to the rodenticide brodifacoum. *Journal of Wildlife Management* **65**: 29-34.

Robertson HA, Colbourne RM, Niewland F 1993. Survival of little spotted kiwi and other forest birds exposed to brodifacoum rat poison on Red Mercury Island. *Notornis* **40**: 253-262.

Samaniego-Herrera, A., Aguirre-Muñoz, A., Howald, G.R., Félix-Lizárraga, M., Valdez-Villavicencio, J., González-Gómez, R., Méndez-Sánchez, F., Torresgarcía, F., Rodríguez-Malagón, M. and. Tershy, B.R. (2009). Eradication of Black Rats from Farallón de San Ignacio and San Pedro Mártir islands, Gulf of California, Mexico. Pp. 337–347 in *Proceedings of the 7th California Islands Symposium*.(eds C.C. Damiani, and D.K. Garcelon). Institute for Wildlife Studies, Arcata, CA..

Science Alert 2009, www.sciencealert .com.au/news/20093107-19488.html Accessed 29/9/9.

Schodde, R. and Mason, I.J. (1999). The directory of Australian birds. CSIRO Wildlife and Ecology, Canberra.

Shaw, J. D., Hovenden, M. and Bergstrom, D. M. (2005). The impact of introduced ship rats (*Rattus rattus*) on seedling recruitment and distribution of a subantarctic megaherb (*Pleurophyllum hookeri*). *Austral Ecology* **30**, 118-125.

Shirer, M. (1992). In poison's defence. *Terra Nova* **17**, 3.

Sinclair L, McCartney J, Godfrey J, Pledger S, Wakelin M, Sherley G 2005. How did invertebrates respond to eradication of rats from Kapiti Island, New Zealand? *NZ Journal of Zoology* **32**. 4 293-315.

Smith, V. R. and Steenkamp, M. (1990). Climatic change and its ecological implications at a subantarctic island. *Oecologia* **85**, 1424.

Spurr, E.B. and Drew, K.W. (1999). Invertebrates feeding on baits used for vertebrate pest control in New Zealand. *New Zealand Journal of Ecology* **23**, 167-173.

Stephenson BM, Minot EO, Armstong DP 1999. Fate of moreporks (Ninox novaeseelandiae) during a pest control operation on Mokoia Island, Lake Rotorua, North Island, New Zealand. New Zealand *Journal of Ecology* **23:** 233-240.

Taronga Conservation Society Australia, (2014). Captive management for Woodhen and LHI Currawong associated with the Lord Howe Island Rodent Eradication project. An unpublished report for the Lord Howe Island Board.

Taylor, R. H. and Thomas, B. W. (1989). Eradication of Norway rats (Rattus norvegicus) from Hawea Island, Fiordland, using brodifacoum. *New Zealand Journal of Ecology* **12**, 23-32.

Taylor, R. H. and Thomas, B. W. (1993). Rats eradicated from rugged Breaksea Island (170 ha), Fiordland, New Zealand. *Biological Conservation* **65**, 191-198.

Thompson, R.D., Mitchell, G.C. and Burns, R.J. 1972. Vampire bat control by systemic treatment of livestock with an anticoagualant. *Science* **177**, 806-808.

Thorsen M, Shorten R, Lucking R, Lucking V 1999. Norway rats (Rattus norvegicus) on Fregate Island, Seychelles: the invasion; subsequent eradication attempts andimplications for the island's fauna. *Biological Conservation* **96**: 133-138.

Tomlin, C. (2009) The Pesticide Manual: A World Compendium. BCPC

Torr N 2002. Eradication of rabbits and mice from subantarctic Enderby and Rose Islands. In: Veitch CR, Clout MN eds. Turning the tide: the eradication of invasive species, IUCN SSC Invasive Species Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. Pp. 319-328.

Torr, N.and Agnew, D.(2007).Trial to determine differences in bait fragmentation in various spreader bucket designs used during aerial application of toxic bait. Department of Conservation, New Zealand Government. February 2007.

Towns, D., McFadden, I. and Lovegrove, T. (1993). Offshore islands co-operative conservation project with ICI Crop Care Division: Phase one (Stanley Island). Science and Research Internal Report 138. Department of Conservation, Wellington.

Towns, D.R. (1991). Response of lizard assemblages in the Mercury Islands, New Zealand, to removal of an introduced rodent: the kiore (*Rattus exulans*). *Journal of the Royal Society of New Zealand* **21**, 119-136.

Towns, D.R. (1994). The role of ecological restoration in the conservation of Whitaker's skink (*Cyclodina whitakeri*), a rare New Zealand lizard (Lacertilia: Scincidae). *New Zealand Journal of Zoology* **21**, 457-471.

Towns, D. R. and Broome, K. G. (2003). From small Maria to massive Campbell: forty years of rat eradications from New Zealand islands. *New Zealand Journal of Zoology* **30**, 377-398.

Towns, R. T., Atkinson, I. A. E. and Daugherty, C. H. (2006). Have the harmful effects of introduced rats on islands been exaggerated? *Biological Invasions* **8**, 863-891.

Towns, D.R. and Daugherty, C.H. (1994). Patterns of range contractions and extinctions in the New Zealand herpetofauna following human colonization. *New Zealand Journal of Zoology* **21**, 325-339

Toxikos (2010). Human Health Risk Assessment for the use of Brodifacoum for the Lord Howe Island Rodent Eradication Plan. Unpublished Report for the Lord Howe Island Board. Toxikos Pty Ltd.

Traveset, A., Nogales, M., Alcover, J., Delgado, J., Lopez-Darias, M., Godoy, D., Igual, J., and Bover, P. 2009. A review on the effects of alien rodents in the Balearic (Western Mediterranean Sea) and Canary Islands (Eastern Atlantic Ocean). *Biological Invasions* **11,** 1653-1670.

U.S. Environmental Protection Agency. 1998. Reregistration Eligibility Decision (RED): Rodenticide Cluster. EPA 738-R-98-007. 319 pp.

U.S. Fish and Wildlife Service and Hawai'i Department of Land and Natural Resources. (2008). Final supplemental environmental assessment Lehua Island ecosystem restoration project October 2008. Honolulu, Hawaii.

Vandenbroucke V, Bousquet-Melou A, De Backer P, Croubels S 2008. Pharmacokinetics of eight anticoagulant rodenticides in mice after single oral administration. *Journal of Veterinary Pharmacology and Therapeutics* **31**: 437-445.

Vestena C, Walker A 2010. Ipipiri Rodent Eradication 2009 Post Operational Monitoring Report. Unpublished, Docdm-483696 Bay of Islands Area Office, Department of Conservation, Kerikeri

Walker K, Elliott G 1997. Effect of the poison brodifacoum on non-target birds on the Chetwode Islands. *Ecological Management* 5: 21-27.

Watkins, D. (1993). A National Plan for Shorebird Conservation in Australia. RAOU Report No. 9. Royal Australasian Ornithologists Union, Moonie Ponds.

Wedding CJ. 2007. Aspects of the Impacts of Mouse (Mus musculus) Control on Skinks in Auckland, New Zealand. Unpublished MSc thesis. Massey University, Auckland. 133 p.

Western Australian Marine Parks Authority (2010). http:/www.marineparks.wa.gov.au/fun-facts/

Wilkinson, I .and Hutton, I. (2013). Assessing the risk of Pestoff® 20R brodifacoum baits to the Lord Howe Island flax snail (*Placostylus bivaricosus*). Unpublished Report for the Lord Howe Island Board

Witmer GW and Mauldin R. 2012. Assessing the potential hazard of anticoagulant rodenticides to non-target reptiles. National Wildlife Research Center report QA-1434.

WHO (1995). Anticoagulant rodenticides. International Programme on Chemical Safety. Environmental Health Criteria 175. World Health Organisation, Geneva, Switzerland.

APPENDIX 1 – RISK ASSESMENT OF LOCALLY PROTECTED AVIFAUNA

Risk assessment for locally protected avifauna (i.e. resident and regularly visiting bird species found on the Lord Howe Island Group) as declared under the National Parks and Wildlife Act 1974 and/or the Lord Howe Island Act 1953. Data on species derived from Hutton 1991, McAllan *et al.* 2004 and DECC 2007.

Species	**Resident/visitor**	**Comments**	**Individuals at risk (in the absence of mitigation)**	**Species at risk (in the absence of mitigation)**
Australasian Gannet *Morus serrator*	Rare regular visitor	Numbers seen on LHI are small, typically one or two a year. Gannets feed at sea and secondary poisoning through consumption of poisoned fish is considered unlikely. The baiting will not affect a significant proportion of the regional population.	No	No
Australian Kestrel *Falco cenchroides*	Resident	Established on LHI from the 1940s. Known to prey on mice, therefore at high risk of secondary poisoning from eating dead or dying rodents. No mitigation procedures are proposed for this species.	Yes	Yes; local extinction is probable
Black Noddy *Anous minutus*	Regular visitor	Believed to have begun breeding on LHI on a regular basis in the 1980s, the colony had grown to approximately 200 nests by 2003. The species is mainly present from September to May although a few birds over winter on the LHIG. Because these noddies feed on	No	No

		small fish and crustaceans taken from near the sea surface, secondary poisoning through consumption of fish is considered unlikely.		
Buff-banded Rail *Gallirallus philippensis*	Resident	This species may have been introduced to LHI in the late 19th Century (Hutton 1991). Anecdotally this it is suggested that deliberate introduction was through a LHI resident. Rodent baiting with Brodifacoum on New Zealand islands has resulted in large numbers of the similar Weka (*Gallirallus australis*) being killed. Trials conducted on LHI with a non-toxic bait containing dye indicated that the Buff-banded Rail will eat baits. Therefore it is expected that this species will be significantly affected by the baiting programme. Buff-banded Rails are proficient island colonisers; any reduction in the current LHI population will be made good by the reproductive output of the survivors and/or immigration. No mitigation procedures are proposed for this species.	Yes	Yes; local extinction is possible
Emerald Dove *Chalcophaps indica*	Resident	Trials conducted on LHI using non-toxic bait pellets indicated that this ground-dove would not eat the bait if the pellets are dyed green (which they will be). It is therefore very unlikely that it will be harmed by the proposed baiting.	No	No
Great Cormorant *Phalacrocorax carbo*	Regular visitor	Records of sightings of this species on LHI are mainly from the warmer months (McAllan *et al*. 2004). Sighting numbers range from one to 40. The low numbers of cormorants likely to be present in winter, together with a diet preference of fish, strongly suggest that this species will not be threatened by the proposed rodent baiting.	No	No

Great-winged Petrel *Pterodroma macroptera*	Regular visitor	Most sightings have been at sea, e.g., around Balls Pyramid. The two land records for LHIG include a beach-washed bird (McAllan *et al*. 2004). Balls Pyramid is not included in the areas proposed for baiting. This species feeds at sea; therefore it is very unlikely to be poisoned.	No	No
Magpie Lark *Grallina cyanoleuca*	Resident	Birds were introduced to LHI in 1924 although some appear to have arrived on their own account in the decade before (Hutton 1991). They are insectivorous however secondary poisoning through consumption of poisoned invertebrates is considered unlikely.	No	No
Masked Lapwing *Vanellus miles*	Resident	First recorded on LHI in 1938 but no breeding records prior to 1990 (Hutton 1991). The size of the population present on LHI is less than 30. Their diet is comprised of molluscs, worms, millipedes, centipedes, spiders and insects however secondary poisoning through consumption of poisoned invertebrates is considered unlikely. The small number of resident birds indicate that the baiting programme is not a significant threat to the regional population of this species.	No	No
Pacific Black Duck A*nas superciliosa*	Resident	Have been recorded on LHI as stragglers since 1852. A population became established there in the 1970s (Hutton 1991), and currently numbers less than 20. Ducks have been observed eating non-toxic baits indicating that they are susceptible to primary poisoning. At this stage, no mitigation measures are proposed for this species.	Yes	Yes; local extinction is possible
Purple Swamphen *Porphyrio porphyrio*	Resident	Swamphens were first recorded on the island in the 1880s but there are no known instances of the birds breeding here until 100 years later. In New Zealand, Brodifacoum baiting is known to have caused large numbers of deaths among Purple Swamphen, so the same is likely to happen on LHI. If lost from LHI, they	Yes;	Yes; local extinction is possible

		are likely to re-colonise. At this stage, no mitigation measures are proposed for these species.		
Sacred Kingfisher *Todiramphus sanctus*	Resident	This species probably colonised LHI in the latter half of the 19th Century (Hutton 1991). Its diet consists of fish and crustaceans taken from rock pools, and invertebrates and worms collected from the forests and fields, although there are reports that kingfishers will prey on mice. Therefore secondary poisoning through consumption of poisoned mice is possible, however not considered to be significant.	Yes	No
Welcome Swallow *Hirundo neoxena*	Resident	Its diet of flying insects pose little threat as a source of secondary poisoning.	No	No
White-faced Heron *Ardea novaehollandiae*	Resident	Known to eat mice on LHI therefore it is at risk of secondary poisoning from eating dead or dying rodents however not considered to be significant.	Yes	No

APPENDIX 2A- RISK ASSESMSNET FOR LISTED BIRDS NOT AT RISK

Risk assessment for bird species listed as *Migratory, Marine* or *Vulnerable* in the Environmental Protection and Biodiversity Conservation Act 1999 (the EPBC Act) or as *Vulnerable* in the Threatened Species Conservation Act 1995 (TSC Act) which are not regarded as being at significant risk from the baiting proposal. Data on species derived from Hutton 1991, McAllan *et al*. 2004 and DECC 2007.

Mi= *Migratory* species as listed in various international treaties to which the Australian Government is a signatory.
Ma = *Marine* Species listed under the EPBC Act.
C = Critically Endangered
E = *Endangered*.
V = *Vulnerable*.

Species	**Resident/visitor**	**Comments**	**Individuals at risk (in the absence of mitigation)**	**Species at risk (in the absence of mitigation)**	**EPBC Act**	**TSC Act**
Australasian Bittern *Botaurus poiciloptilus*	Vagrant	Only one verified record for LHI (and that is from 1888) (McAllan *et al*. 2004). The eradication programme is not a threat to this species.	No	No	E	E
Black-browed Albatross *Diomedea melanophris*	Vagrant	Only three records of occurrence in the LHIG, and all were at sea (McAllan *et al*. 2004). This species feeds on fish and squid. The eradication programme is not a threat to this species	No	No	V, Mi, Ma	/

Black-naped Tern *Sterna sumatrana*	Vagrant	Only one bird has been recorded on the LHIG (in April 1989) (McAllan *et al*. 2004). It is very unlikely that a significant population of this species will be in the area during baiting. The eradication programme is not a threat to this species.	No	No	Mi, Ma	/
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 unlikely to be on the island during baiting.	No	No	Mi, Ma	V
Black-winged Petrel *Pterodroma nigripennis*	Regular visitor	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	Ma	V
Brown Booby *Sula leucogaster*	Vagrant	Only four birds seen in the vicinity of the LHIG in the period 1971 to 2003 (McAllan *et al*. 2004). The proposed baiting is not a threat to this fish-eating species.	No	No	Mi, Ma	/
Buff-breasted Sandpiper *Tryngites subruficollis*	Vagrant	Only one record of this species seen on LHI (circa 1980) (McAllan *et al*. 2004). The eradication programme is not a threat to this species.	No	No	Mi, Ma	/
Caspian Tern *Sterna caspia*	Irregular visitor	This tern may be in the area during winter (movements poorly known), although the only two birds seen on the LHIG were recorded in September through to November (McAllan *et al*. 2004). The unlikely occurrence of this species on the LHIG during August and its diet of fish and some insects (taken in pastures) indicate that the species is not threatened by the eradication.	No	No	Mi, Ma	/

Cattle Egret *Ardea ibis*	Regular visitor	Eats invertebrates, lizards, frogs and fish. Prey items usually < 3 cm. Typically birds migrating between Australia and New Zealand stop over on LHI in May-June and October to December, although a small number may over-winter on LHI (Hutton 1991). The diet of Cattle Egrets, and the small number of birds that may be present during the baiting make it unlikely that the rodent eradication poses a significant threat to this species.	No	No	Mi, Ma	/
Chatham Albatross *Thalassarche eremita*	Vagrant/irregular visitor; seabird	Known to forage in the area but feeding occurs over deep water so there is negligible risk of either primary or secondary poisoning	No	No	E, Mi, Ma	/
Common Greenshank *Tringa nebularia*	Vagrant/irregular visitor; wader	There have only been 13 sightings of this species on LHI between 1963 and 2003 (McAllan *et al.* 2004); all but one occurred in the months October to March. One record (of one individual) is from July 1992. Although their diet is mostly crustaceans, molluscs, insects, fish and frogs, they have been recorded eating rodents. Any Common Greenshank on LHI at the time of baiting is at risk of secondary poisoning but the likelihood that many, if any, would be killed is remote. Therefore, the proposed rodent eradication does not pose a significant threat to the species.	No	No	Mi, Ma	/
Common Sandpiper *Tringa hypoleucos*	Vagrant/irregular visitor; wader	There are nine positive records, mostly of one or two birds, from LHI covering the period 1959-2002, and from the months November to March. The proposed rodent eradication in June- August does not pose a significant threat to the species.	No	No	Mi, Ma	/

Common Tern *Sterna hirundo*	Irregular visitor	The five birds found on the LHI (1915-1967) were all recorded as summer visitors (McAllan *et al*. 2004). The Common Tern is not threatened by the rodent baiting.	No	No	Mi, Ma	/
Curlew Sandpiper *Calidris ferruginea*	Vagrant/irregular visitor; wader	There have been 12 or so sightings of the Curlew Sandpiper on LHI from 1963 to 2002, although some may be multiple records of the same individual (McAllan *et al.* 2004). Most of the sightings were made over the spring to autumn period but one was noted in late August. Foraging on tidal flats, its diet is made up of worms, molluscs, crustaceans, insects, small fish and seeds. The limited risk this diet poses, and the small number of birds that may be present in June - August suggest the baiting programme is not a significant threat to this species.	Yes	No	CE, Ma, Mi	E
Double-banded Plover *Charadrius bicinctus*	Regular visitor	It feeds on insects caught on lawns, and on marine worms and crustaceans taken at low tide along beaches. A small number of these plovers are seen on LHI between February and July (Hutton 1991). It is unlikely to be present in large numbers on LHI when the baiting is proposed, therefore the rodent eradication does not pose a significant threat to this species.	No	No	Mi, Ma	/
Eastern Curlew *Numenius madagascariensis*	Regular visitor	Records of the Eastern Curlew on LHI are for Autumn (March and April), Spring (September and November) and Summer. There is no indication that the species is on LHI in June-August, therefore it appears that individuals, let alone the species, will not be harmed by the baiting.	No	No	CE, Mi, Ma	/

Eastern Great Egret *Ardea modesta*	Irregular visitor	Eats invertebrates, lizards, frogs, fish and birds. Prey items usually < 15 cm. Only ten Great Egrets reported on LHI since the 1930s (McAllan *et al*. 2004). The low numbers recorded on LHI indicate that, although individuals may be at risk of secondary poisoning, the eradication programme is not a threat to this species at the population level.	Yes	No	Mi, Ma	/
Eastern Reef Egret *Egretta sacra*	Vagrant; land bird	Only one record from the LHIG (McAllan *et al.* 2004). Eats mainly fish, some crustaceans, molluscs, lizards, noddy chicks. Food items < 15 cm. The eradication programme is not a significant threat to the species.	No	No	Ma	/
Fork-tailed Swift *Apus pacificus*	Vagrant; land bird	An insectivorous bird only recorded on LHI in November 1971 (McAllan *et al.* 2004).	No	No	Mi, Ma	/
Glossy Ibis *Plegadis falcinellus*	Vagrant; land bird	Food is mostly aquatic invertebrates and insects, some fish, rice seed. Only one record for LHI. The eradication programme is not a threat to this species.	No	No	Mi, Ma	/
Gould's Petrel *Pterodroma leucoptera*	Vagrant	Only two at-sea records and one beach-wash record for this species. The eradication programme is not a threat to it.	No	No	Ma/E	V
Great Knot *Calidris tenuirostris*	Vagrant	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	Mi, Ma	V

Greater Sand Plover *Charadrius leschenaultii*	Vagrant	The three records for this species, spanning 1914 to 2002, are confined to Spring and Summer 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	Mi, Ma	V
Grey Plover *Pluvialis squatarola*	Vagrant	The low numbers of birds recorded (two from 1959, one from 1971), together with when they were seen (November, January) suggests that this species is not threatened by the proposed baiting.	No	No	Mi, Ma	/
Grey-tailed Tattler *Heteroscelus brevipes*	Regular visitor	Tattlers feed on crustaceans and other invertebrates on mudflats. In over a hundred years of records for LHI, only three tattlers were seen in August and four in September; all other sightings ($\geq$ 37) were reported in the months November to April. This species is not at significant risk from the proposed rodent eradication because it is unlikely to be present during baiting in significant numbers.	No	No	Mi, Ma	/
Kermadec Petrel *Pterodroma neglecta*	Regular visitor	Breeds on Balls Pyramid from November to May (Hutton 1991), and may been seen flying around Mt. Gower during summer. As it is not in the area when the baiting is planned, the eradication programme is not a threat to it.	No	No	V	V

Latham's Snipe *Gallinago hardwickii*	Regular visitor	There are no reports of this species being on the LHIG in August; most records are for the period November to May but "several" were recorded in September 1963 (McAllan *et al.* 2004). From 1956 to 1989 there have been 13 sightings of about 40 birds. (McAllan *et al*. 2004). The eradication programme is not a threat to this species.	No	No	Mi, Ma	/
Least or Lesser Frigatebird *Fregata ariel*	Vagrant	The only positive record of occurrence on the LHIG is from 1915. There are two possible sightings from the 1970s, but at least one of these was during cyclonic conditions (McAllan *et al*. 2004), possibly suggesting that the frigate had been blown to the area. Unlikely to be present at the LHIG during baiting. This, together with its fish diet, indicate that the species will not be threatened by the rodent eradication.	No	No	Mi, Ma	/
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	Mi, Ma	V
Little Curlew *Numenius minutus*	Irregular visitor	Only seven records of this species on LHI; and these are for the months from November to March. As it will not be present during baiting, the eradication will not be detrimental to it.	No	No	Mi, Ma	/
Little Tern *Sternula albifrons*	Vagrant	Unlikely to be in the area during baiting; the five individuals recorded on LHI from 1967 to 2003 were seen in the period October to March	No	No	Mi, Ma	E

		(McAllan *et al*. 2004). Also their diet of mainly fish (but also crustaceans, insects and molluscs) collected by diving into the sea or gleaning from its surface, make it unlikely that this species will be affected by the baiting.				
Long-tailed Jaeger *Stercorarius pomarinus*	Vagrant	Only two birds recorded for the LHIG; one in April 1975, the other in March 2002. The jaeger is unlikely to be in the area in sufficient numbers for the proposed eradication to be a significant threat to the species.	No	No	Mi, Ma	/
Marsh Sandpiper *Tringa stagnatilis*	Vagrant	Only four birds seen on LHI between 1977 and 1998 (McAllan *et al*. 2004). The rodent eradication will not be detrimental to this species.	No	No	Mi, Ma	/
Oriental Cuckoo *Cuculus saturatus*	Vagrant	Recorded on LHI in December 1913 and between February and May 1915. Cuckoos are unlikely to be on LHI during baiting.	No	No	Mi, Ma	/
Oriental Plover *Charadrius veredus*	Vagrant	Recorded on LHI twice. Up to 53 birds were reported in September 1982 and one bird seen in November 2002 (McAllan *et al*. 2004). It is unlikely that a significant number of Oriental Plovers would be on LHI during the eradication, therefore the eradication will not pose a significant threat to the species.	No	No	Mi, Ma	/
Oriental Pratincole *Glareola maldivarum*	Vagrant	There are only two records (each for one bird) for this species on LHI (circa 1979 and 1987) (McAllan *et al*. 2004). The baiting does not pose a significant risk to the species.	No	No	Mi, Ma	/
Painted Snipe *Rostratula*	Vagrant	There has only been one Painted Snipe recorded on LHI, and that was in February 1990. The	No	No	E, Mi	V

benghalensis		proposed baiting is not a threat to this species.				
Pectoral Sandpiper *Calidris melanotos*	Vagrant	The first record of a Pectoral Sandpiper on LHI is from 1945 (McAllan *et al*. 2004). Another four have been recorded up to 2003. These five birds were present on LHI during Spring to Autumn. Baiting in August is unlikely to pose a threat to the species or to individual birds.	No	No	Mi, Ma	/
Pied Oystercatcher *Haematopus longirostris*	Vagrant; wader	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 negligible.	No	No	/	V
Rainbow Bee-eater *Merops ornatus*	Vagrant	One bird seen in August 1990. It is extremely unlikely that any bee-eater will be present on LHI during the baiting, therefore the eradication programme is not a threat to this insectivorous species.	No	No	Mi, Ma	/
Red Knot *Calidris canutus*	Rare regular visitor	Records of Red Knot occurrence on LHI suggest only a few birds (one to three) may be on the island in any one Spring and "it is evident that either the (Lord Howe Island) Group is not on the regular migration path (between Australia and New Zealand) of the species or the Red Knot rarely needs to stop during migration" (McAllan *et al*. 2004, page 42). The Red Knot will not be adversely affected by the proposed rodent eradication.	No	No	Mi, Ma	/

Red-footed Booby *Sula sula*	Vagrant	Only one individual has been recorded on the LHIG (in February 1974) (McAllan *et al*. 2004). The species is not at risk from the rodent eradication.	No	No	Mi, Ma	/
Red-necked Stint *Calidris ruficollis*	Rare regular visitor	Records suggest that low numbers of Red-necked Stints (one to three individuals) are likely to be present on LHI over Spring to Autumn (McAllan *et al*. 2004). As such, the low numbers involved and the period when present indicate that the rodent eradication will not significantly harm the species.	No	No	Mi, Ma	/
Sharp-tailed Sandpiper *Calidris acuminata*	Regular visitor	Records suggest that low numbers of Sandpipers (one to four individuals) are likely to be present on LHI over Spring and Summer (McAllan *et al*. 2004). As such, the low numbers involved and the period when present indicate that the rodent eradication will not significantly harm the species	No	No	Mi, Ma	/
Short-tailed Shearwater *Puffinus tenuirostris*	Vagrant	Apart from five beachcast specimens found on LHI, all sightings, about 100+ birds, have been recorded off Balls Pyramid or between this island and LHI (McAllan *et al*. 2004). All sightings at sea were made in September or October, while the beachcast birds were found in December or January. Therefore this species will not be present when baiting is proposed. Also they feed at sea on a diet of fish and squid.	No	No	Mi, Ma	/
Sooty Oystercatcher *Haematopus fuliginosus*	Vagrant; wader	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. Any Sooty Oystercatcher foraging on the beaches on LHI in August will be at risk of secondary poisoning but this is highly unlikely.	No	No	/	V

Sooty Shearwater *Puffinus griseus*	Vagrant	Apart from a beachcast shearwater found in November 1964 and three seen off Balls Pyramid in October 1999, there are no other records of this species in the LHIG. The low numbers of birds seen, the rarity of sightings, the indication that if the species visits the area it will be in Spring and the fact that it feeds at sea all strongly suggest that this species will not be threatened by the rodent eradication.	No	No	Mi, Ma	/
Southern Giant Petrel *Macronectes giganteus*	Vagrant	Only four confirmed records for LHI; all prior to 1965, three of which were beach-cast specimens. There are reports of sightings on Balls Pyramid between 1978-1980 (McAllan *et al*. 2004). The eradication of rodents does not constitute a threat to this species.	No	No	E, Mi, Ma	/
Swift Parrot *Lathamus discolor*	Vagrant	One record only, and that is of a dead bird found in 1968. The eradication programme will not threaten this species.	No	No	E, Ma	E
Terek Sandpiper *Xenus cinereus*	Vagrant	Only five Terek Sandpipers seen on LHI from 1959 to 1991 (McAllan *et al*. 2004). The four records that have dates are for Spring and Summer. Baiting LHI in August will not threaten this species.	No	No	Mi, Ma	V
Wandering Albatross *Diomedea exulans*	Vagrant	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. This species feeds on fish and squid. It is not at risk of poisoning or collision with the baiting aircraft.	No	No	V, Mi, Ma	E
Wandering Tattler *Tringa incana*	Regular visitor	Records indicate that this bird may be present on LHI only over late Summer and Autumn. As it is unlikely to be in the area in June- August, the baiting programme is not a danger to it.	No	No	Mi, Ma	/
Westland Petrel *Procellaria westlandica*	Vagrant	Only one at-sea record for this species for the LHIG. The eradication programme is not a threat to it.	No	No	Mi, Ma	/

Whiskered Tern *Chlidonias leucoptera*	Vagrant	Several sightings in December 1999 were probably of the same bird. Apart from that December set of records, there have been no other sightings on the LHIG.	No	No	Mi, Ma	/
White-bellied Storm-petrel *Fregetta grallaria*	Regular visitor	The White-bellied Storm-petrel is present on the LHIG from September to May. It feeds at sea, and visits its nesting burrows only during the night. It will not be harmed by the rodent eradication which is scheduled to take place in August.	No	No	V, Ma	V
White-tailed Tropicbird *Phaethon lepturus*	Vagrant	The seven records of this species, from 1890 to 2003, suggest that if this species was to visit the LHIG it would be sometime from February to May (McAllan *et al*. 2004). The combination of its diet of fish caught offshore and the unlikely event that any will be in the vicinity of LHI, especially in winter, indicate that the proposed rodent eradication is not a threat to this species.	No	No	Mi, Ma	/
White-throated Needletail *Hirundapus caudacutus*	Irregular visitor	An insectivorous bird that may be present between September and April. The eradication programme is not a threat to this species.	No	No	Mi, Ma	/
White-winged Black Tern *Chlidonias leucopterus*	Irregular visitor	The six sets of records, totalling 30 or so birds, cover the years 1915 to 2003 (McAllan *et al*. 2004). All sightings spanned November to February, indicating that if this tern was to visit the island it would be in late Spring or Summer, not Winter when the baiting is proposed to take place.	No	No	Mi, Ma	/
Wilson's Storm- petrel *Oceanites oceanicus*	Vagrant	Only one record; a bird seen near Balls Pyramid in March 2002 (McAllan *et al*. 2004).	No	No	Mi, Ma	/

APPENDIX 2B – RISK ASSESMENT FOR LISTED BIRDS THAT MAY BE AT RISK

The *Migratory*, *Vulnerable* or *Endangered* bird species, as listed in the Environmental Protection and Biodiversity Conservation Act 1999 (the EPBC Act) and/or the Threatened Species Conservation Act 1995 (TSC Act), which are residents or regular visitors to the Lord Howe group, and which may be harmed due to the proposed rodent-eradication project. Data on species derived from Hutton 1991, McAllan *et al*. 2004 and DECC 2007.

M = *Migratory* species as listed in various international treaties to which the Australian Government is a signatory.
Ma = *Marine* Species listed under the EPBC Act.
E = *Endangered*.
V = *Vulnerable*.

Species	**Resident/visitor**	**Comments**	**Individuals at risk (in the absence of mitigation)**	**Species at risk (in the absence of mitigation)**	**EPBC Act**	**TSC Act**
Bar-tailed Godwit *Limosa lapponica*	Regular visitor	The Godwit diet consists of crustaceans, molluscs, worms, insects and some plant material. They arrive on LHI from September (Hutton 1991). The Godwit is a summer migrant to LHI in small numbers (McAllan *et al*. 2004). Most depart from March. Some young non-breeding birds (typically five or less) over-winter on LHI. Those birds that over-winter are at risk of secondary poisoning if they eat crustaceans, such as sandhoppers, that have fed heavily on pellets although the risk is considered very low. Given the low number of Bar-tailed Godwits that will be on LHI in June - August, the proposed eradication programme is unlikely to result in significant harm to the species.	No	No	Mi, MA	/

Brown Noddy *Anous stolidus*	Regular visitor	Although present mainly from September to May, Brown Noddies have been seen on the LHIG in all months (NSWBA cited in McAllan *et al*. 2004). They surface-skim the sea for fish and small crustaceans (Hutton 1991). Egg laying commences in October. Their diet and method of feeding will safeguard them from Brodifacoum poisoning.	No	No	Mi, Ma	/
Flesh-footed Shearwater *Ardenna carneipes*	Regular visitor	This deep-sea fish-eater arrives at LHI in August and departs in May (McAllan *et al*. 2004). Because the birds feed at sea and given the low risk of bioaccumulation in the marine environment, the population is not at risk of primary or secondary poisoning.	No	No	Mi, Ma	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.	No	No	Ma	V
Little Shearwater *Puffinus assimilis*	Regular visitor	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.	No	No	Ma	V

Lord Howe Island Currawong *Strepera graculina crissalis*	Endemic sub-species	Currawongs are very unlikely to eat baits but there is a significant risk that they will succumb to Brodifacoum by eating poisoned rodents. To mitigate for this, birds (~80% of the population) will be captured prior to the baiting and will remain in captivity for several months, i.e. until the likelihood that birds will encounter edible rodents has passed. The captive facility will be located on LHI and will be managed by a highly experienced aviculturist. To ensure all husbandry protocols are correct, a trial involving placing into captivity a small number of birds was undertaken in 2013.	Yes	Yes	V	V
Lord Howe Island Golden Whistler *Pachycephala pectoralis contempta*	Endemic sub-species	The whistler feeds on 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 however this is considered unlikely.	No	No	/	V
Lord Howe Island Silvereye *Zosterops lateralis tephropleura*	Endemic sub-species	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. 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. However, as a precaution against the eradication programme significantly reducing the population of this sub-species, a small number of silvereyes will be captured prior to the baiting and will remain in captivity for the duration of the operation, i.e. until the baits have disintegrated and pose no further risk.	Yes	No	/	V

Lord Howe Woodhen *Gallirallus sylvestris*	Endemic species	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 ground baiting that currently takes place around the settlement. The protection of this species necessitates that it be taken into captivity during the eradication. Birds (~ 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 have disintegrated and pose no further risk. Captive facilities will be located on LHI and on the mainland, and will be managed by highly experienced aviculturists. To ensure all husbandry protocols are correct, a trial involving holding a small number of birds in captivity was conducted in 2013. The trial showed that woodhens can successfully be managed in captivity for extended periods of time and released without harm.	Yes	Yes	V	E
Masked Booby *Sula dactylatra tasmani*	Resident	On LHI year round. Breeds from June to February. LHI is the most southerly breeding colony of boobies in the world (McAllan *et al*. 2004). This sub-species breeds 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..	No	No	Mi, Ma	V

Masked Owl *Tyto novaehollandiae castanops*	Resident	Masked Owls were introduced to LHI in the 1920s in an attempt to control the rats. There may be up to 100 pairs present on LHI (DECC 2007). Although the species is classified as *Vulnerable* under the TSC Act, the LHI population is shot under licence. Masked Owls are currently unlikely to be a significant threat to threatened birds such as the woodhen but this may change if rats, the owls' staple diet, are eliminated from LHI. A large proportion of the local owl population will likely succumb to secondary poisoning as a result of the proposed rodent eradication. No mitigation is proposed. To the contrary, the survivors are likely to be targeted for extermination to safeguard the woodhen population.	Yes	Yes; local extinction is probable	/	V
Pacific Golden Plover *Pluvialis fulva*	Regular visitor	They arrive on LHI in September and leave in April, although some, less than 10, may over-winter. They feed on insects, molluscs, crustaceans and some plant material (Hutton 1991). The small number of birds present during the proposed baiting and the negligible risk posed by their diet, make it unlikely that the baiting will significantly affect the species.	No	No	Mi, Ma	/
Providence Petrel *Pterodroma solandri*	Regular visitor	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; but from helicopter-strike, not from baiting	No	Mi, Ma	V

Red-tailed Tropicbird *Phaethon rubricauda*	Regular visitor	Summer-breeder; with about 500 to 1000 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	Mi, Ma	V
Ruddy Turnstone *Arenaria interpres*	Regular visitor	Begin to arrive on LHI in September and most have left by April. A few remain (10-20) to over winter (Hutton 1991). They eat crustaceans, molluscs and worms sheltering under organic debris such as seaweed (Hutton 1991). Turnstones will also eat carrion. Those birds that over-winter on LHI are at risk of secondary poisoning. However the low number (~20) of turnstones that will be on LHI in August, the proposed eradication programme will not result in significant harm to the species.	No	No	Mi, Ma	/
Sooty Tern *Onychoprion fuscata*		This species has been recorded on the LHIG in all months but it is most common from August to February (Hutton 1991). Sooty Terns are not susceptible to poisoning by the rodent eradication because, in winter, they only feed at sea.	No	No	Ma	V
Wedge-tailed Shearwater *Puffinus pacificus*	Regular visitor	Small numbers arrive at breeding sites on LHI in late August, but the bulk of the population only arrives in mid to late September. Adults depart April, chicks leave in May. Although adults may be on the islands at time of baiting, they are extremely unlikely to be poisoned as they feed at sea. Birds return to the island and their burrows on or after dusk.	No	No	Mi, MA	/

Whimbrel *Numenius phaeopus*	Regular visitor	This bird is a summer migrant to LHI in small numbers (McAllan *et al*. 2004). Some (typically only one or two birds) over-winter. Diet is mostly limited to worms, molluscs, crustaceans, insects, reptiles, tern chicks and seeds. However, secondary poisoning is considered unlikely. The small number of birds likely to be present in June-August (<20) will result in the baiting programme not being a significant threat to this species.	No	No	Mi, Ma	/
White Tern *Gygis alba*	Regular visitor	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. About 60-100 pairs nest annually on LHI. 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	Ma	V

APPENDIX 3 – 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.

APPENDIX 4 – 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**

Application for a Minor-use Permit to bait Lord Howe Island with the Unregistered Rodent Bait Pestoff 20R

Part 8: EFFICACY AND SAFETY

Module 8.3—Level 3 Limited Efficacy and Safety Assessment
in relation to an agricultural chemical product which involves a minor use on a new crop or situation

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PART 8-1: PROBLEM FORMULATION

The Lord Howe Island Board (LHIB) is applying for an APVMA Minor Use Permit for use of an unregistered product (Pestoff 20R) with an approved active constituent (Brodifacoum) for the Lord Howe Island Rodent Eradication Project (LHI REP).

The project 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, hereafter referred to as the Lord Howe Island Group (LHIG).

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 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 the remaining dairy herd containment area.

Given the size and rugged terrain of the LHIG, 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.

A summary of the LHIG, the impact of rats and mice on the LHIG and justification for the eradication are described in detail in Part 7.

This section summarises the problem including important features of the LHIG with relevance to the proposed REP, the current impact of rats and mice on the LHIG, the current control program, justification for eradication and justification for a minor use permit.

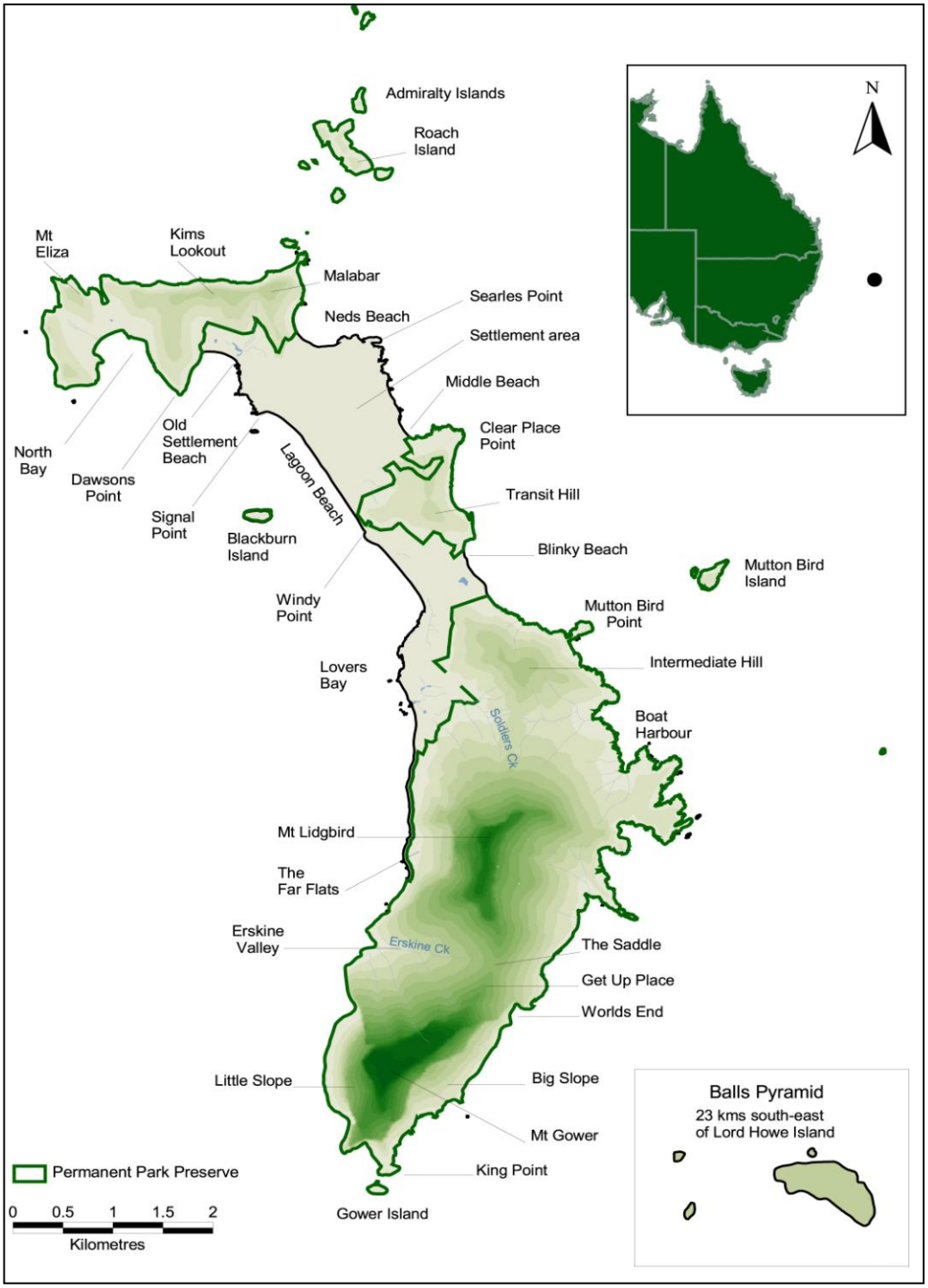
*8-1.1. **LORD HOWE ISLAND SUMMARY***

The Lord Howe Group (LHIG; 31°31'S, 159°03'E) is located 760 kilometres north east of Sydney. It comprises the main island (Lord Howe Island) and 28 smaller islets and rocks (Figure 1). The most significant of the outer islands are the Admiralty Islands (1 km to the north of LHI) and Balls Pyramid, (approximately 23 km south –east from LHI). Balls Pyramid will be excluded from baiting due to the absence of rodents and separation distance to LHI.

The main island is 12 km long, 1–2.8 km wide with a two dimensional area of 1455 ha. It is formed in the shape of a crescent with a coral reef enclosing a lagoon on the western side (Figure 1). 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 (Figure 2). The settlement area is restricted to the central lowlands and covers about 15% of the island. North of the settlement area the land rises gradually to about 200 m at the top of the sheer sea cliffs that fringe the northern end of the island. The terrain in the northern and southern mountains is extremely rugged and cannot safely be traversed by foot in many parts. 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.

Lord Howe Island was first permanently settled in 1833. The resident population is now about 350. LHI is the only island within the LHIG on which settlement has occurred. Tourism and the export of Kentia Palm (*Howea forsteriana*) seedlings are the island's two major sources of income. About



16,000 tourists visit the island each year, but numbers are regulated, with a maximum of 400 allowed on the island at any one time.

Figure 1. The Lord Howe Island Group (DECC 2007).

Figure 2. Lord Howe Island as seen from the north (DECC 2007).

Fish are harvested and sold locally, but there is no export of fish from the island. There are approximately 100 beef cattle on the island and a small dairy herd of approximately 14 cattle. The beef herd will be removed prior to the REP; however the dairy herd will remain. The dairy herd will be contained in a small area treated with bait stations only and hand fed during the REP. Many residents keep chickens, which in total number approximately 300. These will also be removed prior to the REP. Beef cattle and chickens will be reintroduced after the REP; once bait breakdown monitoring has confirmed break down of all baits (~100 days).

Other livestock includes 2 horses and approximately 4 goats. These will also be contained in small areas treated with bait stations during the REP. There are also around 50 pet dogs on the island. During the REP residents will be given the option of kennelling their dogs off island during the REP or muzzling their dogs. Cats are prohibited.

The LHIG falls under the jurisdiction of the New South Wales State Government. The LHIB is responsible for the care, control and management of the LHIG in accordance with the *Lord Howe Island Act 1953*. Approximately 75% of the main island plus all outlying islands, islets and emergent rocks within the LHIG are protected under the Permanent Park Preserve (PPP), which has similar status to that of a national park. The LHIG is on the Register of National Estate and was listed as a World Heritage Area in 1982.

The LHIG is an outstanding example of an oceanic island of volcanic origin with a unique biota of plants and animals and important and significant natural habitats for in-situ conservation of biological diversity, including those containing species of plants and animals of outstanding universal significance from the point of view of science and conservation.

The LHIG supports a diverse terrestrial flora and fauna with a high degree of endemic species and communities. Most of the LHIG is protected under the 1,300 ha PPP which includes both the northern and southern mountains of the main island, the Admiralty Islands, Balls Pyramid and surrounding

islands. Examples of World Heritage values of the LHIG specific to the terrestrial environment (DOECC 2007) include:

- the diversity of bird taxa comprising 164 bird species, including species of conservation significance with many endemics
- seabird breeding habitats which, together, comprise one of the major breeding sites in the southwest Pacific, including habitat for species of conservation significance
- high levels of species richness of terrestrial invertebrate taxa of which 50% are endemic including 100 species of spiders
- the diversity of vegetation communities which includes 25 associations, 20 alliances and 14 sub-formations
- the diversity of indigenous vascular plant taxa comprising at least 241 species, including species of conservation significance with many endemics (44%).

Many of these species are threatened and are listed under either New South Wales legislation or Australian Commonwealth Government legislation. Over 60 bird species recorded on the LHIG are listed as migratory under international agreements.

Populations of house mouse and ship rat were accidentally introduced to LHI. Mice are thought to have arrived around 1860 and rats arrived in 1918. Both species have had, and continue to have, significant adverse impacts on the unique flora and fauna of the LHIG.

8-1.2. **THE IMPACT OF HOUSE MICE AND SHIP RATS ON THE LHI GROUP**

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 albatross.

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 & 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 droppings, 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 can be 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 white bellied storm petrel is vulnerable due to its small size.

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 (*Cyclodina 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, which 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 Wood-feeding Cockroach *Panesthia lata* which now only occur on offshore islands including the Admiralty Group. Rats are probably 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;). 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 Black 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 fledglings 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 fledglings (Cuthbert & 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 & 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 affects 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 & Skeenkamp 1990).

From the perspective of the human population, rats and mice are major domestic pests. They infest residences, destroying foodstuffs and contaminating 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.).

8-1.3. **CURRENT CONTROL PROGRAMME**

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. Control 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 coumatetryl. The prolonged use of warfarin has led to house mice becoming resistant to this poison.

The LHIB currently use an alternative poison to Brodifacoum (Coumatetryl in the product Racumin) in a limited control program consisting of bait stations placed throughout the Island's Settlement Area and in some sections of the Permanent Park Preserve for conservation purposes (approximately 10% of the island). The LHIB also supplies Coumatetryl to residents on a pulse baiting schedule (approximately every 6 weeks) to control rats and mice and minimise the use of Brodifacoum in order to reduce the potential build up of resistance to Brodifacoum. The current rodent control program uses approximately 3 tonnes of Coumatetryl-based bait annually at a cost of around $83,000 per year but neither the rat or mouse population is being reduced to a level that reduces ecological impacts.

A range of anticoagulant toxicants including Brodifacoum baits (mostly wax blocks @ 50ppm) are currently used in the settlement area by residents to control rats and mice on their properties and inside dwellings. The LHIB have no control over this. The quantity of commercial rodenticide, (i.e. other than that provided by the Board) used by residents each year on the island is estimated at approximately 400 kg.

The present control baiting program does not adequately protect the island group's native flora and fauna. 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. Ongoing use of poison in the environment also presents a major risk to non-target species including humans, pets and livestock through continued exposure. As such, the effectiveness and long-term sustainability of the existing localised control programme, or an expanded programme, are highly questionable.

Table 1: The type and amount of bait used to control rodents on LHI from 1986–2015.

Date	Poison	Concentration of poison (parts per million)	Approximate quantity used (tonnes per annum)	Total bait used over period (tonnes)	Total active ingredient used over period (g)
Forest					
1986–1988	Warfarin	250	7	21	5250
1989–1999	Warfarin	800	7	77	61600
2000–2009	Warfarin	800	1.2	12	9600
2010-2015	Bromadiolone/ coumateteralyl	50	?		
Subtotal				**110**	**76450**
Nursery					
2000–2009	Brodifacoum	50	0.1	1.0	50
Settlement					
1986–2009	Warfarin	800	0.38	9.1	7296
2010-2015	Bromadiolone/ coumateteralyl	50	2.8	14	700
2000–2015	Brodifacoum	50	0.1	1.5	75
Subtotal				**25.6**	**8121**
Total				**135.6**	**84571**

Between 1986 and 2009, approximately 121 tonnes of bait containing 84 kg of toxicant were distributed on LHI, concentrated largely in 140 ha of palm forest and the settlement area (approximately 120 ha). In the palm forest approximately 786 kg of bait containing 546 g of poison were distributed over each hectare. In the settlement approximately 93 kg of bait containing 62 g of poison were distributed over each hectare. In 2015, 2.8 tonne of rodenticide (coumatetralyl) was supplied by the LHI Board for use by residents on Lord Howe Island. Coumatetryl has been chosen to reduce the risk of brodifacoum resistance developing particularly in the mice population.

8-1.4. **THE CASE FOR ERADICATION**

The do nothing scenario and continuation of the current control situation on LHI are considered unacceptable, 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 & 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 20 years of development and implementation involving more than 300 successful eradications worldwide (Howald *et al.* 2007). Systematic techniques for eradicating rodents from islands were first developed in New Zealand in the 1980s (Moors 1985; Taylor & Thomas 1989; Taylor & 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 & 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 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 from 39 attempts) (DIISE 2015). Whilst attempts at eradicating mice from offshore islands using Brodifacoum have been less successful, with a 49% success rate internationally (MacKay et al. 2007), many of these failures can be attributed to inappropriate planning or implementation. The success rate for mouse eradications on NZ islands using Pestoff 20R with 20ppm brodifacoum (the bait to be used on Lord Howe) aerially applied 1997- 2014 is 100% or 11 from 11 attempts (Broome et al, 2016).

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

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 rat 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.

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 an eradication programme on the LHIG include:

- a marked increase in birds, reptiles and insects abundance – this boost in diversity 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) that have long been absent due to the predation of rats and mice, such as the LH gerygone, grey fantail 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.

8-1.5. **JUSTIFICATION FOR MINOR USE**

The justification of an APVMA Minor Use permit for the LHI REP is detailed below.

Unsuitability of currently registered products

Brodifacoum rodent baits currently registered in Australia are not suitable for this project chiefly because they pose a significantly greater threat to non-target wildlife than the preferred, but locally unregistered, Pestoff Rodent Bait 20R. The concentration of Brodifacoum in Pestoff 20R is 0.02g/kg or 20 parts per million, which is only 40% of the concentration of Brodifacoum in those baits registered in Australia (0.05g /kg).

Another important difference between the locally registered baits and Pestoff 20R is that the registered baits contain Bitrex, a bitter-tasting compound. Bitrex is added to the baits to deter people from eating them. There are indications that this additive may cause bait aversion in some rodents and this may have contributed to the failure of at least one island operation targeting mice. Because the project aims to eradicate rodents from the LHIG, it is imperative that all rodents eat the bait that will be dispersed onto the area. Consequently, Bitrex will not be incorporated into baits used in the eradication on LHI.

The available baits are not suitable for distribution by helicopter as the wax baits clog the bucket spinner and the grain baits do not spread well. Pestoff 20R baits have been field tested in over 50 eradications.

Pestoff bait pellets come in two sizes; a 10mm diameter pellet and a 5.5 mm pellet. The 10mm baits increases the precision with which they can be dispersed from the spreader bucket because the helicopter pilot can see their line of fall much easier than if smaller baits were used. Therefore, it is easier for the pilot to avoid dropping baits into areas excluded from aerial baiting where these areas adjoin sections of the island that are to be aerially baited.

The cereal base of the pellet allows quicker environmental breakdown of the bait again reducing non target impacts. Pestoff 20R has been specifically designed for use by the manufacturer in conjunction with New Zealand Department of Conservation for aerial eradication of rodents on islands and has been used in Australia for several island rodent eradications. The rugged terrain of Lord Howe Island makes the aerial application of the bait, along with hand baiting and use of bait stations, the only feasible option to cover the Island Group with the density of bait required to kill every rodent.

Pestoff 20R pellets have been manufactured so as to be able to withstand aerial dispersal from mechanical spreaders without excessive fragmentation. Rodent baits currently registered in Australia are registered for use in bait stations or trays; they are not registered for aerial application.

Minor Use:

The LHI REP is considered to trigger the Minor use category based on either of the following:

- Schedule 2: Limited use in a Major Non food Situation (agricultural non-crop areas, domestic and public service areas, non crop areas, bushland / native forests) or other Situation (pastures). Limited use area of 1,400 ha 2D (or 2,100 ha 3D) on Lord Howe Island only. Or
- Schedule 3: Insufficient economic return – one off pest eradication of small area only.

Unregistered product

Pestoff Rodent Bait 20R w Brodifacoum @ 20mg/kg is not currently registered in Australia (previous permits have been issued for the product and for use in eradications with aerial baiting components).

Approved active constituent

The Brodifacoum that the manufacturer of Pestoff 20R uses is currently registered for use in Australia under **Product No.: 56139.**

The APVMA has granted minor-use permits to use Pestoff 20R on a number of Australian islands. The APVMA has granted minor-use permits (permit numbers 13966, 13536, 12498 10895, 10788, 8423) to use Pestoff 20R on a number of Australian islands. These include Montague Island in NSW, Hermite Island in WA and Macquarie Island in Tasmania.

The Minor Use Permit is for an existing active constituent in a minor use situation. This means Module 8.3—Level 3 Limited Efficacy and Safety Assessment applies.

Both the active constituent and the end-use product are manufactured overseas and the finished product is imported fully-packaged into Australia; no further mixing or preparation of the product is required prior to its use. Accordingly, in relation to this application, assessment is not required for manufacture of the active constituent or product.

The efficacy and safety of Brodifacoum has previously been assessed by the APVMA in connection with the registration of over 70 rodenticides such as Talon and several minor use permits, therefore only limited data is provided in this application in relation to these aspects. The major focus of the application is on the Efficacy and Safety regarding the use of the bait on the LHIG. The Efficacy and Safety of Brodifacoum in the proposed bait product is not expected to be significantly different to that previously assessed by the APVMA. Application rates (in total, nominally 20kg bait/hectare; 0.002%

Brodifacoum bait: average 0.40g active component/hectare) are low-moderate and Brodifacoum is moderately persistent in soils. Brodifacoum does not leach into ground water.

8-1.6. **OTHER APPROVALS REQUIRED**

A number of other regulatory approvals and permits will need to be obtained prior to commencement of the operation including:

- A referral to the Commonwealth Department of the Environment under the *Environment Protection and Biodiversity Conservation Act 1999*
- Civil Aviation Safety Authority approval for flight operations
- NSW Department of Planning and Environment approval under the *Environment Planning and Assessment Act* 1979 and associated approvals from various concurrence agencies including:
    - Office of Environment and Heritage - a Species Impact Statement and Threatened Species licence under Section 91 of the NSW *Threatened Species Conservation Act* 1995
    - NSW Environmental Protection Agency - permissions to aerially bait within 150 m of dwellings and public places required under the NSW *Pesticides Act 1999*
    - NSW Dept of Primary Industries (Marine Parks and Fisheries) - assessment under Division 2 of the NSW *Marine Parks Act* 1997 and *Fisheries Act 1994*

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.

PART 8-2 EFFICACY

Recent advances in rodent eradication techniques 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 300 successful eradications worldwide.

*8-2.1. **SELECTION OF METHODOLOGY***

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). A review of island eradications in 2007 found that rodents had been eradicated from 284 islands, and of 387 invasive rodent campaigns, 332 were reported as successful, 35 failed and 20 did not have a reported outcome (Howald et al. 2007). 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.

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 and Geographic Information Systems 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 (13000 ha), where rabbits (*Oryctolagus cuniculus*), ship rats and mice were successfully eradicated (Springer 2016).

Prior to 2007 there were 174 reported attempts to eradicate Ship Rats, with a success rate of 92%; and 37 attempts to eradicate mice, with a success rate of 81% (Howald et al. 2007). Another review of mouse eradication attempts (MacKay et al. 2007) calculated a lower success rate: 62% (28 successes from 47 attempts). Since these reviews were written there have been at least another ten successful operations to eradicate mice.

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.

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 broadcast relatively sparsely. The solution for bait station operations is to use smaller spacing between stations, no larger than 10 m. 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.

On Lord Howe Island mice are already totally resistant to warfarin and trials indicate they may also be developing a resistance to Brodifacoum.(Priddel et al 2013 unpublished report Office of Environment and Heritage). 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 and tourism

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.

A variety of techniques involving the use of traps and or toxicants have been used to eradicate rodents from islands. Most recent operations worldwide (and in New Zealand and Australia in particular) have used baits containing one of the second generation anticoagulants, principally brodifacoum; although others such as floucoumafen and bromadiolone have also been used successfully. Diphacinone, a first-generation anticoagulant, has also been used.

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. A far more cost-effective option is to spread bait aerially using a helicopter. Consequently, this approach has become the standard technique for most 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 method tends to be used over the minimum area possible.

A range of possible methods and mortality agents were considered for use in eradicating both rats and mice on LHI (Table 2). 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. Brodifacoum is the preferred toxicant because it is has been well tested and proven successful in numerous rodent eradication projects throughout the world. 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*".

8-2.2. *SELECTION OF TOXICANT*

Mortality agents assessed as unsuitable

A number of other 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.

Cholecalciferol
A form of vitamin D 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 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.

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

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.

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 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.

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.

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 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.

*8-2.3. **THE PREFERRED TOXICANT***

A critical component in any eradication is the choice of toxicant. 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 a few days longer to die than rats (Fisher 2005).

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 rodents 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.
- 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 below in Table 2.

Table 2: 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 & Kaukeinen (1978)
Female	0.65	Dubock & Kaukeinen (1978)
Ship rat (caught from wild)	0.46	O'Connor and Booth (2001))

Table 3. Suitability of potential toxicants for the eradication of rats and mice
FGAC, first generation anticoagulant; SGAC, second generation anticoagulant; 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

8-2.4. THE PREFERRED BAIT

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

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 (LHIB, 2007). 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. (Simmons 2006). This document is designed to achieve

- The safe utilisation of Pestoff® Rodent Bait 20R within specified areas of New Zealand 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 by the residents on Lord Howe Island.

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 10mm and 5mm 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.

In a non-toxic bait trial conducted on Lord Howe Island in 2007 to asses bait uptake, both small (5.5 mm) and large (10 mm) Pestoff® 20R baits were shown to be palatable to rats and mice. Consequently, large baits are recommended for aerial operations and small baits for hand broadcasting where it is critical to increase bait encounter rates for mice (LHIB 2007). It is believed that the benefits of using two bait sizes justify the added complexity of the operation.

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. Consequently, Bitrex® along with any other related additive will not be incorporated into baits used in the eradication on LHI.

The amount of Pestoff 20R bait rats and mice need to consume to result in death is shown below in Table 4.

Table 4: 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	AMOUNT (grams) OF 0.05 g/kg BRODIFACOUM BAIT FOR LD50
House Mouse	0.52	20	0.5	0.2
Ship Rat	0.73	160	5.8	2.3

*8-2.5. **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). 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 LD50 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 (LD100), as determined in the feeding trial, is 0.81 mg kg-1. Based on an observed LD100 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.

The trial also found that the observed LD50 for mice on Lord Howe Island was approximately five times the standard LD50 for mice, with some individuals showing a high level of tolerance, up to at least 13 LD50 (5.2 mg kg-1). The unusually high LD50 for mice on Lord Howe Island indicates that this population exhibits increased tolerance to brodifacoum. Based on an observed LD50 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 cited in Wheeler and Carlile, 2013). 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 (LD100) is at least 15 LD50. Based on an observed LD100 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.

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. 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.

The feeding trial conducted in 2013 produced 100% mortality in those mice fed the equivalent of 15 LD50 but the sample size was small, too small to assume that the most tolerant mouse on LHI will succumb to such a dose.

PART 8-3 SAFETY

Brodifacoum is an anticoagulant that inhibits blood coagulation in vertebrates by preventing the regeneration of Vitamin K once it has been used to produce clotting agents in the blood. When the available clotting factors in the blood are used up by the body the lack of Vitamin K prevents the manufacture of more clotting factor. This is why poisoning with anticoagulants can be treated with the provision of additional Vitamin K1 until the body is able to start resynthesising its own. As brodifacoum can stay in the liver for a long period of time, the treatment many need to continue for several months in severe cases of brodifacoum poisoning (Eason and Wickstrom 2001). As Brodifacoum is a bioaccumulent the NOEL (No Observed Effect Level), varies depending on the period of exposure. For an acute single dose, the most likely scenario, the NOEL is 0.15 milligram per kg of body weight (0.15 mg/kg) for 42 days of daily exposure the NOEL is 0.005 mg/kg and for 90 days exposure it is 0.001 mg/kg/d. (Toxikos 2010).

Humans are not particularly vulnerable to brodifacoum poisoning, which is why products containing it are available 'over the counter' in Australia (and many other countries) for household rodent control (Holm et al. 2006). There have been few reported cases of humans being poisoned by brodifacoum in Australia, despite its widespread use both in rural areas and for household rodent control.

From over 79,000 cases of anti-coagulant exposure and poisoning reported to the American Association of Poison Control National Database between 1988 and 1995, only 8 deaths are recorded. The majority of reported cases relate to ingestion by young children or intentional ingestion by suicidal adults (Chua & Friedenberg 1998).

Given that Brodifacoum is already an approved constituent in Australia and therefore has established regulatory standards (including Poison Scheduling), toxicology assessment was not triggered by this Minor Use Application. Some information on human health risks and project specific controls are provided below.

A detailed Human Health Risk Assessment has also been undertaken for the project (Toxikos, 2010) and updated in 2015. These are supplied as supporting documents to the application.

8-3.1. **HUMAN TOXICOLOGY**

There is no clearly defined LD50 dose for humans. As little as 1-2 mg of Brodifacoum can produce clinical coagulopathy (defect in the body's mechanism for blood clotting) in adult humans. However, there is a wide variation in susceptibility to Brodifacoum among individuals. People suffering from anaemia or liver disease, or who are taking prescription anticoagulants are more susceptible to Brodifacoum poisoning and should be protected from Exposure (WHO, 1995). The most common exposure route is orally, followed by inhalation.

The onset of toxicity takes days in acute cases. In minor poisoning cases there may be no obvious signs of poisoning, while in moderate cases symptoms include haematomata, haematuria, blood in faeces, bleeding gums and excessive bleeding from minor cuts or abrasions. Signs of acute poisoning are severe gastrointestinal bleeding, cerebrovascular accidents, and massive haemorrhage (internal bleeding) resulting in shock. Nevertheless, a person would need to eat an exceedingly large number of baits and not receive treatment to cause death.

Table 5: Amount of brodifacoum bait needed to be ingested by a human to result in death based on the LD50 (Fisher and Fairweather, 2006).

These figures represent the amount of bait that would have to be consumed in one sitting for a 50% chance of death. The calculations use the lowest reported oral LD50 in eutherian mammals of 0.17 mg/kg. These are straightforward acute toxicology calculations and are only for indicative purposes.

	LD50 (mg/kg)	AVERAGE WEIGHT (kg)	AMOUNT (grams) OF 0.02 g/kg BRODIFACOUM BAIT FOR LD50	AMOUNT (grams) OF 0.05 g/kg BRODIFACOUM BAIT (g) FOR LD50
Child	0.25	15	187.5	75 /93
Adolescent	0.25	30	375	150 /187
Small adult	0.25	60	750	300 /375
Large adult	0.25	90	1125	450 562

8-3.2. **EFFECTS OF SUB LETHAL POISONING**

The long term effect of sub lethal poisoning is uncertain although Brodifacoum is a slight skin irritant and a mild eye irritant. It is classified as non mutagenic (World Health Organisation 1995) and unlikely to be carcinogenic.

The persistence of brodifacoum means repeated sub lethal doses could accumulate – a situation that is unlikely to result from the LHI REP if eradication is successful and Biosecurity is managed to prevent reinvasion form rodents.

There is no evidence that brodifacoum has sub-lethal effects on reproduction or lactation at realistic doses. However, as may be expected, high maternal mortality and abortions have been observed in higher dose groups of available relevant animal studies (Broome et al, 2016). Brodifacoum is transferred to young in milk.

8-3.3. **EXPOSURE PATHWAYS**

8-3.3.1. DIRECT POISONING

Direct ingestion

Although brodifacoum is toxic to humans, the quantity of bait that would need to be consumed to induce sickness or death is substantial and most unlikely to be ingested accidentally (Toxikos 2010). The lowest reported amount of brodifacoum that has induced the need for medical treatment is 1–2 mg (equivalent to 50–100 g of Pestoff 20R bait). Although there is no confirmed fatal dose in humans, the amount required is estimated to be approximately 15 mg of brodifacoum for a 60 kg person, equivalent to 750 g of bait (Table 4). For serious illness or mortality to result, the affected person would also have to forego medical assistance (which is a course of Vitamin K injections).

Table 6: The amount of Pestoff 20R bait that would have to be consumed for a 50% chance of death if no treatment was sought.

	• Amount needed to be eaten at one time to cause fatality if not treated	Number of pellets	Area that would need to be cleared of bait
15kg child	187.5g of bait	375 pellets	156 sq m
60kg adult	750g of bait	1500 pellets	624 sq m
90kg adult	1125g of bait	2250 pellets	936 sq m

Give the amount of bait that an individual would need to consume over a relatively short period without seeking medical assistance this would need to be deliberate and as such is likely to only be an issue with children or people with impaired interpretive abilities.

Commercially available or registered baits contain a taste deterrent (Bitrex®) to deter the accidental intake of baits by children, and this bitter-flavour additive may deter some mice and rats. These products also have a higher concentration of brodifacoum compared to Pestoff 20R (50 parts per million compared to 20 parts per million), which makes the registered baits significantly more potent to non-targets including humans.

Most island residents are already familiar with anticoagulant rodent baits, as they have been and are still currently in widespread use around the island including within the settlement area. Many of the bait stations are readily accessible, and therefore pose a risk to humans, particularly children. As such, residents are already familiar with the risks of consuming and handling rodenticides. The major difference will be the accessibility of broadcast bait which will require an education programme to inform people of the risk and appropriate actions in the event that bait is consumed. Assuming the eradication is successful, the use of rodenticides will no longer be required thus removing this risk entirely. A detailed information sheet outlining the hazards associated with brodifacoum will be prepared for residents and distributed prior to the operation. Talks will also be given at the island's school to inform children of the operation and how they should behave around the toxic baits. Information sheets will also be given to tourists who will be present on the island during the baiting and over the time that the pellets will still be present.

Residents will be informed of the date of baiting as far in advance as possible, allowing for the uncertainties of weather, and will be issued with reminders closer to the date. Residents will be kept informed of progress and will be notified when baits have disintegrated and there is no further risk of poisoning.

Brodifacoum is insoluble in water (World Health Organisation 1995). So even if baits landed in water bodies, the water would not be contaminated with brodifacoum. Brodifacoum has never been detected in water bodies after an eradication operation, even when baits were present in streams. Notwithstanding, bait distributed in the settlement area will be hand-broadcast (rather than aerial broadcast) to ensure that no baits enter rainwater tanks or other potable water supplies.

To reduce the risk of young children accessing bait stations will be used around agreed dwellings rather than hand broadcast. All dwellings on the island will have an individual property plan developed to ensure all risk factors are identified and recorded, including children's play area. These areas will be mapped and discussed with parents for appropriate safety measures for children during the implementation phase.

In order to have the desired likelihood of successfully eradicating both rats and mice it is crucial that bait is made available in every rodent territory. The simplest and most effective way to achieve this is to aerially broadcast bait over the whole of the island (Broome et al 2014). However this is not legally or socially acceptable. 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 30m to dwellings. In these buffer zones bait will either be applied by hand or if agreement to the contrary is not reached, then the buffer zone will be 150 m, and will be baited by hand. This will be covered in a Property Management Plan for each property. The techniques which provide the best access to bait for rodents also provides the easiest access for humans i.e. broadcast bait presents bait out in the open readily accessible to all rodents and humans while bait in bait stations is not so readily accessible to either. However in order to reduce the likelihood of young children accessing Pestoff ® 20R, bait stations will be used where ever the risk of hand broadcasting bait is deemed unacceptable.

Pestoff bait is available in both 10mm and 5.5mm sizes. The 10mm bait is the preferred option for aerial broadcast as it has a successful track record and known dispersal properties. It is believed that the 5.5mm bait presents a lower risk to humans as it takes more than twice as many baits to get the same dose of toxicant. In addition 5.5mm baits are harder to locate in vegetation making accessing multiple baits less likely. As such while it complicates the operation to use multiple bait sizes 10mm baits will be used for aerial broadcast while 5.5mm baits will be used for hand broadcast around the settlement and outlying dwellings.

Inhalation of Dust

The likelihood of people on the ground breathing in toxic dust as a result of the aerial baiting is so low as to be virtually non-existent. Pestoff® 20R is manufactured to stringent specifications to contain little dust. On average it contains less than 0.6% of fine particles (less than 2 mm in diameter). Studies indicate that when Pestoff® 20R is aerially distributed through a spreader bucket the amount of fine particles increases, but does not exceed 2% (range: 0.78–1.92%). Risks associated with inhalation of the poison will be negligible for residents given the pellet nature of baits and the low levels of dust associated with this particular product. In line with standard OH&S procedures and the manufacturers label personnel working with the bait around the helicopter, when the maximum dust is present will wear full PPE including overalls, gloves and a face mask. Personnel distributing baits by hand will wear protective gloves and face masks to eliminate the minimal risk posed by inhaling, or absorbing the poison through the skin. The concentration of brodifacoum in the air following aerial distribution of baits is so low that it poses negligible risk to human health.

The proposed operation will distribute, during the first baiting, an average of 12 kg of baits per hectare. The concentration of brodifacoum in these baits is 20 parts per million (20 mg/kg). Hence, a total of 240 mg of brodifacoum will be distributed per hectare; of which a maximum of 2% will be fragments and dust. If we assume that this 2% is solely comprised of dust, and this dust is evenly distributed through the air column from the ground to the 50 metre altitude at which the helicopter flies we will have a poison concentration in the air of 0.0000096 ug/litre. In reality the actual dust levels are likely to be considerably less than that quoted. While there are no national exposure standards for inhalation of brodifacoum, the manufacturer of Talon®, Syngenta Australia, has adopted a standard for the work environment of 0.002 micrograms of brodifacoum per litre (ug/litre) of air. The maximum concentration of brodifacoum in the air expected during the eradication operation on Lord Howe Island will be less than 0.00001 ug/litre, many orders of magnitude less than the recommended maximum safety limit.

There is potential for dust to be blown over dwellings during the aerial baiting operations but this will be minimised by only spreading bait in low wind conditions and having a flying buffer around the dwellings. Due to the very low solubility of brodifacoum any dust which did land on a roof will rapidly bind to the sediment in the bottom of the water tank and not pose a risk to human or animal health.

Dermal absorption

Brodifacoum is readily absorbed into the body from the gastrointestinal tract and lungs, but much less through the skin (Toxikos 2010). It is classified as a slight skin irritant. However the concentration of brodifacoum in Pestoff® 20R is so low that the threat of absorption through the skin is negligible and technically, the product is not rated as harmful if in contact with skin (R21/22), as defined by the Australian Safety and Compensation Council. Pestoff® 20 R baits only contain 40% of the brodifacoum that can be found in a similar weight of Ratsak or Talon, both of which have been registered in Australia for sale to the general public.

Nevertheless, all staff involved in handling the pellets will be issued with the appropriate protective clothing, including impervious gloves, overalls, dusk masks and eye protection to avoid any unnecessary dermal contact as well as being instructed to wash the affected areas if the bait comes into contact with the skin.

8-3.3.2. SECONDARY POISONING / INDIRECT CONSUMPTION

Fish

Whilst Brodifacoum can bio-accumulate in fish and aquatic organisms 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. Some studies have found that there is no impact on marine fish from aerial bait applications (Empson and Miskelly 1999). However there have been other cases where fish have been poisoned or at least ingested the toxicant at Palmyra (Masuda et al 2015).

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).

This means that secondary poisoning via marine fish is a potential pathway to humans.

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. Significant mitigation through the use of the deflector arm on the spreader buckets, handing baiting within the Lagoon foreshore area and baiting above the high water mark will minimise bait entry into the water to the extent possible.

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 30m offshore to a depth of 10m 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 with the particles binding to the substrate on the bottom until the toxicants were broken down. As bait is likely to remain intact and accessible to fish for a longer period in the sheltered waters of the lagoon additional measures will be taken to minimise the amount of bait entering this environment. A buffer around the accessible areas of the lagoon will be hand baited to reduce the amount of Pestoff® 20R entering the water.

Within the lagoon, where there is limited wave action, disintegration will take longer. Consequently, special care will be taken to minimise the bait entering the lagoon. This will be done by hand-broadcasting of bait along the shoreline of the lagoon where safely and logistically possible.

Outside the lagoon, some marine organisms may feed on the residual particles and some fish may feed on the bait before it disintegrates. However the low amount of bait that will enter the marine environment; evidence that fish are unlikely to eat the bait (refer below); and the amount of contaminated fish that would need to be consumed mean that there is minimal human health risk.

A number of studies have examined the fate of cereal baits, either toxic or non-toxic, that entered the sea in line with normal aerial baiting operations where bait was dispersed from a hopper slung beneath a helicopter.

In 2001 a programme was instigated to eradicate the introduced Ship Rat from the three islets that comprise Anacapa Island, in the United States of America. The steepness and ruggedness of the three islets dictated the need for the aerial application of the bait which was cereal pellets containing brodifacoum at 25 ppm (Howald et al. 2005). Aerial baiting with brodifacoum was seen as the only alternative that "offered a reasonable probability of eradicating rats and that any negative impacts would be short-term and not significant to native populations" (Howald et al. 2005). Bait was broadcast at 15 kg per hectare. Boat and island-based observers reported that no bait was directly spread into the ocean but, as expected, a small amount of bait was seen to enter the water as a result of bouncing off the cliff faces (Howald et al. 2005). SCUBA divers were used to count bait pellets on the sea floor and to observe the behaviour of marine organisms that encountered the baits. 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. No brodifacoum residues were detected in the water samples collected. Mussels and crabs were also sampled at days 15 and 30 post-application, as were tide-pool sculpins, a carnivorous fish species of the Cottidae family, at 15, 30 and 90 day post-application. No brodifacoum was detected in any of these samples.

The New Zealand Department of Conservation monitored reef fish populations around Kapiti Island after a baiting operation. Cole and Singleton (1996) concluded: …"The surveys provide no evidence that the fish densities had been affected by the poison application. Initial and final survey densities of both species at all three sites were similar, and our incidental observations of other fish species did not suggest any alterations in the density of those species either. Further, in the more than 20 diver hours spent underwater in the study sites, we observed no dead or moribund organisms, nor any changes to the benthic assemblages suggestive of poison entering food webs." Laboratory studies confirmed these observations and demonstrated that populations of three of the commonest fish species around Kapiti Island were unlikely to be affected by the poisoning operations (Empson and Miskelly 1999).

Aerial baiting with brodifacoum in cereal pellets conducted in the Gulf of Mexico on two islands also did not result in harm to marine life (Samaniego-Herrera et al. 2009). The application rate on one island was 24.4 kg/ha, and on the other it averaged 17.6 kg/ha. One of the pre-baiting trials conducted on the islands involved the dispersal of non-toxic bait into the marine environment. Observations were made of how fish reacted to cereal baits. The only reaction recorded for all of the 23 species tested involved one individual that took a bait, but spat it out (Samaniego-Herrera et al. 2009).

Similar placebo tests were conducted on Lehua Island in Hawaii in 2004 (U.S. Fish and Wildlife Service and Hawai'i Department of Land and Natural Resources 2008). While nine of the 21 species routinely inspected bait pellets in the water, none actually consumed the bait.

There have been at least two examples where marine fish die-offs have coincided with aerial applications of rodenticide: Rangitoto ((Fisher et al 2001) and Lehua (Parkes *et. al* 2011) however despite investigations there was no evidence found linking the rodenticide with the mortality of fish deaths during the eradication program.

Fish up take trials were also carried out in the LHI lagoon in 2010. When non toxic 10mm Pestoff® 20R bait was presented to individual fish through the water column, fish mouthed the pellets but immediately rejected them. No pellets during the trials were consumed by any fish species. Pellets settled on the lagoon seabed and quickly disintegrated (Bower & Haselden pers comm.)

In order to ensure that fish are not a pathway for the toxicant into humans, residents and tourists will be advised not to eat any inshore fish until testing by an independent laboratory has confirmed that there is no risk.

Meat/domesticated animals

The consumption of contaminated meat is a recognised pathway for humans to consume brodifacoum (Eason et.al. 2001) however the amount of contaminated muscle tissue a person would need to eat to pose a significant risk is considerable. As brodifacoum concentrates in the liver it is a wise precaution to avoid eating any liver part of cattle present on the island during the eradication program.

The beef cattle herd on the island will be reduced as far as possible (ideally to zero) with replacements bought in after the bait is no longer present. Any stock which does remain will be held in confined quarters and fed supplemental food bought onto the island. Baiting around the quarters will be closely controlled so as to minimise the likelihood of any animals accessing bait. As an added precaution livestock owners will be advised not to eat any animals which remain on the island during the baiting operation and to use them for breeding stock only.

The poultry flock on the island will be reduced as far as possible. If there are any remaining birds, they will be held in raised cages for the duration of the operation so that they cannot access baits. Residents will also be advised not to eat island chickens until bait break down monitoring confirms absence of pellets.

Milk

There is a small dairy herd (approximately 10 animals) present on the island which is likely to remain throughout the operation. Coumarin anticoagulants (including both warfarin and brodifacoum) are not excreted in milk (Greaves 1993) so there is little likelihood of brodifacoum entering the human food chain via milk from the dairy herd. However to eliminate any risk all milk from the herd will be purchased by the project and disposed of until bait is no longer present and testing confirms that there is no risk. In order to minimise the risk presented by the animals or their food to the success of the eradication the cows will be confined to a small paddock and will receive supplementary feed during the period that bait poses a risk (approximately 100 days).The food will be stored in rodent proof containers and cattle fed in such a way as to avoid leaving any food for rodents. While the surrounding area will be baited aerially a buffer will be left around the paddock that will be baited by hand broadcast. The area immediately outside the boundary will be baited at a rate approximately 50% higher than the set average and livestock proof bait stations will be positioned around the boundary.

This will create a buffer around the holding paddocks to ensure any rats or mice leaving the paddock are exposed to the bait. Baiting within the holding paddock will use cattle-proof bait stations.

Eggs

Brodifacoum can be transferred in eggs (Fisher 2009); as such special precautions will be taken to manage this risk to human health. The poultry flock on the island will be reduced as far as possible. If there are any remaining birds, they will be held in raised cages for the duration of the operation so that they cannot access baits. In addition any eggs which are produced will be purchased by the project. Once the bait is no longer present replacement 1 day old chicks will be provided. Poultry owners will be advised not to eat any birds which have been present during the baiting operation.

Plant material

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 (Brown 1994; Ogilvie et al. 1997). As such there is a negligible risk of human consumption of brodifacoum via eating plant material and no special precautions are proposed for this pathway.

8-3.4. **RISK MANAGEMENT**

While there is some risk to human health from both primary (e.g. children consuming baits) and secondary poisoning (e.g. people eating fish or meat containing toxicant), this risk is considered minimal due to the operational controls, the volume that would need to be consumed and the presence of a readily available antidote (Vitamin K).

Regardless, as part of operational planning, comprehensive mitigation measures have been developed to minimise the poisoning risk to people. A major component of the risk mitigation will be effective communication with all residents and visitors to ensure they understand the hazard and how to keep themselves safe from exposure. These include providing educational material targeting both residents and visitors, talks at the school and provision of signage

8-3.5. **TREATMENT**

The primary antidote to brodifacoum poisoning is immediate administration of vitamin K1 (dosage for humans: initially slow intravenous injections of 10–25 mg repeated all 3–6 hours until normalisation of the prothrombin time; then 10 mg orally four times daily as a "maintenance dose"). It is an extremely effective antidote, provided the poisoning is caught before excessive bleeding ensues. As high doses of brodifacoum can affect the body for many months, the antidote must be administered regularly for a long period (several months, in keeping with the substance's half-life) with frequent monitoring of the prothrombin time.

Brodifacoum is slow acting and several days are available from consumption or even the identification of symptoms before treatment needs to be commenced (Toxikos 2010). In the unlikely event that a person ingests bait, medical advice and treatment will be provided on the island.

There is a hospital on LHI and diagnostic and treatment procedures will be discussed with the island resident medical doctor as part of the operational planning process. A supply of the antidote (Vitamin K) will be held on the island for the duration of the operation. Additional supplies can be readily obtained if required.

8-3.6. **PETS**

Brodifacoum has been shown to be toxic to dogs with acute oral toxicity varying between .25-3.56 (LD50 mg/kg) depending on animal size (Godfrey 1985). All dog owners on Lord Howe Island will be briefed to the risk of poisoning occurring to dogs during the project and given several options to avoid accidental poisoning of pets. Owners will be provided with muzzles to fit while pets are outside as well as been given the option of free removal and kennelling of the dog to the mainland for the duration of the program. In the unlikely event of accidental poisoning occurring, vets will be present of the island while bait remains viable to administer Vitamin K antidote which will be stored on Lord Howe during the program.

PART 8-4 REFERENCES

Angel, A., Wanless, R. and Cooper, J. 2009. Review of impacts of the introduced house mouse on islands in the Southern Ocean: are mice equivalent to rats? *Biological Invasions* **11**, 1743-1754.

Auld, T.D., Hutton, I., Ooi, M.K.J. and Denham, A.J. 2010 Disruption of recruitment in two endemic palms on Lord Howe Island by invasive rats. *Biological Invasions* **12**, 3351-3361

Billing, J. (1999). The management of introduced rodents on Lord Howe Island. Unpublished report. Lord Howe Island Board, Lord Howe Island.

Broome, K.G.; Fairweather, A.A.C.; Fisher, P. 2016: Brodifacoum Pesticide Information Review. Version 2016/1. Unpublished report docdm-25436, Department of Conservation, Hamilton, NZ. Pg 137.

Carlile, N. (2015). *Monitoring, evaluating and reporting the biodiversity benefits of eradicating exotic rodents from Lord Howe Island*. Unpublished report for the LHIB. Office of Environment and Heritage, NSW

Chua JD, Friedenberg WR 1998. Superwarfarin poisoning. *Arch Intern Med* 158: 1929-1932.

Cole, R. G. and Singleton, R. J. (1996). Monitoring of reef fish populations at Kapiti Island during aerial poisoning for rats 1996. Unpublished report prepared for Wellington Conservancy, Department of Conservation, Wellington. National Institute of Water and Atmospheric Research, Nelson, New Zealand.

Cogger, H. G. (1971). The reptiles of Lord Howe Island. *Proceedings of the Linnean Society of New South Wales* **96**, 23-38

Cuthbert, R. and Hilton, G. (2004). Introduced house mice Mus musculus: a significant predator of threatened and endemic birds on Gough Island, South Atlantic Ocean? *Biological Conservation* **117**, 483-489.

Department of Environment and Climate Change (NSW) 2007, *Lord Howe Island Biodiversity Management Plan*,Department of Environment and Climate Change (NSW), Sydney.

DIISE 2015: Database for Island Invasive Species Eradications accessed December 2015: http://diise.islandconservation.org

Eason C T, Wright G R G, Milne L M, and Morriss G A 2001: Laboratory and field studies in relation to risk of exposure to wildlife and people. Science for Conservation 177B: 11-23r

Eason, C. T., Hix, S., MacMorran, D. and Murphy, E. C. (2009). The first stage of preliminary screening of candidate MtHb inducers as potential rodenticides including PAPP and sodium nitrite by oral gavage and in bait. Unpublished Connovation Contract Report. Landcare Research, New Zealand.

Eason, C. T. and Ogilvie, S. (2009). A re-evaluation of potential rodenticides for aerial control of rodents. DOC Research & Development Series 312. Department of Conservation, Wellington, New Zealand.

Eason, C. T. and Spurr, E. B. (1995). Review of the toxicity and impacts of brodifacoum on non-target wildlife in New Zealand. *New Zealand Journal of Zoology* **23**, 371-379.

Empson, R. A. and Miskelly, C. M. (1999). The risks, costs and benefits of using brodifacoum to eradicate rats from Kapiti Island, New Zealand. *New Zealand Journal of Ecology* **23**, 241–254.

Fisher, P. (2005). Review of house mouse (*Mus musculus*) susceptibility to anticoagulant poisons. *DOC Science Internal Series* **198**, 1-18.

Fisher P (2013) Environmental residues of anticoagulants used for pest animal control, Landcare Research, unpublished report for Environment Southland.

Godfrey,M.E.R. 1985: Non-target and secondary poisoning hazards of 'second generation' anticoagulants *Acta Zoologica Fennica 173:* 209-212

Greaves, M. (1993). Anticoagulants in pregnancy . *Pharmacology and Therapeutics* **59**, 311-327.

B. Groombridge, (ed.) 1992. Global Biodiversity. Status of the Earth's Living Resources. A Report Compiled by the World Conservation Monitoring Centre. xx + 585 pp. London, Glasgow, New York, Tokyo, Melbourne, Madras: Chapman & Hall.

Harden, R. H. and Leary, C. (1992). The Lord Howe Island Board rat control program: report to the Lord Howe Island Board. Unpublished report to the Lord Howe Island Board, Lord Howe Island. NSW National Parks and Wildlife Service, Armidale.

Higgins P. J. (ed.), 1999**.** Masked Owl. Pp. 908-930 in *Handbook of Australian, New Zealand and Antarctic Birds. Vol. 4. Parrots to Dollarbird*. Oxford University Press, Melbourne, Vic.
Hone, J. and Mulligan, H. (1982). Vertebrate pesticides. *Science Bulletin 89.* New South Wales Department of Agriculture, Orange.

Howald, G., Donlan, C. J., Galvan, J. P., Russell, J. C., Parkes, J., Samaniego, A., Wang, Y., Veitch, D., Genovesi, P., Pascal, M., Saunders, A. and Tershy, B. (2007). Invasive rodent eradication on islands. *Conservation Biology* **21**, 1258-1268.

Lavoie, C., Donlan, C. J., Campbell, K., Cruz, F. and Carrion, V. G. (2007). Geographic tools for eradication programmes of insular non-native mammals. *Biological Invasions* **9**, 139-148.

LHIB (2007). Report on non-toxic bait trials Lord Howe Island – August 2007. Unpublished report for the Lord Howe Island Board.

MacKay, J. W. B., Russell, J. C. and Murphy, E. C. (2007). Eradicating house mice from islands: successes, failures and the way forward. In 'Managing Vertebrate Invasive Species: Proceedings of an International Symposium '. Eds G. W. Witmer, W. C. Pitt and K. A. Fagerstone. pp. 64-66. (USDA/Aphis/WS, National Wildlife Research Center: Fort Collins.)

Marris, J. W. M. (2000). The beetle (Coleoptera) fauna of the Antipodes Islands, with comments on the impact of mice: and an annotated checklist of the insect and arachnid fauna. *Journal of the Royal Society of New Zealand* **30**, 169-195.

Masuda BM, Fisher P, Beaven., B. (2015) Ecotoxicol Environ Saf. 2015 Mar;113:1-8. Residue profiles of brodifacoum in coastal marine species following an island rodent eradication.

Moore Jr, H. E. (1966). Palm hunting around the world. IV Lord Howe Island. *Principes* 10, 12-21.

Moors, P. J. (1985). Eradication campaign against *Rattus norvegicus* on the Noises Islands, New Zealand, using brodifacoum and 1080. In ' Conservation of Island Birds: Case Studies for the Management of Threatened Island Species. Technical Publication No. 3'. pp. 143-155. (International Council for Bird Preservation: Cambridge.)

Nevill, J. (2004). Eco-tourism as a source of funding to control invasive species: The case of the Seychelles. *International Journal of Island Affairs*. **February,** 99 – 102.

Newman, D. G. (1994). Effects of a mouse, Mus musculus, eradication programme and habitat change on a lizard population on Mana Island, New Zealand, with special reference to McGregor's skink, Cyclodina macgregori. *New Zealand Journal of Zoology* 21, 443-456.

Ogilvie, S. C., Pierce, R. J., Wright, G. R. G., Booth, L. H. and Eason, C. T. (1997). Brodifacoum residue analysis in water, soil, invertebrates, and birds after rat eradication on Lady Alice Island. *New Zealand Journal of Ecology* **21**, 195-197.

Parkes J, Fisher P, Forrester G 2011. Diagnosing the cause of failure to eradicate introduced rodents on islands: brodifacoum versus diphacinone and method of bait delivery. Conservation Evidence 8: 100-106. *(Journal Article, 2011*)

Parkes, J., Ruscoe, W., Fisher, P. and Thomas, B. (2004). Benefits, constraints, risks and costs of rodent control options on Lord Howe Island. Unpublished report to the Lord Howe Island Board. Landcare Research, Lincoln, New Zealand.

Pickard, J. (1983). Vegetation of Lord Howe Island. *Cunninghamii* 1, 133-265.

Priddel, D., Carlile, N., Humphrey, M., Fellenberg, S. and Hiscox, D. (2003). Rediscovery of the 'extinct' Lord Howe Island stick-insect (*Dryococelus australis* (Montrouzier)) (Phasmatodea) and recommendations for its conservation. *Biodiversity and Conservation* **12**, 1391-1403.

Samaniego-Herrera A., A. Aguirre-Muñoz A., Rodríguez-Malagón M, González-Gómez R., Torres-García F., Méndez-Sánchez F., .Félix-Lizárraga M., and Latofski-Robles M (2009). Rodent eradications on Mexican islands: advances and challenges. In: Veitch, C. R.; Clout, M. N. and Towns, D. R. (eds.). 2011. Island invasives: eradication and management. IUCN, Gland, Switzerland. 350-355

Smith, V. R. and Steenkamp, M. (1990). Climatic change and its ecological implications at a subantarctic island. *Oecologia* **85**, 1424.

Springer, K . (2016). Methodology and challenges of a complex multi-species eradication in the sub-Antarctic and immediate effects of invasive species http:www.newzealandecology.org/nzje/

Taylor, R. H. and Thomas, B. W. (1989). Eradication of Norway rats (Rattus norvegicus) from Hawea Island, Fiordland, using brodifacoum. *New Zealand Journal of Ecology* **12**, 23-32.

Taylor, R. H. and Thomas, B. W. (1993). Rats eradicated from rugged Breaksea Island (170 ha), Fiordland, New Zealand. *Biological Conservation* **65**, 191-198

Torr, N. (2002). Eradication of rabbits and mice from subantartic Enderby and Rose islands. In 'Turning the Tide: the Eradication of Invasive Species '. Eds C. R. Veitch and M. N. Clout. pp. 319-328. (IUCN SSC Invasive Species Specialist Group. IUCN: Gland, Switzerland and Cambridge, UK.)

Tomlin, C. (2009) The Pesticide Manual: A World Compendium. BCPC

Torr N 2002. Eradication of rabbits and mice from subantarctic Enderby and Rose Islands. In: Veitch CR, Clout MN eds. Turning the tide: the eradication of invasive species, IUCN SSC Invasive Species Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. Pp. 319-328.

Torr, N.and Agnew, D.(2007).Trial to determine differences in bait fragmentation in various spreader bucket designs used during aerial application of toxic bait. Department of Conservation, New Zealand Government. February 2007.

Towns, D., McFadden, I. and Lovegrove, T. (1993). Offshore islands co-operative conservation project with ICI Crop Care Division: Phase one (Stanley Island). Science and Research Internal Report 138. Department of Conservation, Wellington.

Towns, D.R. (1991). Response of lizard assemblages in the Mercury Islands, New Zealand, to removal of an introduced rodent: the kiore (*Rattus exulans*). *Journal of the Royal Society of New Zealand* **21**, 119-136.

Towns, D.R. (1994). The role of ecological restoration in the conservation of Whitaker's skink (*Cyclodina whitakeri*), a rare New Zealand lizard (Lacertilia: Scincidae). *New Zealand Journal of Zoology* **21**, 457-471.

Towns, D. R. and Broome, K. G. (2003). From small Maria to massive Campbell: forty years of rat eradications from New Zealand islands. *New Zealand Journal of Zoology* **30**, 377-398.

Towns, R. T., Atkinson, I. A. E. and Daugherty, C. H. (2006). Have the harmful effects of introduced rats on islands been exaggerated? *Biological Invasions* **8**, 863-891.

Towns, D.R. and Daugherty, C.H. (1994). Patterns of range contractions and extinctions in the New Zealand herpetofauna following human colonization. *New Zealand Journal of Zoology* **21**, 325-339

Towns, DR & Broome K.G.(2003). From small Maria to massive Campbell: forty years of rat eradications from New Zealand Islands. *New Zealand Journal of Zoology* 30: 377-398.

Toxikos (2010). Human Health Risk Assessment for the use of Brodifacoum for the Lord Howe Island Rodent Eradication Plan. Unpublished Report for the Lord Howe Island Board. Toxikos Pty Ltd

U.S. Fish and Wildlife Service and Hawai'i Department of Land and Natural Resources (2008)

Wheeler, R. and Carlile, N. (2013). 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 for the Lord Howe Island Board

World Health Organisation (1995). Anticoagulant rodenticides. International Programme on Chemical Safety.Environmental Health Criteria 175. World Health Organisation, Geneva.

Report on non-toxic bait trials
Lord Howe Island – August 2007

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.

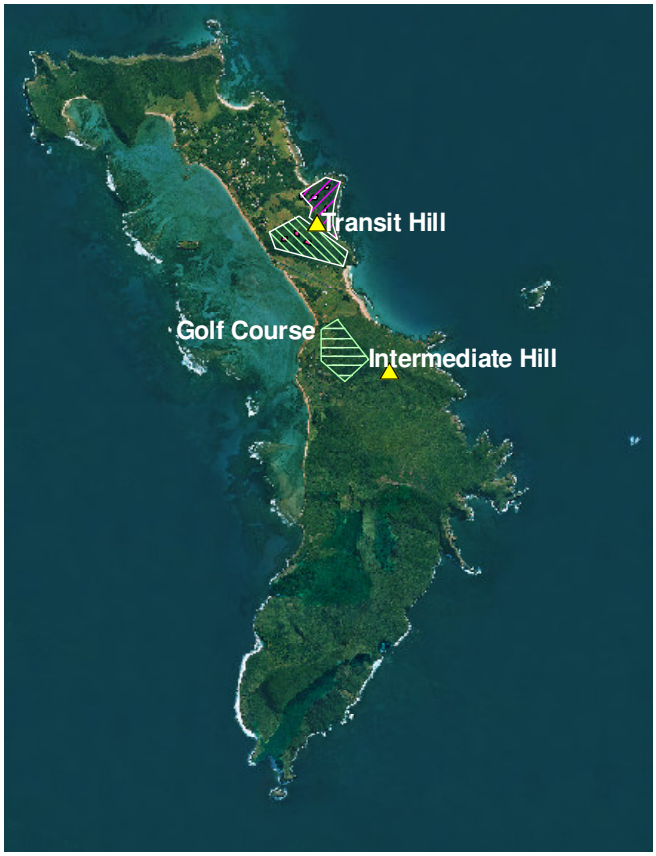


Fig. 1. An aerial photograph of Lord Howe Island showing the location of aerial baiting areas.

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.

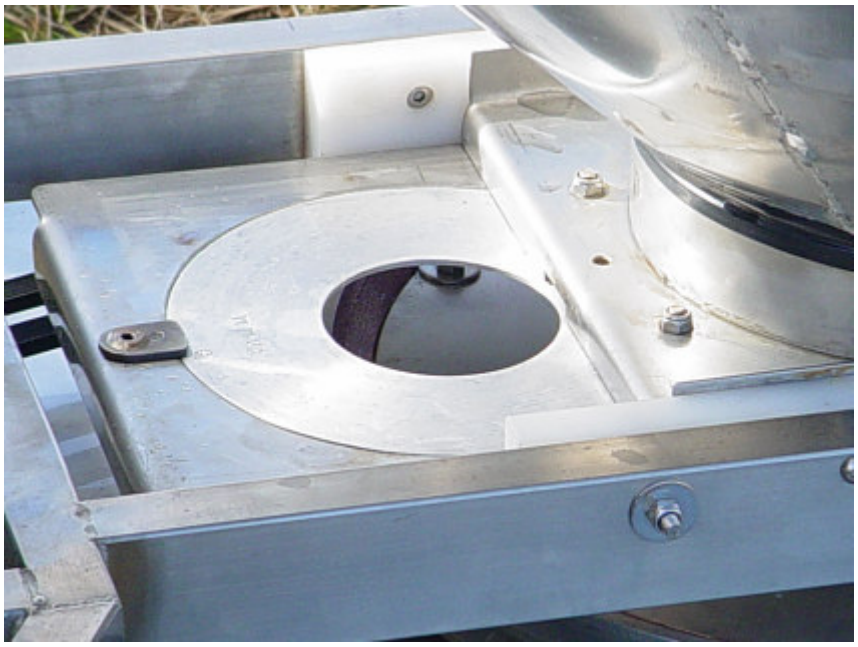


Fig. 11. Adjustable bait flow rate aperture.

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).

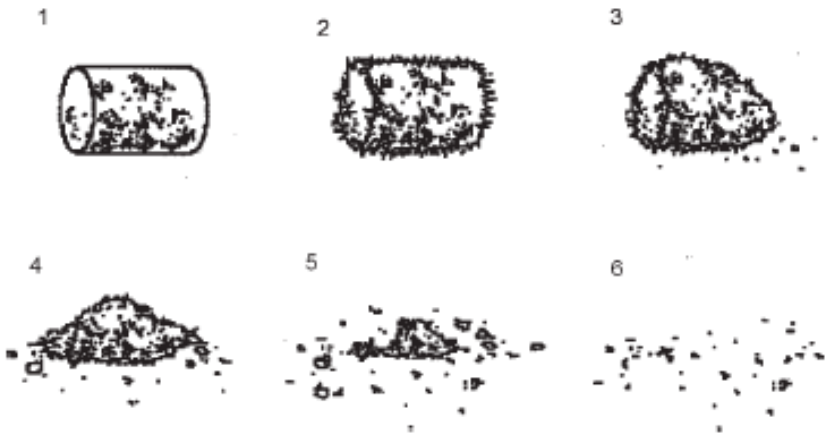


Fig. 15. Scale used to measure bait decomposition (see Green & Dilks 2004).1 = fresh, 2 =soft (may have some mould), 3 = mushy pellet (> 50% may have some mould), 4 = pile of mush (> 50% with mould), 5 = disintegrating pile of mush, 6 = gone or identifiable by grain flakes.

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.

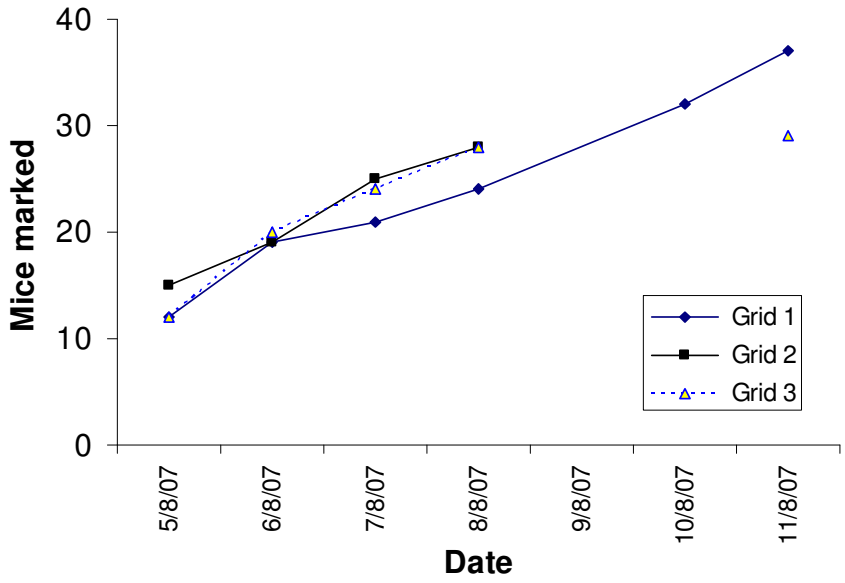


Fig. 16. Cumulative numbers of mice marked on trapping grids prior to aerial baiting.

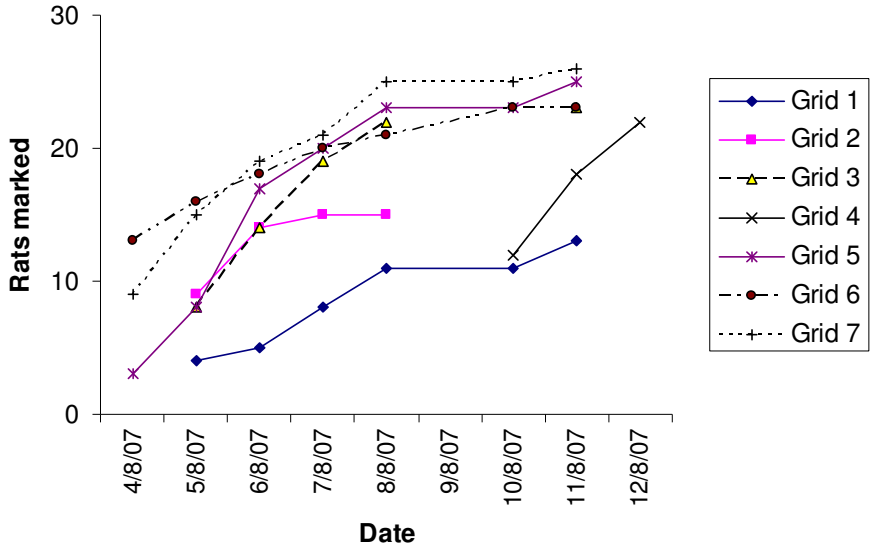


Fig. 17. Cumulative numbers of rats marked on trapping grids prior to aerial baiting

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.

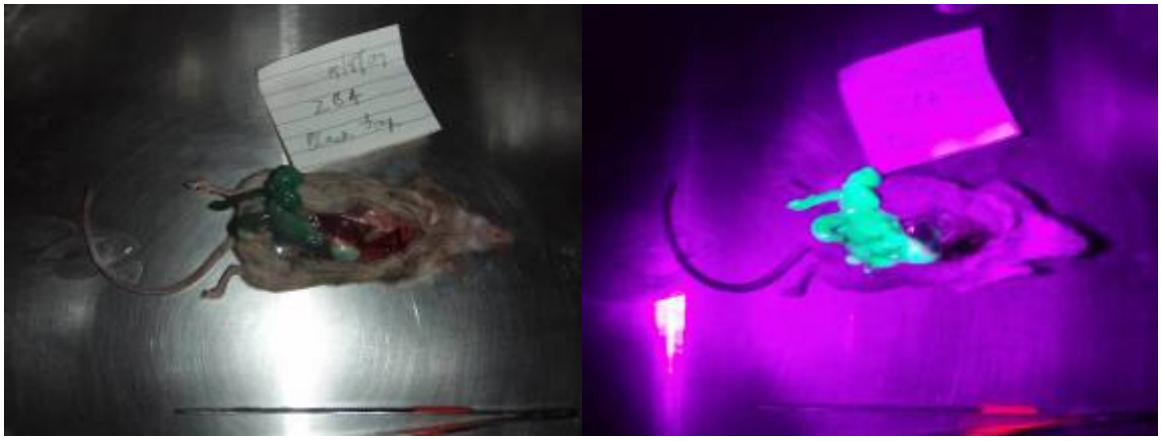


Fig. 18. Mouse captured on 5.5 mm trapping grid 2 showing green colouring in gastro intestinal tract under natural light (left), and pyranine fluorescence confirming ingestion of bait under UV light (right).

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).

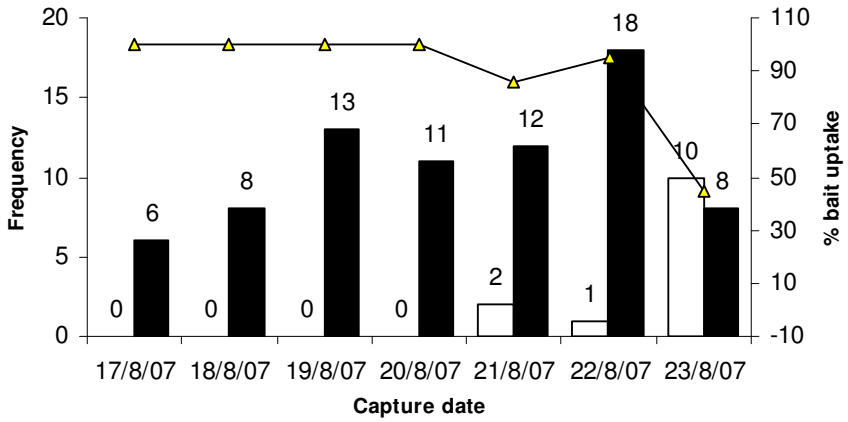


Fig. 19. Numbers of mice in grids other than grid 1 recording positive (solid bars) and negative (hollow bars) pyranine fluorescence by day through the trapping period, and the percentage of inferred bait uptake (line)

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).

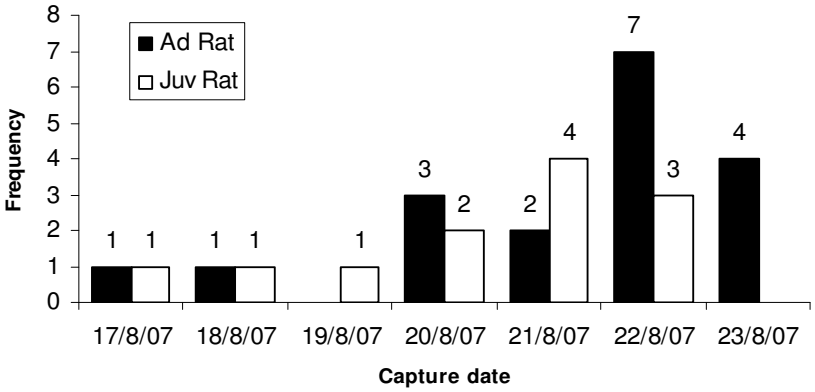


Fig. 20. Daily captures of juvenile and adult rats in the 5.5 mm bait area

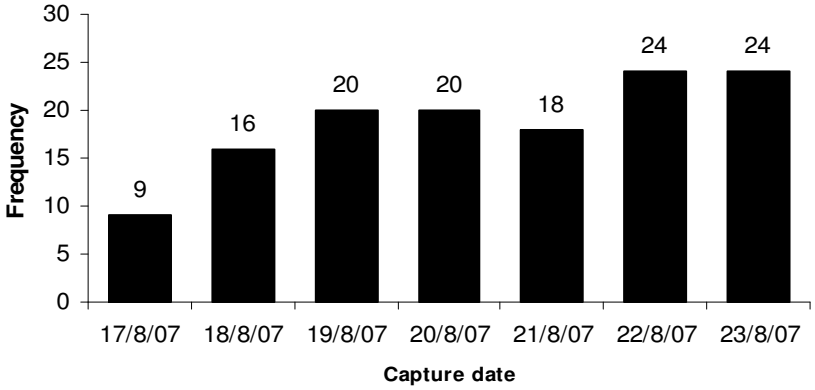


Fig. 21. Daily captures of mice in the 5.5 mm bait area

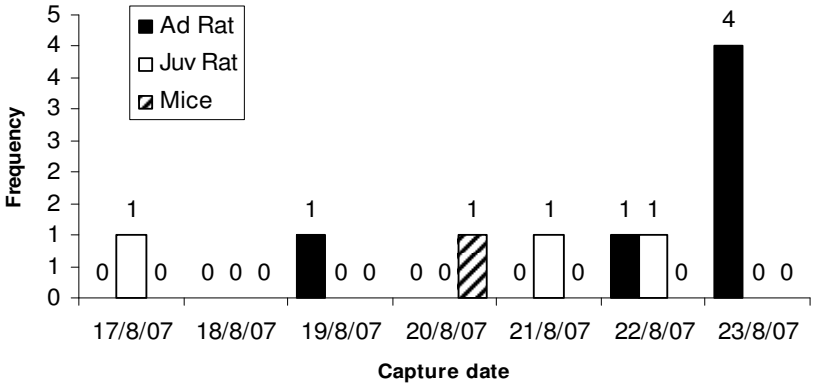


Fig. 22. Daily captures of juvenile and adult rats, and mice in the 10 mm bait area

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.

Acknowledgements

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References

Billing, J. 1999 The management of introduced rodents on Lord Howe Island. Unpublished report to Lord Howe Island Board.

Booth, L.H.; Fisher, P.; Heppelthwaite, V.; Eason, C.T. 2003. *Toxicity and residues of brodifacoum in snails and earthworms*. Science Internal Series 143. New Zealand Department of Conservation, Wellington. 14 pp.

Craddock, P. 2003. (unpublished) Aspects of the ecology of forest invertebrates and the use of brodifacoum. PhD Thesis, School of Biological Sciences, University of Auckland, Auckland, N.Z. 236 pp.

Dowding, J.E.; Murphy, E.C.; Veitch, C.R. 1999. Brodifacoum residues in target and non-target species following an aerial poisoning operation on Motuihe Island, Hauraki Gulf, New Zealand. *New Zealand Journal of Ecology 23:* 207-214.

Eason, C.T.; Spurr, E.B. 1995. Review of the toxicity and impacts of brodifacoum on nontarget wildlife in New Zealand. *New Zealand Journal of Zoology 22:* 371-379.

Eason, C. T., E. C. Murphy, G. R. G. Wright, and E. B. Spurr. 2002. Assessment of risks of brodifacoum to non-target birds and mammals to New Zealand. Ecotoxicology 11:35-48.

Empson, R.A.; Miskelly, C.M. 1999. The risks, costs and benefits of using brodifacoum to eradicate rats from Kapiti Island. *New Zealand Journal of Ecology 23:* 241-254.

Godfrey, M.E.R. 1985: Non-target and secondary poisoning hazards of "second generation" anticoagulants. *Acta zoologica fennica 173:* 209-212.

Greene, TC.; Dilks, P.J. 2004. *Effects of a non-toxic bait application on birds.* Department of Conservation Science Internal Series 175. Department of Conservation, Wellington, N.Z.

Haydock, N.; Eason, C. (eds) 1997. Vertebrate Pest Control Manual: Toxins and Poisons. Department of Conservation, Wellington.

Hoare, J. M., and K. M. Hare. 2006. The impact of brodifacoum on non-target wildlife: gaps in knowledge. New Zealand Journal of Ecology 30:157-167.

Howald et al. 2007.

O'Connor, C.; Booth, L. 2001: Palatability of rodent baits to wild house mice. *Science for Conservation 184*. Department of Conservation, Wellington, New Zealand. 11 p.

Ogilvie, S.C.; Pierce, R.J.; Wright, G.R.G.; Booth, L.H.; Eason, C.T. 1997. Brodifacoum residue analysis in water, soil, invertebrates, and birds after rat eradication on Lady Alice Island. *New Zealand Journal of Ecology 21:* 195-197.

Pickard, J. (1983). Vegetation of Lord Howe Island. *Cunninghamia* 1, 133–266.

Saunders, A. & Brown, D., 2001, An assessment of the feasibility of eradicating rodents from the Lord Howe Island Group. Report to the Lord Howe Island Board, Endangered Species Recovery Council, New Zealand.

Spurr, E.B.; Drew, K.W. 1999. Invertebrates feeding on baits used for vertebrate pest control in New Zealand. *New Zealand Journal of Ecology 23:*167-173.

Stephenson, B.M.; Minot, E.O.; Armstrong, D.P. 1999. Fate of moreporks (*Ninox novaeseelandiae*) during a pest control operation on Mokoia Island, Lake Rotorua, North Island, New Zealand. *New Zealand Journal of Ecology 23:* 233-240.

Taylor, D. P. 1984: The identification and detection of the rats in New Zealand and the eradication of ship rats on Tawhitinui Island. Unpublished dissertation for Diploma in Parks and Recreation, Lincoln College, Canterbury, New Zealand. 73 p.

Towns, D. R., and K. G. Broome. 2003. From small Maria to massive Campbell: forty years of rat eradications from New Zealand islands. New Zealand Journal of Zoology 30:377-398.

Towns, D. R., I. A. E. Atkinson, and C. H. Daugherty. 2006. Have the harmful effects of introduced rats on islands been exaggerated? Biological Invasions 8:863-891.

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.

[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.

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

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

References

Billing, J. 1999. The management of introduced rodents on Lord Howe Island. Unpublished report to Lord Howe Island Board.

Billing, J. 2000. The control of introduced *Rattus rattus* L. on Lord Howe Island. II. The status of warfarin resistance in rats and mice. *Wildlife Research* **27,** 659-661.

Broome, K. 2009. Beyond Kapiti - A decade of invasive rodent eradications from New Zealand islands. *Biodiversity* **10,** 14-24.

Courchamp, F. Clutton-Brock, T, & Grenfell, B. 1999. Inverse density dependence and the Allee effect. *Trends in Ecology & Evolution* 14, 405-410. 99.

DECC (2007) Lord Howe Island Biodiversity Management Plan. Department of Environment and Climate Change DECC, Hurstville.

Dowding, J.E., Murphy, E.C. and Veitch, C.R. 1999. Brodifacoum residues in target and non-target species following an aerial poisoning operation on Motuihe Island, Hauraki Gulf, New Zealand. *New Zealand Journal of Ecology 23:* 207-214.

Eason, C.T. and Spurr, E.B. 1995. Review of the toxicity and impacts of brodifacoum on nontarget wildlife in New Zealand. *New Zealand Journal of Zoology 22:* 371-379.

Eason, C. T. and Wickstrom, M.Vertebrate pesticide toxicology manual (poisons): Information on poisons used in New Zealand as vertebrate

pesticides. 2001. Wellington, New Zealand, Department of Conservation. DoC Technical Series.

Goldwater, N. 2008. Ecology of House Mice Within the Tawharanui Open Sanctuary. MSc Thesis, University of Auckland, Auckland.

Howald, G., Donlan, C.J., Galv´an, J.P., Russell, J.C., Parkes, J., Samaniego, A., Wang, W., Veitch, D., Genovesi, P., Pascal. M., Saunders, A. and Tershy, B. 2007. Invasive Rodent Eradication on Islands. *Conservation Biology, 21*: 1258–1268

LHIB 2009, *Draft Lord Howe Island Rodent Eradication Plan*, Lord Howe Island Board, Lord Howe Island.

Mackay, J. W. B., Russell, J. C., and Murphy, E.C. 2007. Eradicating House Mice From Islands: Successes, Failures And The Way Forward . In: *Managing Vertebrate Invasive Species: Proceedings of an International Symposium. eds.* G.W. Witmer, W.C. Pitt, and K.A. Fagerstone, K. A. Fort Collins, CO, USDA/APHIS/WS, National Wildlife Research Center. pp. 294-304

O'Connor, C. and Booth, L. 2001. Palatability of rodent baits to wild house mice. *Science for Conservation 184*. Department of Conservation, Wellington, New Zealand. 11 pp.

Pickard, J. 1983. Vegetation of Lord Howe Island. *Cunninghamia 1*, 133–266.

Saunders, A. and Brown, D. 2001, An assessment of the feasibility of eradicating rodents from the Lord Howe Island Group. Report to the Lord Howe Island Board, Endangered Species Recovery Council, New Zealand.

Towns, D. R. and Broome, K.G. 2003. From small Maria to massive Campbell: forty years of rat eradications from New Zealand islands. *New Zealand Journal of Zoology 30*:377-398.

Towns, D. R., Atkinson, I. A. E. and Daugherty, C.H. 2006. Have the harmful effects of introduced rats on islands been exaggerated? *Biological Invasions 8*:863-891.

Wanless, R. M., Fisher, P., Cooper, J., Parkes, J., Ryan, P. G., and Slabber, M. 2008. Bait acceptance by house mice: an island field trial. *Wildlife Research* 35: 806-811.

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.

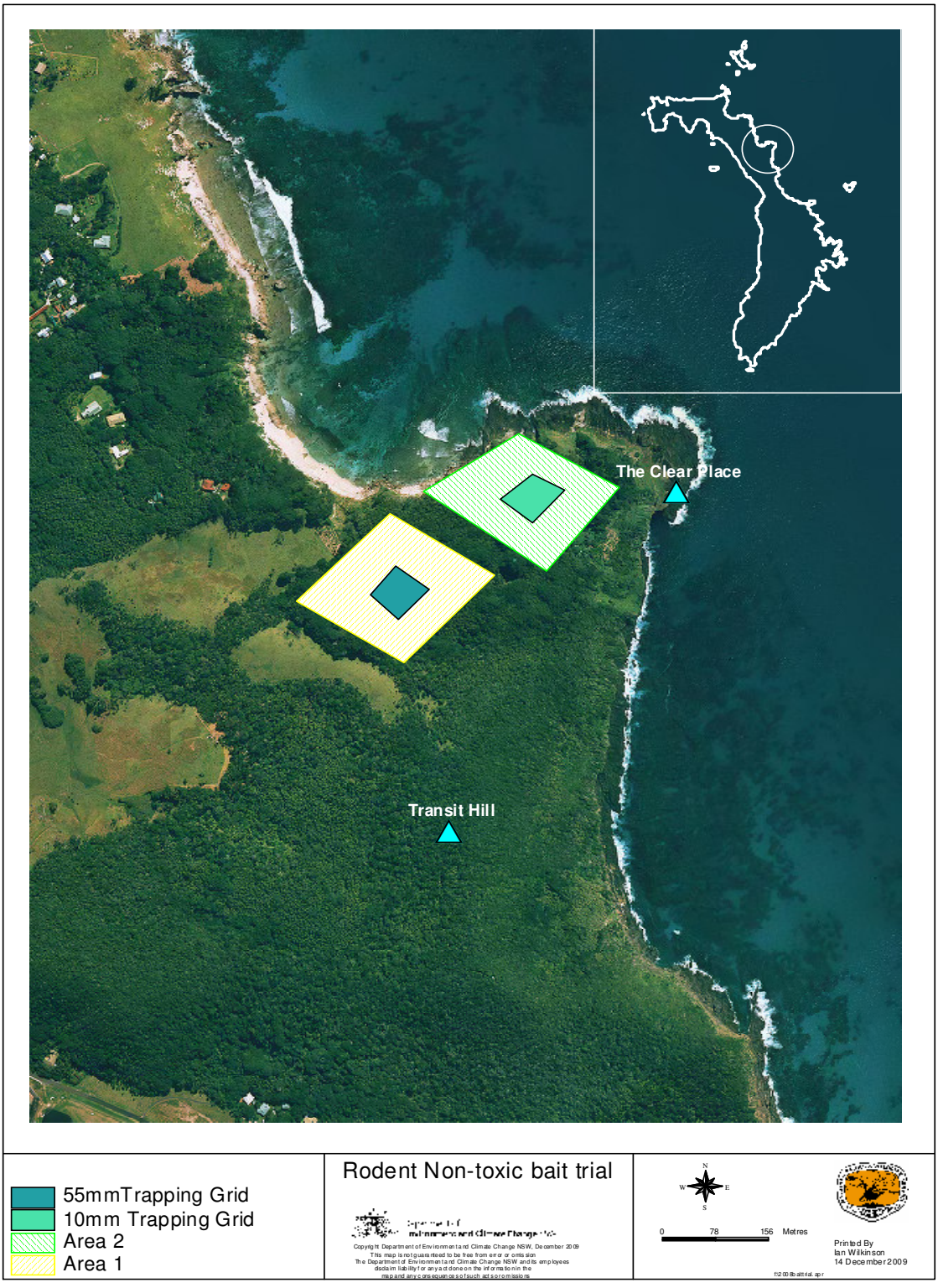

Figure 1 : Map of Lord Howe Island showing the locations of baiting areas and trapping grids for the non-toxic bait trial at the Clear Place.

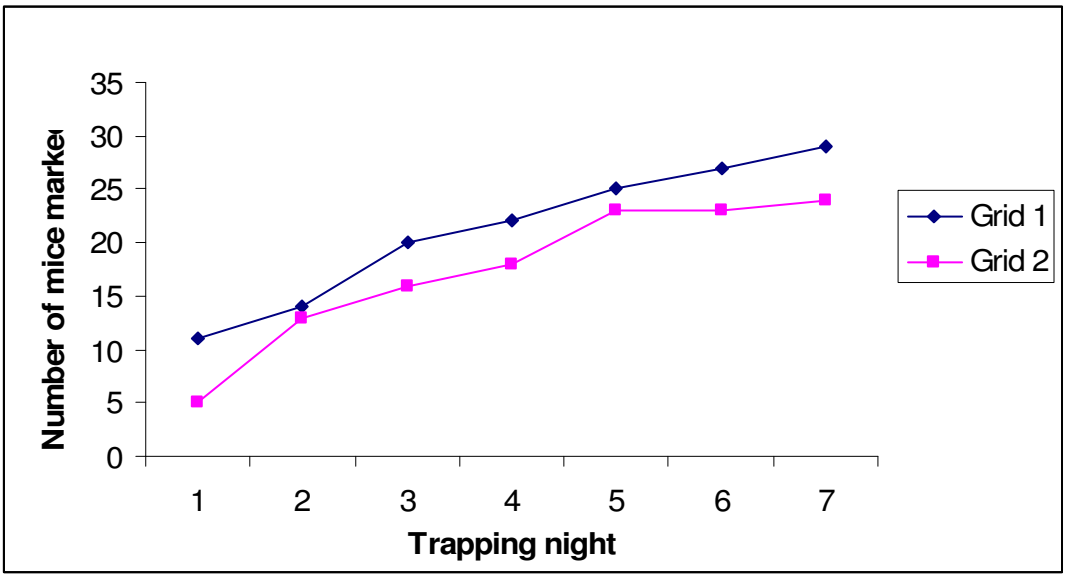

Figure 2. Cumulative numbers of mice marked on trapping grids prior to baiting.

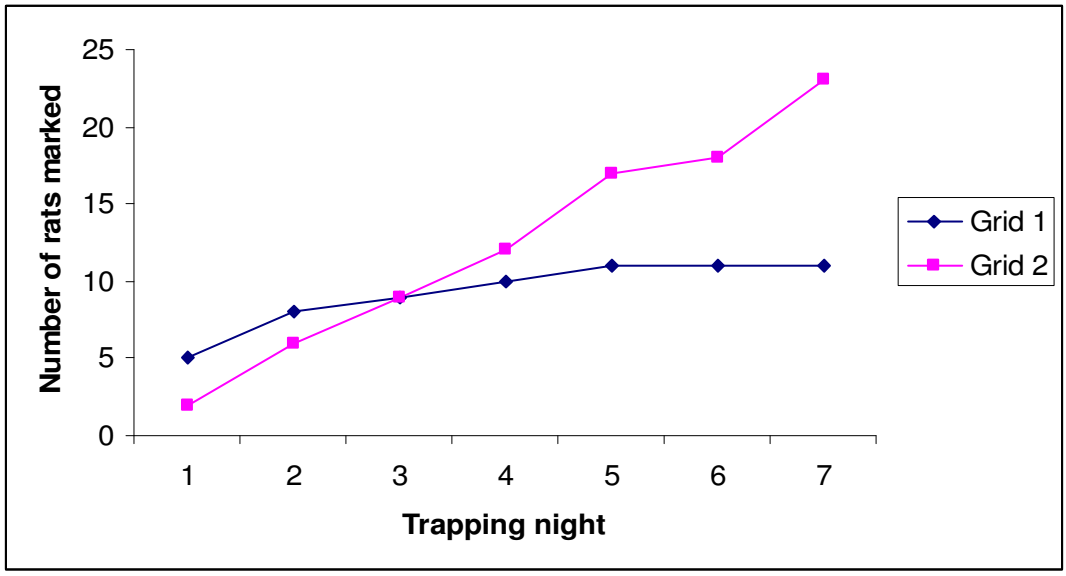

Figure 3. Cumulative numbers of rats marked on trapping grids prior to baiting.

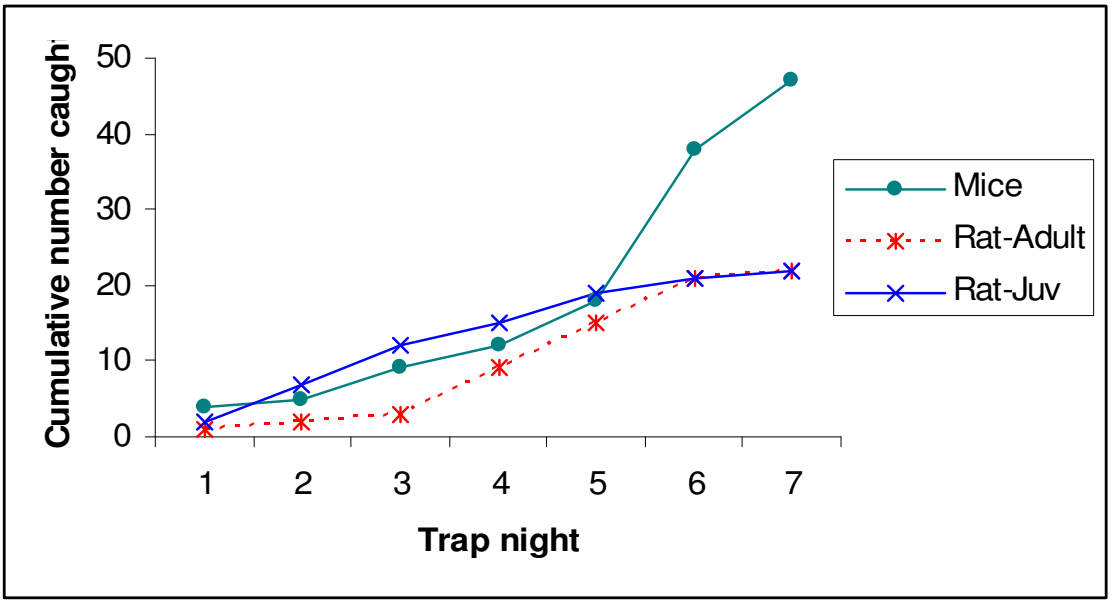

Figure 4. Cumulative captures of adult and juvenile rats and mice.

Figure 5. Juvenile rats captured in the same snap trap.

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.

REFERENCES

Cogger, H.G. 1971. The Reptiles of Lord Howe Island. *Proceedings of the Linnaean Society, NSW*. **96(1)**: 23-28.

Cuthbert, R. J., Visser, P., Louw, H., and Ryan, P. G. (2011). Palatability and efficacy of rodent baits for eradicating house mice (*Mus musculus*) from Gough Island, Tristan da Cunha. *Wildlife Research* **38**, 196-203.

Harden, R.H., Leary, C. 1992. The Lord Howe Island Board rat control program: report to the Lord Howe Island Board. Unpublished report to the Lord Howe Island Board.

Hindwood, K.A. 1940. The Birds of Lord Howe Island. *Emu* **40**: 1-86.

Howald, G., Donlan, C.J., Galvan, J.P., Russell, J.C., Parkes, J., Samaniego, A., Wang, Y., Veitch, D., Genovesi, P., Pascal, M., Saunders, A. and Tershy, B. (2007). Invasive rodent eradication on islands. *Conservation Biology* **21**, 1258-1268.

Hutton, I., 2001, Report on the IUCN Island Invasives conference Auckland February 19-23, 2001, unpub.

Morriss, G. A., O'Connor, C. E., Airey, A. T., and Fisher, P. (2008). Factors influencing palatability and efficacy of toxic baits in ship rats, Norway rats and house mice. Science for Conservation 282 Department of Conservation, Wellington, New Zealand.

O'Connor, C. E., and Booth, L. H. (2001). Palatability of rodent baits to wild house mice. Science for Conservation 184. Department of Conservation, Wellington, New Zealand.

Priddel, D., Carlile, N., Humphrey, M., Fellenberg, S., Hiscox, D., 2003, Rediscovery of the 'extinct' Lord Howe Island stick-insect (*Dryococelus australis* (Montrouzier)) (Phasmatodea) and recommendations for its conservation. *Biodiversity and Conservation* **12**, 1391-1403

Recher, H.F. & Clark, S.S. 1974, Environmental Survey of Lord Howe Island, Report to the Lord Howe Island Board, NSW Government Printer, Sydney.

Saunders, A. & Brown, D., 2001, *An assessment of the feasibility of eradicating rodents from the Lord Howe Island Group*. Report to the Lord Howe Island Board, Endangered Species Recovery Council, New Zealand.

Wade, J. (2011). Know your poison. *Pest magazine* September and October, 32-33.

Wilkinson, I., Priddel, D., Carlile, N., and Wheeler, R. (2008). 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. Unpublished report to the Lord Howe Island Board.

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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References

Atkinson, I. A. E. (1985). The spread of commensal species of *Rattus* to oceanic islands and their effects on island avifaunas. In 'Conservation of island birds. Vol. ICBP technical publication no. 3.' (Ed. P. J. Moors) pp. 35-81. (International Council for Bird Preservation: Cambridge.)

Bailey, C. I., and Eason, C. T. (2000). Anticoagulant resistance in rodents. Conservation Advisory Science Notes Department of Conservation, Wellington, New Zealand.

Billing, J. (2000). The control of introduced *Rattus rattus* L. on Lord Howe Island. II. The status of warfarin resistance in rats and mice. *Wildlife Research* **27**, 659-661.

Billing, J., and Harden, B. (2000). Control of introduced *Rattus rattus* L. on Lord Howe Island. I. The response of mouse populations to warfarin bait used to control rats. *Wildlife Research* **27**, 655-658.
Boyle, C. M. (1960). Case of apparent resistance of *Rattus norvegicus* Berkenhout to anticoagulant poisons. *Nature* **188**, 517.

Brown, D., Wylie, M., and McClelland, P. (2006). Assessment of environmental effects for the eradication of: Ship rats (*Rattus rattus*) from Taukihepa, Pukeweka and Solomon (Rerewhakaupoko) Islands; and Kiore (*Rattus exulans*) from Big Moggy (Mokonui) Island. Unpublished report. Department of Conservation, New Zealand.

Buckle, A. (2013). Anticoagulant resistance in the United Kingdom and a new guideline for the management of resistant infestations of Norway rats (*Rattus norvegicus* Berk.). *Pest Management Science* **69**, 334-341.

Cleghorn, M., and Griffiths, R. (2002). Palatability and efficacy of Pestoff 20R bait on mice from Mokoia Island, Rotorua. DOC Science Internal Series 25. New Zealand Department of Conservation, Wellington.

Cuthbert, R., and Hilton, G. (2004). Introduced house mice *Mus musculus*: a significant predator of threatened and endemic birds on Gough Island, South Atlantic Ocean? *Biological Conservation* **117**, 483-489.

Cuthbert, R. J., Visser, P., Louw, H., and Ryan, P. G. (2011). Palatability and efficacy of rodent baits for eradicating house mice (*Mus musculus*) from Gough Island, Tristan da Cunha. *Wildlife Research* **38**, 196-203.

DECCW (2010). Lord Howe Island Permanent Park Preserve Plan of Management. Department of Environment, Climate Change and Water, Sydney.
Deparment of the Environment (2013). Lord Howe Island Group. Available at www.environment.gov.au/heritage/places/world/index.html

Desideri, D., Aldighieri, R., Lovet, M. L., and Tardieu, A. (1979). La resistance murine aux anticoagulants dans le port de Marseille. Elat de responde au difenacoum. *Bulletin de la Société de pathologie exotique* **72**, 278-283.

Dodsworth, E. (1961). Mice are spreading despite such poisons as warfarin. *Municipal Engineering, London* **3746**, 1668.

Dubock, A. C., and Kaukeinen, D. E. (1978). Brodifacoum (Talon^{TM} rodenticide), a novel concept. In 'Proceedings of the 8th Vertebrate Pest Conference (1978)', 1978, University of Nebraska - Lincoln, pp. 126-137. (University of Nebraska - Lincoln:

Fisher, P. (2005). Review of house mouse (*Mus musculus*) susceptibility to anticoagulant poisons. *DOC Science Internal Series* **198**, 1-18.

Fukami, T., Wardle, D. A., Bellingham, P. J., Mulder, C. P. H., Towns, D. R., Yeates, G. W., Bonner, K. I., Durrett, M. S., Grant-Hoffman, M. N., and Williamson, W. M. (2006). Above- and below-ground impacts of introduced predators in seabird-dominated island ecosystems. *Ecology Letters* **9**, 1299–1307.

Gill, J. E., Kerins, G. M., and MacNicoll, A. D. (1992). Inheritance of low grade brodifacoum resistance in the Norway rat. *Journal of Wildlife Management* **56**, 809-816.

Godfrey, M. E. R. (1985). Non-target and secondary poisoning hazards of "second generation" anticoagulants. *Acta Zoologica Fennica* **173**, 209-212.

Greaves, J. H. (1994). Resistance to anticoagulant rodenticides. In 'Rodent Pests and their Control.' (Eds. A. P. Buckle and R. H. Smith) pp. 127-160. (CAB International: Wallingford.)

Greaves, J. H., Shepherd, D. S., and Quy, R. (1982). Field trials of second-generation anticoagulants against difenacoum-resistant norway rat populations. *Journal of Hygiene* **89**, 295-301.

Green, P. S. (1994). 'Flora of Australia. Vol. 49. Oceanic Islands 1.' (Australian Government Publishing Service: Canberra.)

Groombridge, B. (1992). Global biodiversity: status of the earth's living resources: a report. Report prepared for the World Conservation Monitoring Centre, British Museum (Natural History), and International Union for Conservation of Nature and Natural Resources. Chapman and Hall, London.

Hadler, M. R., and Shadbolt, R. S. (1975). Nivel 4-hydroxycoumarin anticoagulants active against resistant rats. *Nature* **253**, 277-282.

Harden, R. H., and Leary, C. (1992). The Lord Howe Island Board rat control program: report to the Lord Howe Island Board. Unpublished report to the Lord Howe Island Board, Lord Howe Island. NSW National Parks and Wildlife Service, Armidale.

Holdaway, R. N., Hawke, D. J., Hyatt, O. M., and Wood, G. C. (2007). Stable isotopic ($\delta^{15}N$, $\delta^{13}C$) analysis of wood in trees growing in past and present colonies of burrow-nesting seabirds in New Zealand. I. $\delta^{15}N$ in two species of conifer (Podocarpaceae) from a mainland colony of Westland petrels (*Procellaria westlandica*), Punakaiki, South Island. *Journal of the Royal Society of New Zealand* **37**, 75–84.

Howald, G., Donlan, C. J., Galvan, J. P., Russell, J. C., Parkes, J., Samaniego, A., Wang, Y., Veitch, D., Genovesi, P., Pascal, M., Saunders, A., and Tershy, B. (2007). Invasive rodent eradication on islands. *Conservation Biology* **21**, 1258-1268.

Hunter, K. (1983). Determination of coumarin anticoagulant rodenticide residues in animal tissue by high-performance liquid chromatography: I. Fluorescence detection using post-column techniques. *Journal of Chromatography A* **270**, 267–276.

Hutton, I. (1998). 'The Australian Geographic book of Lord Howe Island.' (Australian Geographic: Terrey Hills.)

ICI (1983). Method PPSM 500. The determination of brodifacoum in baits, concentrates and technical material by high performance liquid chromatography. ICI Plant Protection Division, Yalding, UK.

Lavoie, C., Donlan, C. J., Campbell, K., Cruz, F., and Carrion, V. G. (2007). Geographic tools for eradication programs of insular non-native mammals. *Biological Invasions* **9**, 139-148.

LHIB (2009). Draft Lord Howe Island Rodent Eradication Plan. Lord Howe Island Board, Lord Howe Island.

Lund, M. (1981). Comparative effect of the three rodenticides warfarin, difenacoum and brodifacoum on eight rodent species in short feeding periods. *Journal of Hygiene* **87**, 101-107.
4313. Lund, M. (1984). Resistance to the second-generation anticoagulant rodenticides. In 'Proceedings of the 11th Vertebrate Pest Conference', 1984. (University of Nebraska: Lincoln.)

MacKay, J. W. B. (2011). Improving the success of mouse eradication attempts on islands. PhD Thesis, University of Auckland, Auckland.

MacKay, J. W. B., Russell, J. C., and Murphy, E. C. (2007). Eradicating house mice from islands: successes, failures and the way forward. In 'Managing Vertebrate Invasive Species:

Proceedings of an International Symposium.' (Eds. G. W. Witmer, W. C. Pitt and K. A. Fagerstone) pp. 64-66. (USDA/APHIS/WS, National Wildlife Research Center: Fort Collins.)

Mathur, R. P., and Prakash, I. (1981). Evaluation of brodifacoum against *T. indica*, *M. hurrianae* and *R. rattus*. *Journal of Hygiene* **87**, 179-184.

Moors, P. J. (1985). Eradication campaign against *Rattus norvegicus* on the Noises Islands, New Zealand, using brodifacoum and 1080. In 'Conservation of island birds: case studies for the management of threatened island species. Technical Publication No. 3.' pp. 143-155. (International Council for Bird Preservation: Cambridge.)

Morriss, G. A., O'Connor, C. E., Airey, A. T., and Fisher, P. (2008). Factors influencing palatability and efficacy of toxic baits in ship rats, Norway rats and house mice. Science for Conservation 282 Department of Conservation, Wellington, New Zealand.

O'Connor, C. E., and Booth, L. H. (2001). Palatability of rodent baits to wild house mice. Science for Conservation 184. Department of Conservation, Wellington, New Zealand.

Pelz, H.-J., Rost, S., Hünerberg, M., Fregin, A., Heiberg, A.-C., Baert, K., MacNicoll, A. D., Prescott, C. V., Walker, A.-S., and Oldenburg, J. (2005). The genetic basis of resistance to anticoagulants in rodents. *Genetics* **170**, 1839-1847.

Rance, B. (2001). Titi Islands expedition, March 2001. Unpublished Report RI 6418. Department of Conservation, Invercargill.

Recher, H. F., and Clark, S. S. (1974). Environmental survey of Lord Howe Island. A report to the Lord Howe Island Board. New South Wales Government Printer, Sydney.

Redfern, R., and Gill, J. E. (1978). The development and use of a test to identify resistance to the anticoagulant difenacoum in the Norway rat (*Rattus norvegicus*). *Journal of Hygiene* **81**, 427-431.

Redfern, R., Gill, J. E., and Hadler, M. R. (1976). Laboratory evaluation of WBA 8119 as a rodenticide for use against warfarin resistant and non-resistant rats and mice. *Journal of Hygiene* **77**, 419-426.

Rowe, F., Plant, C., and Bradfield, A. (1981). Trials of the anticoagulant rodenticides bromadiolone and difenacoum against the house mouse(Mus musculus L.). *Journal of Hygiene* **87**, 171-177.
Samama, M. M., Gerotziafas, G. T., Elalamy, I., Horellou, M. H., and Conard, J. (2003). Biochemistry and clinical pharmacology of new anticoagulant agents. *Pathophysiology of haemostasis and thrombosis* **32**, 218-224.

Saunders, A., and Brown, D. (2001). An assessment of the feasibility of eradicating rodents from the Lord Howe Island Group. A report to the Lord Howe Island Board. Endangered Species Recovery Council, Hamilton, New Zealand.

Shaw, J. D., Hovenden, M. J., and Bergstrom, D. M. (2005). The impact of introduced ship rats (*Rattus rattus*) on seedling recruitment and distribution of a subantarctic megaherb (*Pleurophyllum hookeri*). *Austral Ecology* **30**, 118-125.

Siddiqi, Z., and Blaine, W. D. (1982). Anticoagulant resistance in house mice in Toronto, Canada. *Environmental Health Review* **26**, 49-51.

Taylor, R. H., and Thomas, B. W. (1989). Eradication of Norway rats (*Rattus norvegicus*) from Hawea Island, Fiordland, using brodifacoum. *New Zealand Journal of Ecology* **12**, 23-32.

Towns, D. R., Atkinson, I. A. E., and Daugherty, C. H. (2006). Have the harmful effects of introduced rats on islands been exaggerated? *Biological Invasions* **8**, 863-891.

Towns, D. R., and Broome, K. G. (2003). From small Maria to massive Campbell: forty years of rat eradications from New Zealand islands. *New Zealand Journal of Zoology* **30**, 377-398.

Wade, J. (2011). Know your poison. *Pest magazine* **September and October**, 32-33.

Wilkinson, I., Priddel, D., Carlile, N., and Wheeler, R. (2008). 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. Unpublished report to the Lord Howe Island Board.

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)

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Human Health Risk Assessment on the use of Brodifacoum for the Lord Howe Island Rodent Eradication Plan

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15th September 2010

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About Toxikos Pty Ltd

Toxikos Pty Ltd is a consulting company formed on December 1st 2000 to provide clients with independent excellence in toxicology and health based risk assessment. Its charter is to assist industry and government make science based decisions regarding potential effects and management of environmental and occupational chemicals. For over twelve years, prior to and since the establishment of Toxikos, staff have provided toxicology and health risk assessment advice to clients in a wide range of industries and government in Australia, New Zealand and South Africa.

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Executive Summary

The Board of Lord Howe Island (LHI) is intending to eradicate mice and rats on the Lord Howe group of islands using brodifacoum in a rodent baiting program. A draft eradication plan has been released for public comment (LHI 2009). The bait chosen for the eradication programme is Pestoff®20R and has been extensively used in New Zealand for similar purposes. The bait contains brodifacoum at 0.002% and also a water soluble emerald green dye which makes it less attractive to birds. The dye will also colour moist tissues such as the tongue and mouth. It is intended to spread large size baits (10 mm in diameter) from helicopters in areas outside the settlement and outside defined buffer zones. There will be a 30 m buffer between the edge of aerial baiting and dwellings, and other sensitive areas such as stock holding locations. Smaller bait (5.5 mm diameter) will be hand broadcast in the settlement, around dwellings, and public space. On average a large pellet will contain 40 micrograms (µg) of brodifacoum and the smaller pellet 10 µg.

Toxikos has been requested to undertake a human health risk assessment for the eradication campaign as proposed in the draft plan.

The effects of brodifacoum:
Brodifacoum is an anticoagulant that indirectly inhibits blood coagulation by inhibiting the regeneration of Vitamin K after it has catalysed the synthesis of vitamin K dependent clotting factors. When the existing clotting factors are used up by the body more cannot be made because there is insufficient Vitamin K. Hence frozen plasma (which contains clotting factors) and Vitamin K (which allows more to be made) are efficient antidotes to the effects of brodifacoum.

In humans the toxic signs are bleeding from the gums, nosebleeds, small red or purple spots on the skin caused by capillary haemorrhage, predilection to bruising after usually inconsequential bumps, blood in the urine and faeces (tarry stools). These effects occur before the onset of life threatening internal bleeding. There are no other toxic effects. The toxicity of brodifacoum is easily treated with the antidotes. However, since brodifacoum stays in the liver for a long time oral treatment with Vitamin K may need to continue over a few to several months depending on the severity of poisoning. If a large amount is suspected to have been ingested then within a few hours, a slurry of charcoal and laxative may be given to decrease absorption from the gut. Death is very rare in situations of incidental ingestion (e.g. in children mistaking rodent bait as candy), and even when brodifacoum rodent bait is intentionally eaten for suicide death is

uncommon if treatment is provided within a reasonable time frame. The onset of clinical signs of poisoning may be delayed several days after exposure to an effective single large dose or after a few weeks of repeated ingestion of small doses.

The severity of poisoning is monitored by a simple test which measures how quickly blood coagulates. The test is called the prothrombin coagulation time (PT). An increase in PT occurs before any signs of toxicity (i.e. before effects associated with increased bleeding occur). Thus PT is a precursor event before the onset of toxicity. A certain amount of brodifacoum in the body is required to increase PT and across a number of species the threshold dose of brodifacoum to affect PT is about the same. There are no major differences between mammalian non-ruminant species regarding their toxicological sensitivity to acute doses of brodifacoum. The no observed effect level (NOEL) is the dose of brodifacoum that does not cause an increase in PT; i.e. this is the dose that has no effect on the body.

No observed effect levels (NOELs):
Because brodifacoum can accumulate in the liver with continuous daily doses, the NOEL is different for different periods of exposure. For an acute single dose the NOEL is 0.15 milligram per kilogram body weight (shortened to 0.15 mg/kg), for 42 days of daily exposure the NOEL is 0.005 mg/kg/d, and for 90 days exposure it is 0.001 mg/kg/d. The acceptable daily intake (ADI) over an entire lifetime is 0.0000005 mg/kg/d.

Because the LHI rodent eradication programme is finite and noting bait completely disintegrates with 100 days, the appropriate NOEL for judging the importance of human exposure to brodifacoum is either the 42 or 90 day NOEL. For many of the assumed exposure pathways the 42 day value is appropriate. The ADI is inappropriate because this is a guideline intended for situations where exposure could be for every day of a person's lifetime of 70 years.

Potential exposure pathways:
This health risk assessment for human exposure to brodifacoum rodent bait is specific for the Lord Howe Island group and takes into account the particular bait intended to be used, the method of application, the longevity of the bait in the terrestrial and aquatic environments, and management practices to be undertaken to minimise human exposure to the broadcasted bait.

A number of possible theoretical exposure pathways have been considered (Figure 3.1). These include:

- Direct ingestion of rodent bait.
- Inhalation of dust containing brodifacoum

- Ingestion of soil contaminated by brodifacoum from bait.
- Dermal exposure to bait and contaminated soil.
- Ingestion of water (ground water and tank water) that may become contaminated by bait.
- Consumption of:
    - vegetables and fruit,
    - poultry produce,
    - fish that may have ingested bait inadvertently distributed to shore waters,
    - meat and dairy produce,
    - goat produce,
    - wild ducks.

Many of these exposure pathways will not occur due to pre-emptive management practices that are to be put in place during and after the proposed eradication campaign (e.g. removal of poultry and cattle from the Island, and isolating cows and goats from exposure to rodent bait). Consumption of wild ducks is said not to occur on the Island.

An important consideration in estimating exposure to brodifacoum by direct ingestion of bait pellets, or indirectly via potentially contaminated water, soil, and seafood is the stability of the pelletised form of the bait in the environment. The bait completely disintegrates into a few particles of grain within 100 days of being broadcast. It only remains as an entity that can be picked up by children or birds for about 15 – 21 days. Hence with two broadcast campaigns approximately two weeks apart, solid bait may be on the ground in such a 'pick-up-able' form for about 4 – 5 weeks. In water, bait pellets are reported to disintegrate within 15 minutes, sooner if there is wave action.

Direct ingestion of rodent bait:
The most important way that a young child may be exposed to rodent bait during the proposed eradication campaign is by picking the bait up and eating it. Pestoff®20R rodent bait contains a water soluble green dye that will colour the tongue and mouth and thus assist to alert parents.

Even though brodifacoum is acutely very toxic to a range of species including humans, the amount of bait needed to be ingested by a child at one time to cause health effects is quite large. Small bait pellets (5.5mm diameter) are intended to be hand distributed in the settlement and around dwellings. These are therefore the ones most likely to be picked up by a child. The number of pellets required to be ingested to reach the acute NOEL (0.15 mg/kg) for

prolongation of prothrombin time is approximately 200 which weigh about 100 g. This amount of bait is put into perspective by considering commercial rat bait Talon®, which has two-and-a-half times the amount of brodifacoum, is sold in 150 g packets containing six prepacked pellet trays of 25 g each.

Assuming there will be two bait campaigns about two weeks apart, the time that bait will be in a physical form able to be picked up by a child is 4 -5 weeks. It will require ingestion of 6 -7 small pellets every day by a small child over this period to acquire a dose equivalent to the 42 day NOEL. This is unlikely to occur.

It is a fact that unless it is consumed with the intention self harm (e.g. suicide attempt) it is unusual for a person to suffer toxic effects (anticoagulant symptoms) from incidental ingestion of brodifacoum rodent bait. The parents of children who have accidently eaten rat bait understandably seek medical advice; however the majority of children do not require medical intervention. Even with intentional ingestion with the aim of suicide most people do not die. This is because there are several days between ingestion and the appearance of toxic effects which allows time to objectively gauge the severity of poisoning with the PT test, and if need be administer the antidotes which are very efficient.

It is also theoretically possible that Island residents could be exposed to bait dust in the air during, or soon after broadcast by helicopters. A reasonable maximum estimate of the amount of brodifacoum that might be inhaled during this time is 5 million times less than the dose that does not affect the body.

Indirect exposure pathways:
Brodifacoum, because of its physical chemical properties, is unable to contaminant groundwater. It doesn't leach from soil. Similarly it does not contaminate vegetables and fruit because it is not transported from water or soil into the plant. The surface of the plant could become contaminated if the bait was physically broadcast onto the plant. While this should not occur (as bait is to be hand broadcast in the settlement area), if it does, bait particles can be easily washed off during food preparation.

Contamination of soil, fish and seafood, and tank water are hypothetical but nonetheless plausible pathways through which LHI residents may become exposed to brodifacoum. Even though it is very unlikely such exposure will occur, possible intake of brodifacoum by a 2 year old child has been estimated for these pathways. This is the population sector most at risk from exposure to chemicals in the environment. It is emphasised there is uncertainty associated with

accurately calculating brodifacoum intakes. Consequently conservative 'high end' estimations have been undertaken so any error is more likely to be on the side of over-estimation rather than under-estimation.

The high end estimation of brodifacoum dose by these exposure routes is less than the 42 day and 90 day NOELs. For some of the indirect exposure routes the dose is many orders of magnitude lower.

Overall, it is concluded there is negligible risk for human health from these exposure pathways. This includes infants and young children[1] who are the most vulnerable group.

It is unlikely fish will have much opportunity to eat bait that might fall into the ocean, it is also unlikely humans will catch such fish in numbers where it may become a health issue. In New Zealand there has been a very large accidental spill of Pestoff®20R into the sea, even so brodifacoum was not measureable in fish flesh.

Contamination of tank water may occur if aerial broadcasting of bait accidently spreads pellets onto roofs. The draft eradication plan has management contingency for this event. Less obvious ways that brodifacoum might get onto roofs is by birds eating bait and depositing droppings on roofs and gutters, or birds picking bait up and discarding it onto roofs. While these events appear plausible they are intuitively unlikely to place significant amounts of brodifacoum onto the roof, this is confirmed by the exposure calculations.

Ingestion of brodifacoum contaminated soil is a very minor pathway. It is unlikely all soil incidentally ingested (mostly by hand to mouth transfer) will be contaminated soil. Soil residue data from New Zealand when incorporated into the intake calculations results in negligible doses of brodifacoum. Furthermore brodifacoum is tightly bound to organic carbon in soil which significantly lowers the amount that may be absorbed into the body. Indeed swallowing a slurry of charcoal is a treatment option for large amounts of brodifacoum that have been ingested up to about 4 hours earlier.

Health risk from current practice

Relative to the health risk associated with current household practice of controlling rodents on LHI, the Pestoff®20R pellets present the same hazard and potential health risk as Ratsak. But

[1] In this report an infant is considered to be a child who is not yet walking, a young child is less than 6 years of age. Calculation of potential exposures to children have followed Australian practice and assumed the child is 2 years old (enHealth 2004).

because they are bigger the health risk associated with ingestion of a large number of pellets of Pestoff®20R is greater than for the same number of Talon® pellets. However, this is put in context when it is considered such incidental ingestion poses negligible risk to the health of infants or young children. Generally for the same weight of bait ingested, Pestoff®20R presents a lower risk because it has a lower concentration of brodifacoum than products sold on the domestic market. This is however balanced by the absence of a taste deterrent which is in some, but not all commercial products. It is noted that with the current use of rodent bait there is an ongoing risk of inadvertent ingestion of rodent bait. This long term risk will be removed if rodents are eradicated from the Island.

Conclusions:

Although brodifacoum is an acutely toxic substance that has the potential to cause toxicity and possibly death through internal bleeding, the human health risk to Lord Howe Islanders during the proposed eradication campaign is very low.

The most important exposure pathway is direct ingestion of bait pellets picked up off the ground or from bait stations. The draft LHI rodent eradication plan indicates there will be an education campaign targeting children and parents of the dangers associated with eating the bait. Nonetheless parents will need to be especially watchful of their young children during the 4 -5 weeks bait will be on the ground and in a form able to be picked up. This vigilance is similar to that currently required with the ongoing use of rodenticides in the settlement area.

Even though exposure is unlikely, indirect exposure pathways are primarily managed during the eradication programme by removing or isolating human food sources that may theoretically become contaminated (e.g. poultry, beef meat and dairy produce). Other human foods (e.g. seafood) are unlikely to be affected.

Tank water may be impacted if bait is strewn over roofs during aerial broadcasting. There are management contingencies to mitigate this. Theoretically tank water may also become contaminated with brodifacoum if birds transport pellets onto roofs or after eating pellets leave their droppings on roofs. Both these scenarios are regarded as improbable but if they do occur are very unlikely to affect tank water to the extent it is unsafe to drink.

Exposure to brodifacoum by indirect pathways (i.e. not direct ingestion of rodent bait) is negligible in comparison to the NOELs and human health effects are very unlikely.

The health risks due to brodifacoum via Pestoff®20R are the same as current practise using commercially available rat bait. However for the same number of pellets ingested, the risk may be higher depending on the constituents and pellet size of the commercial product. Generally for the same weight of bait ingested, Pestoff®20R presents a lower risk because it has a lower concentration of brodifacoum. This is balanced by the absence of a taste deterrent which is in some, but not all commercial products. Notwithstanding the different relative risks associated with different rodent bait products, the likelihood of health effects occurring in infants and young children from incidental ingestion of bait is negligible.

The eradication campaign, if successful in removing rats and mice from LHI, will result in a smaller (zero) ongoing risk of exposure to rodent poisons.

Recommendations:

All mitigation measures as outlined in the *Draft Lord Howe Island Rodent Eradication Plan* should be implemented to minimise risks posed by use of rodent bait during the programme.

As a precautionary measure it would be prudent to advise Islanders not to consume the livers of fish that have been caught within 200m of the shore line until 6 months after the last bait broadcast.

Although there is a negligible health risk from drinking tank water during the eradication campaign, for peace of Islander's mind, consideration could be given to a programme of strategic testing of tank water.

It would be prudent to advise those individuals involved with the control of non-native duck populations that they should not consume duck during the eradication programme, and not the liver for perhaps a year after the program has ceased.

Contents

1. Introduction

The Board of Lord Howe Island (LHI) is intending to eradicate mice and rats on LHI using the rodenticide brodifacoum. A draft eradication plan has been released for public comment (LHI 2009). The draft plan considers many of the benefits and risks which primarily focus on issues associated with:

- operational practicalities to ensure success of the operation,
- impact to wildlife that might result from inadvertently broad casting bait to ecological sensitive locations and
- reinfestation of the island.

Toxikos has been requested to undertake a human health risk assessment for the eradication campaign as proposed in the draft plan.

1.1 Bait use

The following is a compilation of information from the draft eradication plan (LHI 2009) that is useful for understanding how the rodent bait will be distributed and therefore also the possible human exposure pathways. The latter are discussed in detail in Section 3. The reader should consult the plan for more detail and contextual information regarding the aims and management issues associated with the rodent eradication program.

After consideration of a number of rodenticides it was decided by the LHI Board to use a commercial product registered in New Zealand for control of rodents and possums. This product (Pestoff® 20R) contains 0.002% brodifacoum (20 mg brodifacoum/kg bait) and a water soluble bright emerald, water soluble green dye. It is proposed to use 10 mm diameter size baits for aerial application (e.g. to areas outside the settlement and outside identified buffer areas on the island) and 5.5 mm baits for all hand-baiting operations (e.g. hand broad casting within the settlement and around other dwellings, for indoor and under house bait stations/trays for targeting mice).

On average, each 5.5 mm bait pellet weighs approximately 500 mg, and each 10 mm pellet about 2 grams. Each pellet respectively contains 0.01 mg and 0.04 mg of brodifacoum. In the settlement area, 5.5 mm baits will be hand-broadcast at a nominal density of at least one bait every half square metre. However, bait distribution will not always be so uniform for example the density of baits in garden beds will be greater than that on lawns.

The aerial broadcast aims for about one bait per two square metres. For aerial application it is currently planned to have a 30m buffer zone around dwellings, containment areas for livestock and other sensitive areas. Within the buffer zones specialised equipment will be used or the bait will be spread by hand.

All hand spread bait will be in the open, not under buildings or elsewhere where it is not subject to weathering. Trials on LHI found that the Pestoff® 20R bait pellets disintegrated completely after approximately 100 days (further information on the stability of the bait in the field is in Section 2.3.2). It is intended that bait be re-broadcast about 14 days after the first campaign to ensure its availability in a palatable form to rodents that may have missed the first bait campaign (e.g. those that emerge from the nest).

Where broadcasting bait cannot be undertaken, bait stations will be used (See Appendix 1). It is planned to use open trays similar to those provided with commercial rat bait for roof cavities and ceiling/under floor spaces. These are approximately the size of match boxes and will hold about 25 – 50 g of bait. Bait will be removed 100 days after rats or mice are no longer detected.

1.2 Issue identification and scope

As seen in Section 2, brodifacoum is a potent poison to many mammalian species. Because its effects are delayed by up to several days there is potential for ongoing exposure without realising a potentially harmful dose has occurred.

Many residents have expressed apprehension about aerial broadcasting of bait and problems with non-target species and secondary kills occurring. With respect to human health, the primary concern is that the bait will be widely broadcast in the settlement and around dwellings with consequent exposure and potential poisoning of children. This health risk assessment (HRA) only deals with public health risks and theoretical pathways for human exposure to brodifacoum during the eradication campaign.

The HRA does not consider occupational risk to personnel implementing the program as there will be detailed health and safety operating procedures for these people. Nor does the HRA address ecological and non-target species concerns raised during the public comment period.

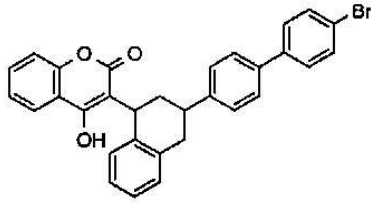
2. Hazard identification

2.2 Properties, toxicology and health effects of brodifacoum

The following information has been obtained from a variety of organisations, particularly the World Health Organization (IPCS 1995, WHO 1995), the Handbook of Pesticide Toxicology (Pelfrene 1991), Encyclopedia of Toxicology (Spiller 2005), European Commission reports (EC 2005a, 2005b, 2005c and 2005d) and Department of Conservation, New Zealand (Fisher and Fairweather 2008). The information in these reviews has been supplemented by scientific articles where indicated.

2.2.1 Physical and chemical properties

Chemical structure:



Chemical name: 3 –{3-(4'-Brombipenyl-4-yl)-1,2,4-terahydro-1-naphthyl]-4-hydroxy-2*H*-chromene-2-one.

CAS Number: 56073-10-0 (formerly 66052-95-7).

Molecular formula: $C_{31}H_{23}BrO_3$

Molecular weight: 523.4

Water solubility: Often described as insoluble, very low solubility, or practically insoluble.
At 20^0C: 0.0038 mg/L at pH 5.2
0.24 mg/L at pH 7.4
10 mg/L at pH 9

pK_a: Dissociation constant in water = 4.5 (calculated).

K_{OC} [2]: 50,000

[2] K_{oc} = Organic carbon partition coefficient. A measure of the tendency for organic substances to be adsorbed by soil or sediment, expressed as:

$$K_{oc} = \frac{\text{(mass adsorbed substance) / (mass organic carbon)}}{\text{(mass concentration of absorbed substance)}}$$

The K_{oc} is substance-specific and is largely independent of soil properties.
The higher the value of K_{OC} the stronger the binding to organic carbon in soil, the more organic carbon the greater the mass of substance that can be bound.

- Brodifacoum binds rapidly and strongly to soil particles with very slow desorption and no leaching (IPCS 1995).
- This property is used in one of the optional treatments; if a toxic dose is suspected to have been ingested, then within 4 hours oral administration of activated charcoal and a cathartic may be given. The charcoal strongly binds the brodifacoum to significantly decrease absorption from the gut and the cathartic hastens the passage of the charcoal-brodifacoum complex through the gut.

Vapour pressure: $<<1 \times 10^{-9}$ kPa at 20^0C.
This, with the low Henry's law constant, indicates very little propensity to vaporise into air.

Henry's Law Constant: $<<2.18 \times 10^{-3}$ Pa m^3 mol-1 at pH 7, and
$<<5.23 \times 10^{-5}$ Pa m^3 mol-1at pH 9.

Log K_{ow} [3]: 8.5 (This an extreme value outside the range that can be determined experimentally, therefore it is a calculated value).
This value indicates brodifacoum has a tendency to distribute into fatty tissue (e.g. liver and adipose).

2.2.2 Toxicology

Mode of action and basis for antidote:

- Brodifacoum is an anticoagulant that indirectly inhibits blood coagulation. It has this effect by slowing down the biosynthesis of vitamin K-dependent clotting factors, i.e. factors II (prothrombin), VII, IX and X. An essential step in their biosynthesis is the Vitamin K dependent carboxylation of glutamate residues, during this process Vitamin K is converted to its epoxide but is normally regenerated by the action of an enzyme called Vitamin K epoxide reductase so more clotting factor can be made. Brodifacoum and warfarin both inhibit Vitamin K epoxide reductase and hence the regeneration of Vitamin K, however brodifacoum is a stronger and longer lasting inhibitor. Inhibition of Vitamin K epoxide reductase is a key event in the toxicity of brodifacoum.

  Under normal physiological conditions there is constant turnover of these clotting factors. As they become catabolised replacement factors are made in the liver. Hence inhibiting the regeneration of Vitamin K means new clotting factors are not made and there is a gradual decrease over several days in circulating levels in blood. This leads to internal haemorrhaging and if uncorrected, death. In humans, low levels of clotting factors also occur in Vitamin K deficiency.

  Administration of plasma (which contains clotting factors) and Vitamin K_1 (which allows synthesis of new clotting factor) efficiently reverse the anti-coagulating effects of brodifacoum. However because brodifacoum is poorly metabolised and eliminated from the body (see below), in symptomatic poisoned patients oral Vitamin K_1 therapy is required for several weeks, or months depending on the severity of poisoning.

[3] K_{ow} = octanol-water partition coefficient. Ratio of the solubility of a chemical in octanol divided by its solubility in water. This a measure of lipophilicity (fat solubility) used in the assessment of both the uptake and physiological distribution of organic chemicals into organisms and prediction of their environmental fate.

The serum circulating half life ($t_{½}$) of Vitamin K dependent clotting factors[4] in humans is:

- Factor II: 48 – 72 hrs,
- Factor VII: 1.5 – 6 hrs,
- Factor IX: 17 – 24 hrs,
- Factor X: 24 – 48 hrs.

With regard to the toxic outcome, insufficiency of clotting factor II (prothrombin) is the most important. Measurement of prothrombin clotting time (PT) is simple and a good method for determining and monitoring the severity of poisoning. A prolongation of PT occurs before signs and symptoms of bleeding tendency appear.

The fact that it takes time for circulating clotting factors to decline to levels that lead to bleeding explains why the onset of toxicity is delayed for up to several days after ingestion of a toxic dose. Thus in cases of human poisoning where a large amount of brodifacoum bait is suspected to have been consumed, PT may need to be measured over several days or weeks. It also means rodents can continue to eat bait even though they most likely consumed more than a lethal dose in the first feeding [5].

Absorption, distribution and elimination:

- Brodifacoum is readily absorbed into the body from the gastrointestinal tract and lungs, but much less so through the skin. For example in rats the dermal dose required for lethality is about 200 times higher than if it is ingested:
  - Oral LD_{50} = 0.27 mg/kg
  - Dermal LD_{50} = 50 mg/kg

  The European Commission estimate intestinal absorption of brodifacoum in the rat to be 64% at 10 mg/kg and >75% at 0.25 mg/kg. Dermal absorption is estimated to be 1.87% (EC 2005 a, c).

- In rats and rabbits dosed with brodifacoum the substance can be found in liver and a number of other tissues. The concentration in liver is approximately 20 times greater than in plasma. It is the primary organ for accumulation and storage of unchanged brodifacoum.

  10 days following a single oral dose to the rat of 0.25 mg/kg, 74.6% of the dose was retained in the tissues. The proportion of the retained dose was highest in the liver (22.8 %), followed by the pancreas (2.3 %), and then the kidney (0.8 %), heart (0.1%) and spleen (0.2 %). The remainder of the dose (approximately 50 %) was present in the carcass and skin (EC 2005c).

  Liver, pancreas and kidney contain vitamin K-epoxide reductase and brodifacoum has high binding affinity for this protein.

[4] From Shapiro and Martinfz (1969), Octapharma (2007) and Samama (2008).

[5] EC (2005b) comment that a wild rat may ingest as many as 80 LD_{50} doses in 6-7 days if feeding only on bait and as many as 40 LD_{50} doses if offered a choice of bait or untreated food. Since severe symptoms or death occur only after several days from brodifacoum consumption, rats and mice will behave normally (feeding and behaviour) during this time, allowing toxicant to build-up in the organism.

- In dogs elimination from the liver is slow and biphasic (Pelfrene 1991):
    - Initial phase: $t_{½}$ = 2 – 8 days.
    - Slow terminal phase: $t_{½}$ ≈ 130 days.

  In rats elimination from the liver is also biphasic at high doses (EC 2005c).
    - Initial phase: $t_{½}$ = 4 days.
    - Slow terminal phase: $t_{½}$ = 128 days,
    - At lower doses not associated with PT prolongation, $t_{½}$ = 282 – 350 days.

  In mice at 0.5 LD_{50} liver $t_{½}$ = 15.8 days (Vandenbroucke et al. 2008).

- Metabolism is slow and metabolites have not been well characterised due to the acute toxicity in mammals. However, by analogy with other coumarins (i.e. the group of anti-coagulant poisons that include brodifacoum and warfarin), metabolites are likely to be various hydroxylated brodifacoums and will be inactive as anticoagulants.

- In poisoned patients (primarily suicide attempts) with clinical symptoms of toxicity, plasma $t_{½}$ ≈ 15 – 56 days (Weitzel al. 1990, Hollinger and Pastoor 1993, IPCS 1995, Spahr et al. 2007, Olmos and Lopez 2007).

  Thus it can take 2 – 5 months for brodifacoum to be removed from the body after poisoning.

  Plasma $t_{½}$ in other species:
    - Rat: >156 days (Pelfrene 1991).
    - Mice: 91.7 days for a 0.5 LD_{50} dose (Vandenbroucke et al. 2008).
    - Chickens: 1.1 days (Fisher 2009).

- The majority of brodifacoum is eliminated in faeces.
  Concentration in rat faeces can be approximately 2 – 12 µg/g dry weight (ppm) (Fisher 2009).
  This makes rodent droppings a potential source of brodifacoum exposure to humans.

Toxic Effects:

- Warfarin has been used for decades for treatment of thromboembolic disease and, when serum levels are stabilised within the therapeutic range, therapy has been relatively free of untoward effects or signs of toxicity.

- Brodifacoum is not mutagenic or genotoxic *in vitro* or *in vivo*, not embryotoxic or teratogenic [6], nor a skin sensitiser.

[6] Brodifacoum did not induce developmental effects in two adequate prenatal toxicity studies in the rat and rabbit, respectively. In particular, in the rat studies maternal hemorrhages were observed at dose levels > 0.01 mg/kg (NOEL 0.001 mg/kg) whereas no effects on conceptuses were detected up to the top dose level of 0.02 mg/kg bw. In the rabbit study, the top dose of 0.005 mg/kg caused a high proportion of maternal deaths, whereas no significant effects on litters were observed (EC 2005b).

- Brodifacoum is highly acutely toxic to a number of mammals. In rats death occurs after 3 - 7 days.

  Single dose LD_{50} (mg/kg) (from Pelfrene 1991 unless otherwise indicated):
  - Rat 0.27 [rat LD_{50} range reported by Fisher (2009) = 0.17 – 0.9]. [0.47 reported in confidential propriety test by EC 2005b]. [0.42 (M) & 0.56 (F) reported by US EPA 1998].
  - Mouse 0.4
  - Guinea pig 0.28
  - Rabbit 0.3
  - Dog 0.25 – 1.0
    0.25 – 3.56 (Eason and Ogilvie 2009).
  - Cat ≈ 0.25
    0.25 – 25 (Eason and Ogilvie 2009).
  - Possum 0.17 (Eason and Ogilvie 2009).
  - Sheep 5 – 25 (Eason and Ogilvie 2009).
  - Feral pigs 0.52 (O'Brien and Lukins 1990).
    0.1 (Eason and Ogilvie 2009).

- In rats, single oral doses of 0.1 – 0.33 mg/kg resulted in a steep dose response for effects on plasma prothrombin complex measured within 24 hours of administration (Pelfrene 1991, details of the study were not provided).
  - 0.1 mg/kg had no effect,
  - 0.2 mg/kg reduced activity to 7% of normal values, and
  - 0.33 mg/kg to 4% of normal.

  The European Commission had access to propriety data conducted to GLP when assessing operator risks associated with handling brodifacoum (EC 2005a, c).

  In the EC (2005a) evaluation of toxicological data, the no observed effect level (NOEL) from a single dose (i.e. acute) study was judged to be 0.15 mg/kg. Rats were given a single non-toxic dose of brodifacoum (0.02 or 0.15 mg/kg) whilst a further group received a dose at 0.35 mg/kg. Blood was taken at regular intervals to measure prothrombin time (PT). At 0.02 and 0.15 mg/kg, clotting times were unaffected throughout the study but were significantly increased at 0.35 mg/kg.

- Above a certain dose the effect is maximal and further changes in clotting factors and coagulation time are minimal in relation to the increase in dose. However with larger doses the inhibition of vitamin K epoxide reductase and hence also clotting factor synthesis lasts longer, which necessitates longer administration of the antidote.

- Given the relative consistency of the LD_{50} between non-ruminant mammal species it would be reasonable to assume similar sensitivity for humans (i.e. on average a lethal dose would be expected to be about 0.25 – 0.5 mg/kg).

- IPCS (1995) estimated the average fatal dose for a human adult (60 kg) to be about 15 mg brodifacoum per person (i.e. 0.25 mg/kg). This is equivalent to:
  - 300 g of 0.005% bait (e.g. Talon® or Ratsak)
  - 750 g of 0.002% bait (e.g. Pestoff®20R)

  In Australia brodifacoum rodent bait is sold under a variety of trade names, for example Talon® and Ratsak both at 0.005% brodifacoum.
  Additional information on commercial baits is in Section 4.

- In a 42 day feeding study in rats a diet concentration of 0.1 ppm (0.005 mg brodifacoum/kg bw/d) did not cause any adverse effects (Pelfrene 1991).

  In Beagle dogs given oral brodifacoum (0.0001, 0.0003, 0.001, 0.003 or 0.01 mg/kg bw/d) for 42 days the NOEL for blood coagulation effects was 0.003 mg/kg/d (EC 2005c, d).

- In a 90 day rat study using feed concentrations of 0.2 and 0.8 ppm brodifacoum (corresponding to doses of 0.001 and 0.004 mg/kg bw/d) summarised by EC (2005a, c) the NOEL for PT was 0.001 mg/kg/d. Haematology measurements were made at 45 and 90 days. There were no effects on prothrombin time after 45 days but significant increases after 90 days but only at the highest dose tested (0.004 mg/kg/d). The NOEL was set at the next lowest dose, 0.001 mg/kg/d.

- The current Australian acceptable daily intake (ADI) is 0.0000005 mg/kg body weight; i.e. 0.0005 µg/kg bw. This was originally set in 1990. The NOEL recorded against this ADI is 0.001 mg/kg. Further information on the ADI derivation is not available but it appears a safety factor of 2000 may have been applied to the NOEL.

  It is important to note the ADI is the daily intake of a chemical which, during a lifetime, appears to be without appreciable risk. 'Without appreciable risk' is taken to mean that adverse effects will not result even after a lifetime of daily exposure to the ADI (enHealth 2004). This is not an appropriate guideline value for judging the importance of human exposure to substances that are acutely toxic and where exposure is limited as is the situation with the proposed rodent eradication programme for LHI.

- The allowable maximum residue limit (MRL) in Australia for brodifacoum is 0.00002 mg/kg for cereal grains and 0.00005 mg/kg for edible offal and meat. These have been set 'at or about' the analytical limit of detection (FSANZ 2010).

  For any food in New Zealand the MRL is 0.001 mg/kg, also described as set 'at or about' the analytical limit of detection (NZFSA 2010).

- Brodifacoum in meat, including liver, is not destroyed during baking at 180^0C for 20 minutes (O'Connor et al. 2001).

- Brodifacoum is non-toxic to plants. This is to be expected since it has low water solubility and is tightly bound to soil it is not taken up by plants (WHO 1995).

2.2.3 Human signs and symptoms

If toxic amounts of brodifacoum have been ingested blood coagulation will be impaired with the following common symptoms usually becoming apparent prior to life threatening internal bleeding. Death is rare in situations of incidental ingestion (e.g. in children mistaking rodent bait as candy). Even when brodifacoum bait is intentionally eaten for suicide attempts fatality is uncommon if treatment is provided within a reasonable time frame. The onset of clinical signs of poisoning may be delayed several days after exposure to a single large dose or after a few

weeks of repeated ingestion of small doses (World Health Organisation (IPCS 1995, WHO 1995). The early signs of toxicity are:

- Gum bleeding.
- Epistaxis (nosebleed).
- Petechial rash (small red or purple spots on the skin caused by minor haemorrhage).
- Ecchymosis (subcutaneous hematoma, a small bruise) which may be spontaneous or in response to minor bumps.
- Hematoma (large bruise), especially of the articulating joints.
- Haematuria (blood in urine).
- Melenae (blood in faeces which makes them black and tarry).

Even though there is only a small difference between a dose of technical brodifacoum (i.e. unformulated brodifacoum) that has no effect on prothrombin time (PT) and that which causes a prolongation of PT, symptomatic poisoning in children caused by incidental ingestion of rodent bait is rare. This is primarily attributed to the low concentrations of brodifacoum in the bait (0.002% or 0.005%). Nevertheless serious symptoms have been described in children who have ingested a large amount of bait in a short time or lower amounts over a longer period. This can occur in children with compulsive behaviour. For example Travis et al. (1993) reported on a 36 month old girl with a history of pica (habitual ingestion of soil). The child was admitted to hospital with excessive bruising that occurred over a week and a day of bleeding from the nose and mouth. On admission the PT was greater than 50 seconds (normal is around 10 – 15 seconds) and the child was treated with intravenous Vitamin K, plasma and packed red blood cells. Bleeding stopped shortly after administration of plasma and PT returned to normal after approximately a week, readmissions to hospital occurred over the next few weeks due to failure of the mother to administer oral Vitamin K as directed. Although serum brodifacoum steadily declined it was measureable for approximately 4 months and Vitamin K therapy was continued until after it was not detected.

Most incidental ingestions of rat bait by children do not cause clinical symptoms and do not require intervention, although medical attention is often provided (US EPA 1998). However it is a feature of poisoning by brodifacoum, that should symptoms develop which is often several days after ingestion of sufficient brodifacoum, Vitamin K treatment is usually required for an extended period.

In adults, most cases of brodifacoum poisoning have occurred as the result of causing intentional harm. Many of these involve consumption of 1 – 8 boxes of rat bait approx 43 gm each at 0.005% active ingredient, i.e. approximately 2 – 18 mg brodifacoum per person, or 30 – 250 µg/kg for a 70 kg person (Kruse and Carlson 1991, Ross et al. 1992, Bruno et al. 2000, Spahr et al. 2007).

Notwithstanding the above, there is a wide variation in susceptibility to brodifacoum among individuals. People suffering from liver disease, or who are taking prescription anticoagulants or other medication that may affect blood clotting (e.g. some non-steroidal anti-inflammatory drugs) are more susceptible to brodifacoum poisoning.

2.3 Properties of the rodent bait

2.3.1 Description

The bait intended to be used in the LHI rodent eradication program is Pestoff® Rodent Bait 20R. It is a pellet containing 0.002% brodifacoum formulated with cereal, sugars, waxes and binders. The pellets are dyed emerald green with water soluble food grade dyes to make them less attractive to birds. The pellets are of two sizes:

- Small, 5.5 mm diameter for hand broadcasting and indoor bait stations, each pellet weighs approximately 500 mg and contains 0.01 mg brodifacoum.
- Large, 10 mm diameter for aerial broadcasting, each pellet weighs approximately 2,000 mg and contains 0.04 mg brodifacoum.

The dye is water soluble and will colour skin if pellets are handled when wet or with wet hands, or colour the mouth and tongue if pellets are eaten. This is evident from observations in trials of Pestoff® on LHI. The beaks and mouths of non target species that consumed baits were coloured (LHI 2009).

Should young children accidently eat Pestoff® pellets it is highly likely parents will notice lips, tongue or mucous membranes are coloured green.

2.3.2 Physical stability of bait

Stability on land:
The bait is cereal based and designed to break down following absorption of soil moisture, or after rain. Baits will break down by swelling, cracking, then crumbling, depending on the

temperature and humidity. Mould and fungi can appear rapidly as breakdown proceeds. Once this has happened baits are less likely to be eaten by non-target species (Brown et al. 2006).

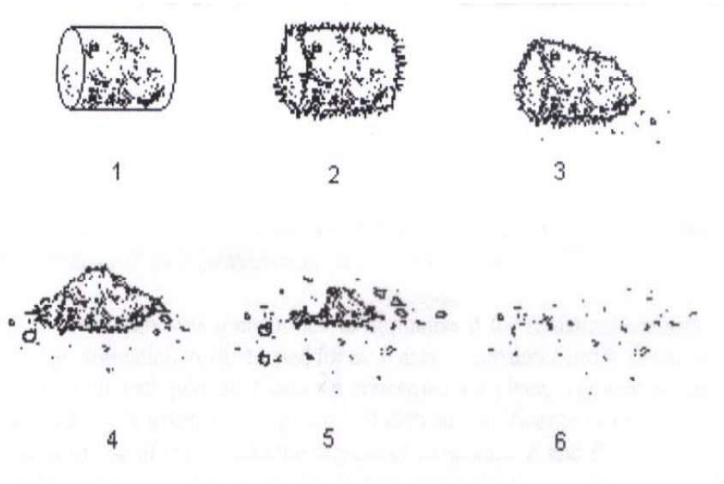
Craddock (2004) undertook field stability trials of Pestoff® in New Zealand (Täwharanui Regional Park, North of Auckland) to determine the time for the pellets to completely disintegrate and how much brodifacoum was left in the soil. Twenty 10 mm diameter pellets (approximately 10 - 50 g) were laid on the ground under wire cages in eight different vegetation types and monitored for 5 months. The descriptions of various stages of bait decay are depicted in Figure 2.1. These descriptions have been incorporated into the New Zealand Code of Practice for aerial and hand broadcast application of Pestoff® Rodent Bait 20R (NZFSA 2006).

In the Craddock (2004) bait stability trail, pellets very quickly started to degrade after being placed on the ground but the rate of decay decreased over time (Figure 2.2). Most pellets had become soft and degraded from condition 1 to condition 2 within 48 hours of placement. After 8 days, most pellets were beginning to lose shape and had reached condition 3 or higher (i.e. mushy pellet or pile of mush). After these degradation stages pellets showed a high degree of variation in breakdown. Pellets frequently varied by up to 4 condition index scores within a single site (i.e. a site could typically have pellets scoring condition indexes 3, 4, 5 and 6 on the same monitoring date).

In pasture the majority of pellets took 80 days to completely degrade, all were degraded in 110 days. The times were slightly, but not significantly different for baits laid in other types of vegetation.

Investigations on the environmental longevity of Pestoff® Rodent Bait 20R have also been undertaken on Lord Howe Island. It was found in these trials that the bait completely disintegrated within 100 days (LHI 2009). These results are similar to those reported by Craddock (2004).

In summary:
Pestoff®20R pellets rapidly, in less than 8 days, become soft and covered in mould thereby losing attractiveness to be picked up by young children. With further degradation the bait reasonably quickly loses its physical form such that after about 2 - 3 weeks a pellet becomes quite difficult to be picked up whole from the ground.



Condition 1: Fresh Pellets/Pellets not discernable 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 2.1: Description of various stages of bait decay
[Taken from Craddock (2004) and NZFSA (2006) Code of Practice for Pestoff® Rodent Bait 20R]

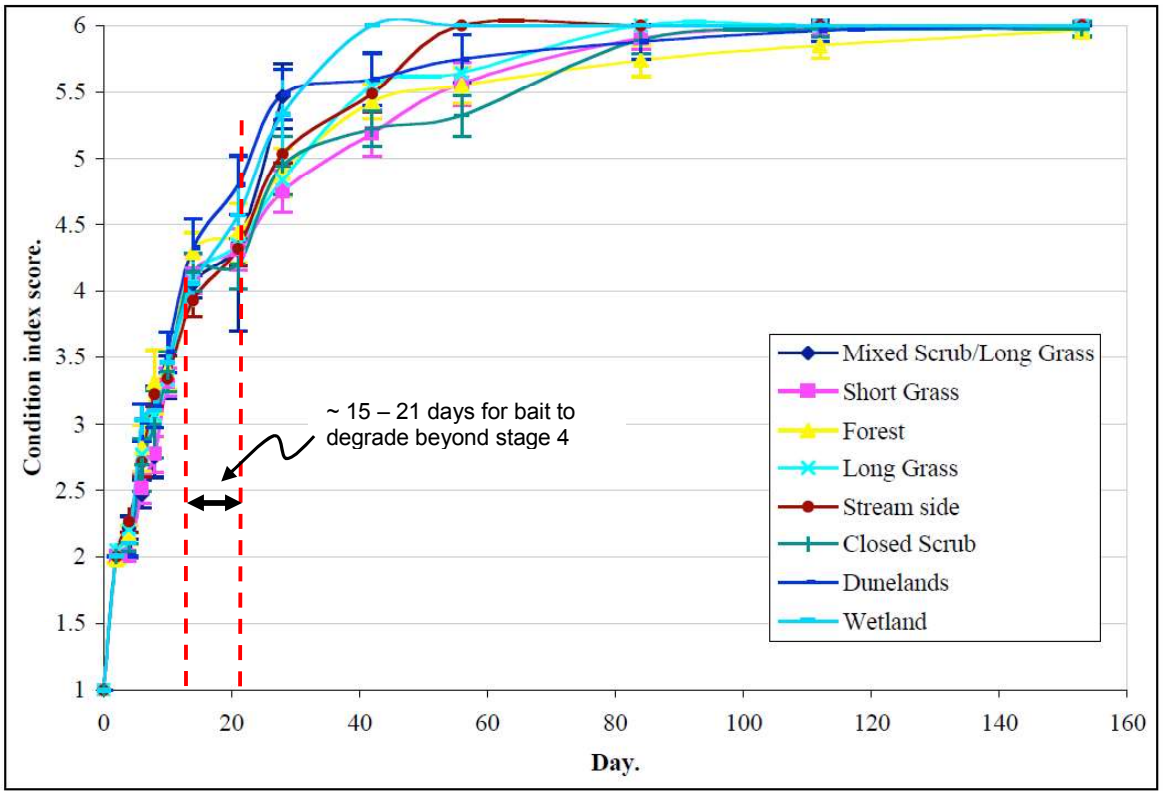


Figure 2.2: Breakdown curves for Pest-Off bait pellets at four sites at Täwharanui Regional Park in New Zealand.
The figure is adapted from Craddock (2004). Bars indicate ± standard error.

The Y – axis represents the various stages of pellet decomposition as depicted in Figure 3.1. After approximately 15 – 21 days the degradation has passed stage 4 and is not in a form that can easily be picked up by children or potentially transported by birds.

Soil residue concentrations

After aerial application of Talon® 20P (0.002% brodifacoum) over an island off New Zealand brodifacoum was not detected in soil when randomly sampled 2, 12, 34 or 210 days post application at a detection limit of 0.02 µg/g soil (Ogilvie et al. 1997). Similarly after application of Talon® 20P to a different island, Morgan and Wright (1996) found no brodifacoum in soil when sampled 1 month after aerial sowing.

In the Craddock (2004) trial, brodifacoum concentration in soil immediately beneath the pellets and after they had completely broken down was very low (0.05 ± 0.02 µg/g soil, mean ± SE,

n = 16). The soil sample was a 4 cm diameter plug taken to a depth of 4 cm, analytical detection limit was 0.02 µg/g. Figure 2.3 shows the average concentration of brodifacoum over time.

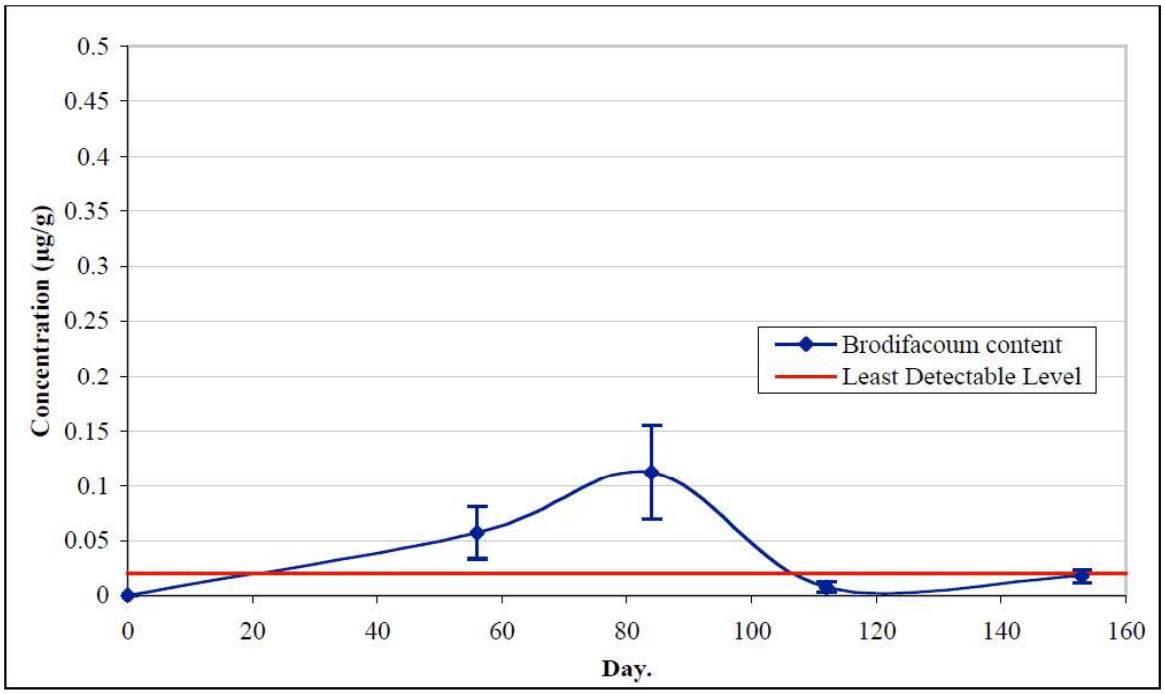


Figure 2.3: Average brodifacoum concentration (µg/g) in soil samples over time at two pasture sites at Täwharanui Regional Park. Least Detectable Level (0.02 µg/g) is also shown.
The figure is reproduced from Craddock (2004). Bars indicate ± standard error.
Soil samples were 4 cm diam plug to a depth of 4 cm taken from where 20 x 10 mm pellets (10 - 50g) were placed.

WHO (1995) describe laboratory investigations of soil binding and leaching using ^{14}C-brodifacoum for different soil types. Binding to soil was rapid and strong, desorption was very slow and no detectable levels of radioactivity were found in leachate.

WHO (1995) concluded binding to soil particles was quick, with very slow desorption and no leaching properties.

Bait stability in water:

Rat eradication on an island off New Zealand was conducted in 1996 with Talon® 7-20 pollard baits (cereal-based pellets containing 0.002% brodifacoum manufactured by Animal Control Products Ltd, the same manufacturer of Pestoff® 20R). Prior to the program being undertaken, 12 mm pellet bait formulated without brodifacoum was distributed into the sea (30 m offshore

and 10 m depth) and monitored by a diver. This experiment was done because it was considered aerial distribution of bait near the shoreline may result in some of it being dropped into the sea. The bait pellets disintegrated within 15 minutes. Under wave action it was rationalised it would be unlikely for bait to remain intact for more than a few minutes (Empson and Miskelly 1999).

As the result of a road transport accident a very large spill of Pestoff® occurred into the sea off the coast of New Zealand. The spill was approximately 18 tonnes packaged in 25 kg double walled paper bags with polyethylene liner, released bait was observed to quickly soften and disintegrate. At the seabed where the spill occurred particles of bait had set into a layer >100 mm which had the consistency of thick porridge. It took about a week for these congealed areas to be dissipated by wave action so kibbled grain material was no longer visible (Primus et al. 2005). Monitoring of the local fauna was undertaken for 21 months (see also Section 3.1.5).

After aerial baiting islands with Talon® 20P (0.002% brodifacoum) brodifacoum was not detected in water from streams sampled up to 1 month after application (Morgan and Wright 1996, Ogilvie et al. 1997).

2.4 Summary of important data for HRA

From the above data and discussion on the toxicology and health effects of brodifacoum there are a number of pieces of information that are important for understanding human exposure and health risks that may be associated with the LHI rodent eradication programme.

Physical and chemical properties of brodifacoum:

1. Binds strongly to soil.
2. Does not leach out of soil.
3. Does not evaporate and contaminate air.
4. Has very low water solubility (~0.2 mg/L).
5. Is fat soluble.

Toxicology and health effects:

1. Brodifacoum is readily absorbed through the gut, but much less so through skin.
2. Brodifacoum has the tendency to distribute to fatty tissue.
3. The majority of brodifacoum is excreted in faeces.
4. Brodifacoum binds strongly to vitamin K epoxide reductase and therefore has very long half life ($t_{½}$) in those tissues with high levels of this protein, especially the liver were $t_{½}$ can be 3 – 4 months.

5. The anticoagulant effect requires depletion of existing Vitamin K dependent clotting factors, therefore onset of toxic symptoms is delayed.
6. Prolonged prothrombin clotting time (PT) is a precursor indicator to toxicity (bleeding).
7. PT is an efficient monitoring method for severity of poisoning.
8. Vitamin K and plasma are effective treatments.
9. Most people, including infants and young children, with incidental ingestion don't require treatment.
10. Symptomatic poisoning, e.g. from suicide attempts, may require treatment with Vitamin K for several months until PT returns to normal.
11. The only toxic effects are associated with anticoagulant activity.
12. Highly toxic to mammals, $LD_{50} \approx 0.2 – 0.5$ mg/kg bw across a number of species, death is within 7 days of ingesting a fatal dose.
13. No observed effect level (NOEL) for affecting PT (the precursor to toxicity):
    - Rat - acute single oral dose, 0.15 mg/kg bw.
    - Rat - 42 day feeding study, 0.005 mg/kg bw.
    - Rat – 90 day feeding study, 0.001 mg/kg bw.
14. The Australian acceptable daily intake (ADI) over a lifetime is 0.0000005 mg/kg bw. (Note this is not suitable as a guideline for the LHI risk assessment because it is for an assumed lifetime exposure).

Bait properties and application:

1. Pestoff® 20R pellets do not contain a taste deterrent.
2. The pellets have a water soluble green dye that will colour lips, tongue and mouth.
3. After 2 -3 weeks on the ground pellets have lost their physical form and are difficult to pick up, after 100 days they are completely disintegrated.
4. Soil residues of brodifacoum have not been detected in field trials, but in an outdoor experiment 0.05 µg brodifacoum/g soil was measured in soil immediately under pellets.
5. In water individual bait pellets disintegrate within 15 minutes.
6. In Pestoff® 20R bait there is:
    - 10 µg brodifacoum in an individual 5.5 mm diameter pellet, each pellet weights approximately 500 mg, and
    - 40 µg brodifacoum in a 10 mm pellet which weighs about 2 g.
7. Target coverage of Pestoff® 20R is:
    - One 5.5 mm pellet per 0.5 m^2 near dwellings, or
    - One 10 mm bait per 2 m^2 away from dwellings.

3. Exposure and risk

There are a number of ways which residents on the island may be potentially exposed to brodifacoum as a result of the proposed rat eradication program. Because the dose of brodifacoum associated with all pathways cannot be reasonably quantitated the exposures and risk for these are discussed qualitatively. For other exposure pathways conservative assumptions have been made to estimate 'high end' intakes of brodifacoum. Judgement has been made on whether a particular exposure pathway, in the circumstances of Pestoff® use on LHI, may be significant and possibly allow enough brodifacoum to be absorbed to cause effects in children or adults. This was done by comparing the estimated intakes with no effect levels (NOELs) for prolongation of PT.

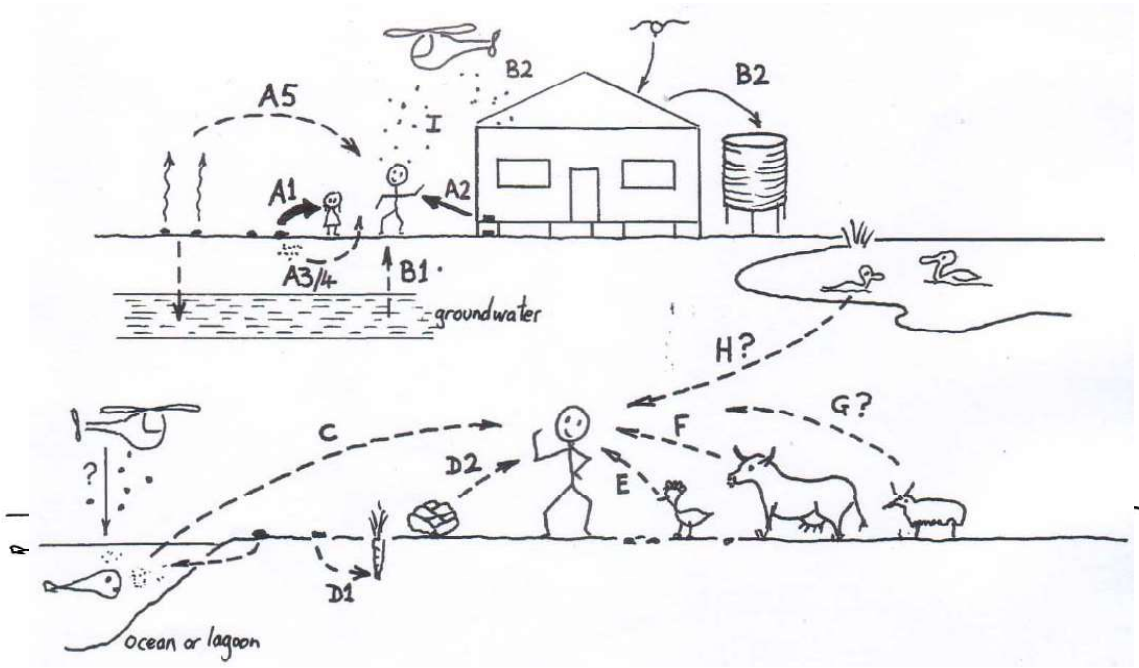
3.1 Potential exposure pathways

Figure 3.1 depicts the theoretical exposure pathways. Some of these have been included because during the commentary period of the draft eradication plan LHI residents expressed concern regarding possible exposure.

The exposure pathways are divided into three groups;

- The first and by far the most important is that associated with direct ingestion of bait, either by being picked up from the ground or from bait stations within or around dwellings.
- The second exposure pathway considered is via water consumption.
- The third set of exposures are those connected to possible contamination of human food.

The specific details and risks for each of these exposure pathways are discussed in detail below.



Potential human exposure pathways				Likelihood
	Route	Media	Description	
A1	Ingest[n]	Bait	Picked up from soil surface	Possible [a]
A2			From bait station in, under or around house	
A3		Soil	Contaminated soil under where bait lay	Very low [b]
A4	Dermal	Soil		
A5	Inhal[n]	Vapour	From broadcast bait or indoor bait stations	Incomplete [c]
B1	Ingest[n]	Water	Percolation into groundwater	Incomplete [d]
B2			Bird faeces or bait dropped onto roof, washed into tank water	Low [e]
C	Ingest[n]	Fish	Bait dropped or flushed into ocean/lagoon and eaten by fish	Very low [d, f]
D1		Garden vegs	Taken up from soil	Incomplete [d, g]
D2			Dropped onto plants	Low [g]
E		Chicken	Chicken eats bait & transferred to flesh and eggs	Incomplete [h]
F		Meat & dairy	Cattle/cows eat bait, brodifacoum transferred to flesh & milk	
G			Goats eat bait and brodifacoum transferred to flesh and milk	
H			Wild ducks eat bait and are shot	Incomplete [j]
I	Inhal[n]	Dust	Fine dust from aerial dispersion	Very low [k]

[a] The most risky exposure to rodent bait is direct ingestion of bait picked up from the ground or from indoor bait stations and eaten. Due to behaviour patterns young children are most at risk.

[b] The probability of consuming soil from the exact spot under a bait pellet is low, the dose would be very low and furthermore brodifacoum binds strongly to soil and absorption into the body is significantly impaired. Dermal absorption of brodifacoum is low even without being adhered to soil.

[c] Brodifacoum is a solid and does not volatilise.

[d] Brodifacoum binds strongly to soil and does not leach.

[e] Birds may eat bait, brodifacoum is excreted in faeces which may be deposited on the roof. Birds may pick up bait pellet and drop onto roof. The amount of brodifacoum washed off the roof will be very small, it is also poorly soluble in water so will be bound to tank sludge. It is unlikely aerial broadcasting will drop bait on roofs (if this is a possibility the management plan has a contingency action).

[f] It is unlikely large amounts of bait will be dropped into the ocean. Bait rapidly disintegrates, the dose to fish should be low, the likelihood of catching a fish that has consumed bait is low, most brodifacoum is in fish liver which is not consumed by humans.

[g] Not taken up by vegetables from soil. If dropped onto plants washing vegetable during preparation will remove bait.

[h] Chickens and cattle will be removed from the Island. Dairy cows are to be isolated from bait. Some goats will remain but these are pets not used for consumption or milk/cheese making.

[j] There is no duck hunting on LHI.

[k] Fine dust particles dispersed during aerial bait broadcasting are inhaled. Exposure is very low.

Figure 3.1: Summary of potential exposure pathways to brodifacoum.

3.1.1 Direct ingestion of bait (Pathways A1 & A2)

It is intended that small 5.5 mm bait be hand broadcast around gardens and public areas in the settlement. It is therefore possible that a young child may pick bait up and suck, chew or swallow it.

The green dye in the bait pellet will colour the mouth and tongue green alerting parents that the child has put rodent bait into its mouth.

All the considerations below are for a healthy 'normal' child or adult; it should be remembered that persons who have anaemia, liver disorder, a blood clotting disorder, or are taking medication that affects blood clotting could be more sensitive to the toxic effects of brodifacoum. In these individuals prothrombin clotting time may not need to be changed as much as in a 'normal' person for bleeding symptoms to occur. Calculations have not been undertaken for such sensitive persons because relevant quantitative dose response data was not located.

Unless specifically stated otherwise, calculations in this and other sections of this report have been performed for the small 5.5 mm Pestoff® 20R bait because this is the size that young children are most likely to encounter. The larger 10 mm diameter bait has four times the amount of brodifacoum (0.04 mg/pellet) so the calculations below need to be adjusted accordingly.

Risk associated with single ingestion of bait:
The acute dose of brodifacoum (B) in the rat that does not cause prolongation of prothrombin clotting time (i.e. the NOEL) is 0.15 mg/kg bw (Section 2.4). The available evidence in Section 2.2.2 indicates no major difference between mammalian non-ruminant species regarding their toxicological sensitivity to acute doses of brodifacoum. Hence it is reasonable to assume a 2 yr old child will be as sensitive as the rat. The default body weight of a 2 year old child is 13.2 kg (enHealth 2004) and there is 0.01 mg brodifacoum/pellet (0.01 mg B/pellet).

The number of pellets that need to be ingested by a 2 yr old to reach the NOEL is:

$$(0.15 \text{ mg B/kg bw} \times 13.2 \text{ kg bw})/(0.01 \text{ mg B/pellet}) \approx 200 \text{ pellets}$$

At a nominal distribution of 1 pellet/0.5m^2 a young child would have to gather up all the pellets from approximately 100 m^2.

Since each pellet weighs approximately 0.5 g, therefore the weight of bait needed to be ingested by a 2 yr old for the NOEL is:

200 pellets x 0.5 g = 100 g

This amount of bait is put into perspective by considering commercial Talon® is sold in 150 g packets containing six prepacked pellet trays of 25 g each. The indoor and under floor open tray bait stations for Pestoff® 20R are proposed to be about the same size, but these will contain only 40% of the brodifacoum that would be found in an equivalent weight of Talon® bait.

Risk associated with low but multiple ingestion of bait:

The LHI plan indicates the bait will be broadcast twice, approximately 14 days apart to ensure all rodents on the islands encounter the bait. Given it takes 2 -3 weeks for bait to lose its physical form and become difficult to pick up as a pellet (Sections 2.3.2 and 2.4), there is a window of about 4 – 5 weeks during which pellets may be available to be picked up and potentially eaten by a 2 yr old. Thus the appropriate NOEL for this scenario is the 42d rat NOEL for no effect on prothrombin time, i.e. 0.005 B mg/kg bw (Sections 2.2.2 and 2.4).

Following the same logic as above, the number of Pestoff® pellets needed to be eaten per day to ingest an amount equivalent to the 42 day NOEL is:

(0.005 mg B/kg/d x 13.2 kg) ÷ (0.01 mg B/pellet) ≈ 6 - 7 pellets/d,

i.e. about half a desert spoon full per day.

Anticoagulant symptoms in adults arising from incidental poisoning by brodifacoum is rare. There are however many recorded instances where purposeful ingestion for self harm has resulted in significant clinical symptoms of bleeding. Efficient treatment with antidote has meant the vast majority of these cases have not resulted in death.

Discussion and conclusions:

It is unlikely that a child will consume at a single time the large amount (about 100 g) of bait required to cause prolongation of prothrombin clotting time. However a much smaller amount (about half a desert spoon of pellet) of Pestoff® 20R per day over 6 weeks is needed for the same effect. While this is unlikely to occur over the 5 week time period when the bait is in a form that could be picked up whole, the small amount of bait involved per day makes it appear feasible.

Notwithstanding the above, the key to ensuring small children are not exposed to the Pestoff® bait is educating children and parents about the bait, and close vigilance by parents during the eradication campaign.

For an adult the World Health Organisation (IPCS1995) considers the lethal dose of brodifacoum to humans to be about 0.25 mg/kg bw, i.e. the same as for a rat. The amount of 0.002% bait required to result in death, assuming treatment is not given, is 750 g. This quantity is put into context by the realisation that a box of commercial Talon (0.005% brodifacoum) contains 150 g of bait.

It is concluded direct incidental ingestion of Pestoff® 20R rodent bait such as may occur if a child mistook the bait for candy is associated with very low, negligible, health risk. This conclusion is based on:

- the large amount of bait that must be consumed at one time in order to affect blood clotting, and
- national, and international, experience that shows the vast majority of such ingestions do not require medical intervention.

3.1.2 Ingestion of soil (Pathway A3)

The inadvertent ingestion of soil is a common and important human exposure pathway to be considered in risk assessments where soil may be contaminated. Young children are particularly prone to ingest soil as they have greater contact during play, have greater hand to mouth activity, and have not developed soil avoidance strategies of older children and adults.

The US EPA *Child-specific exposure factors handbook* (US EPA 2008) recommends a central tendency for outside soil ingestion of 30, 50, 50 mg soil/day for newborns (6–<12 months), 1–5 year olds and 6–20 year olds respectively. These values are recommended for use in Australia when the risk assessment is not considering ingestion of indoor dust (enHealth 2010). Indoor dust is usually considered in situations where outside soil is suspected of being relatively uniformly contaminated such that the contaminant may be tracked indoors by people and pets. In this case the default soil plus house dust ingestion rate of a young child is 0.1 g soil/d (enHealth 2004, 2010). In the scenarios considered for LHI, brodifacoum bait is not uniformly distributed but nominally spread at 1 pellet/0.5m^2, therefore the default incidental soil ingestion of 100 mg/d for a child used in this assessment is considered to be very conservative.

Soil residues of brodifacoum have not been detected in field trails (e.g. Ogilvie et al. 1997) but in an outdoor experiment an average of 0.05 µg brodifacoum/g soil was measured in soil immediately under pellets after they had broken down (Sections 2.3.2 and 2.4).

On the assumption that all the soil ingested by a young child is exactly from underneath where bait pellets lay, the amount of brodifacoum ingested per day will be:

(0.1 g soil/d x 0.05 µg B/g soil) ÷ 13.2 kg = 0.0004 µg B/kg bw/d (or 0.0000004 mg/kg/d).

This is significantly less (12,500 times) than the NOEL dose of 0.005 mg B/kg/d.

Discussion and conclusion:

A very conservative estimate of the daily dose of brodifacoum (0.0004 µg B/kg bw/d) that might be achieved from soil ingestion is 12,500 times lower than the relevant sub-chronic NOEL for prolongation of prothrombin time (0.005 µg B/kg/d).

Furthermore

- The amount of soil assumed to be ingested is higher than what might occur,
- it is highly unlikely that all incidentally ingested soil will be from beneath where pellets lay, and
- brodifacoum tightly binds to carbon in soil thereby markedly lowering its absorption from the gut. Indeed oral administration of a slurry of activated charcoal is an optional treatment soon after ingestion of large amounts of brodifacoum.

It is concluded there is negligible health risk from incidental consumption of soil that may contain brodifacoum.

3.1.3 Dermal exposure (Pathway A4)

Brodifacoum is very poorly adsorbed across the skin (Sections 2.3.2 and 2.4).

If pellets are handled without gloves it is only the brodifacoum on the outside of the pellet that is potentially available to transfer from the pellet to the skin, and thence be subject to absorption through the skin. Thus only a very small fraction of the brodifacoum in a bait pellet is likely to be transferred to the skin, and only a small fraction of that is absorbed.

If soil from beneath distributed bait pellets were contaminated with brodifacoum and each day spread over the entire surface area of the hands of a child (soil adherence 0.5 mg soil/cm^2 of skin [enHealth 2004], surface area of the hands of a 2 – 3 yr old child is 0.03 m^2 [US EPA 2008]) and the soil contains 0.05 µg brodifacoum/g soil (Sections 2.3.2 and 2.4) the amount of brodifacoum on the skin of the hands is:

0.5 mg soil/cm^2 x 0.03 m^2 x 10^4 (cm^2/m^2) x d^{-1} x 0.05 µg B/g soil x 10^{-3} (g/mg soil)
= 0.0075 µg B/d

If 1.8% of this is absorbed through the skin (Section 2.2.2) of a 2 yr old child (weight 13.2 kg) the dose of brodifacoum is:

(0.0075 µg B/d x 0.018) ÷ 13.2 kg = 0.00001 µg B/kg bw/d.

Discussion and conclusion:

The above calculations are conservative and significantly overestimate the amount of brodifacoum that might be absorbed through the skin if contaminated soil was smeared over the hands of a 2 year child. Nevertheless the dose (0.00001 µg brodifacoum/kg bw/d) is 500,000x less than the sub-chronic NOEL for prolongation of prothrombin time (0.005 mg B/kg/d).

The calculated dose is conservative because:

- Not all the soil on hands will be from beneath where pellets lay.
- Not all the surface of the hands (both sides) will be covered in soil.
- This will not happen each day.
- Brodifacoum is tightly bound to soil which significantly decreases the already low absorption through skin.

It is concluded the dermal absorption of brodifacoum through the skin is negligible and not a pathway of importance for residents of LHI during the eradication campaign.

3.1.4 Ingestion of water (Pathways B1 & B2)

Theoretically residents of LHI may become exposed to brodifacoum if ground water used for drinking becomes contaminated, or if brodifacoum from rodent bait contaminates the roof of buildings from which drinking water is collected.

Pathway B1 – contamination of ground water:

Brodifacoum binding to soil is rapid and strong, desorption is very slow and leaching from the soil is negligible (IPCS 1995). WHO (1995) consider the use of brodifacoum rodenticide is unlikely to be a source of water contamination.

Groundwater therefore will not become contaminated with brodifacoum during the rodent eradication campaign. It is noted however that ground water on LHI is not suitable for human consumption (EWS 2000).

Pathway B2 – contamination of tank water:

a. *Accidentally dropped onto roofs when broadcasting:* The most obvious way that tank water may become contaminated with brodifacoum rat bait is if it is accidently dropped onto roofs during aerial broadcasting. The LHI draft rodent eradication plan indicates a 30m buffer zone is to be applied when aerial broadcasting bait near dwellings and containment areas. Assuming this buffer zone is able to be practically maintained then bait should not find its way onto roofs. The draft plan also acknowledges that if it is anticipated bait may drift onto roofs, or if it accidently occurs, then the water collection system will be disengaged and remedial works undertaken.

b. *Brodifacoum in bird droppings:* A potential pathway for brodifacoum to find its way into tank water is if a bird eats rodent bait and excretes the ingested brodifacoum in its faeces onto a roof. Birds have a cloaca, which means there is a common opening for faecal and urinary waste. A bird dropping contains three components urine, solid urate and the faeces. In trials at LHI it was found that most birds did not eat the bright green bait, the beaks or mouths of those that did were coloured green. Should birds eat the bait, the water soluble dye will colour the watery portion of bird droppings a distinct green. It should be noted however that this is not the only way bird droppings may be coloured green; many birds usually have dark green or blackish green droppings. Green faeces may also indicate infection or liver disease.

   Fisher (2009) gave a non-lethal single gavage dose of brodifacoum (0.5 mg/kg) to chickens and measured brodifacoum in their faeces at 1, 4, 7 and 14 days after dosing. This dose is roughly equivalent to a 1.5 kg chicken in a very short time eating about 40 g of 0.002% bait (i.e. about 75 of the small Pestoff pellets) and is much higher than anticipated a wild bird will eat. The highest concentration of brodifacoum in droppings was on day 1 (0.17 µg B/g wet weight dropping) and was not detectable 7 days after administration (Section 3.1.7). It is very difficult to know how much brodifacoum, if any,

may be deposited onto a roof by bird droppings; intuitively it would be expected to be very little. A rough, conservative quantitation of human exposure to brodifacoum introduced into tank water by bird droppings is below.

Small birds with a high metabolism rate defecate more frequently than larger birds which have lower metabolism rates. For example budgerigars defecate approximately once every 30 minutes but magpies and Macaws about once per hour (Harrison and Ritchie 1994; Fowler [date unknown]).

Assuming:

- a bird dropping will be deposited onto a roof once per hour during daylight hours (i.e.12 hours)
- for 25 days (see footnote to Section c below),
- each dropping weighs about a gram, and
- all droppings have brodifacoum content the same as a chicken 1 day after dosing with 0.5 mg/kg (see above), and
- all brodifacoum in droppings is washed into a half full small rain water tank (10,000L capacity).

The concentration of brodifacoum in the water may be:

(1 poo/hr x 12hr/d x 25 d x 0.17 µg B/g poo x 1 g/poo) ÷ 5,000 L ≈ 0.01 µg B/L

Thus an upper end estimate of brodifacoum intake for a 2 year old child weighing 13.2 kg who drinks 1L per day (US EPA 2008) in this theoretical exposure scenario is:

(0.01 µg/L x 1 L/d) ÷ 13.2 kg = 0.0008 µg/kg/d.

This speculative dose to a 2 year old child is substantially lower than the sub-chronic NOEL for prolongation of prothrombin time (0.005 mg B/kg/d) by 6,250 times. The dose estimation is speculative and conservative because:

- From trials on LHI it is not anticipated birds will eat such large quantities of bait as was given to chickens in the Fisher (2009) experiment.
- It is unknown how often birds may defecate onto a roof. Nevertheless the assumptions of 1 poo/hr for 12hr/d and 25 d are likely conservative.
- It is also unknown how much the bird droppings may weigh.

Overall it is considered human exposure to brodifacoum in tank water by this route is unlikely to occur, but if it does it will be very low. However it is acknowledged there is uncertainty regarding the dose calculations but the large difference between the calculated dose and the NOEL indicates negligible risk to human health.

c. *Pellet transport by birds:* Another potential way for rodent bait to get onto roofs is for a bird to pick the bait up and subsequently discard it on the roof or into the gutter. This is anticipated to be a rare event. However if is assumed one hundred 10mm pellets (i.e. approximately 200 gm) were dropped onto the roof by birds during the eradication campaign (i.e. about four every day, ten every 2 -3 days [7]) and the roof collected water into a small tank (say 10,000L), then the amount of brodifacoum potentially washed into the water tank is 4,000 µg. Even though the water solubility of brodifacoum is low (0.24 mg/L, Section 2.2.1) all the brodifacoum in the pellets washed into the tank could theoretically be dissolved in the tank water. This would give a concentration of 0.8 µg/L if the tank was half full (4,000 µg ÷ 5,000 L = 0.8 µg/L). The 95th percentile water intake for a 2 – 3 year old is approximately 1 L/d (US EPA 2008). Thus an upper end estimate of brodifacoum intake for a 2 year old child weighing 13.2 kg in this theoretical exposure scenario is:

(0.8 µg/L x 1 L/d) ÷ 13.2 kg = 0.06 µg/kg/d (i.e. 0.00006 mg/kg/d).

This dose is lower than the sub-chronic NOEL for prolongation of prothrombin time (0.005 mg B/kg/d). However there is much uncertainty associated with the calculation of the dose:

- It is not anticipated that birds will lift pellets off the ground and transport them to roofs, it is nonetheless a possibility.
- The amount of pellets assumed to be dropped onto a roof is most likely an over estimate but to what extent is unknown.
- It has been assumed all the brodifacoum in the pellets is dissolved in the tank water, in reality most will remain bound to pellet constituents and partition into sludge at the bottom of the tank.
- The average size of rain water tanks on LHI is 25,000L, a much smaller tank assumed to be half full has been used in the dose calculations.

[7] From Figure 3.2 bait will remain in a form for birds to pick up for about 10 days, if two applications of bait are made about 14 days apart the 10 mm pellets will be able to be lifted by birds for approximately 25 days. Thus the assumed number of pellets (100) dropped on the roof is equivalent to four every day (i.e. ~ ten every 2 -3 days).

The above scenario is regarded as being quite unlikely and the dose calculations for brodifacoum intake by contaminated tank water to be conservative 'high end' estimates. Nonetheless they are lower than the NOEL for affecting blood coagulation.

Discussion, conclusions and recommendation:

Discussion of each of the transport pathways of brodifacoum into potable water (i.e. into ground water, accidental pellet broadcast onto roofs, bird transporting bait onto roofs, and bird droppings onto roofs) are discussed in the individual sections above.

Although there is uncertainty associated with brodifacoum dose estimations to a 2 year old child, the doses have been calculated to be conservative and overall this exposure pathway (i.e. by drinking water) is very unlikely to be a health threat to residents on LHI.

Although there are negligible health risks from drinking tank water during the eradication campaign, for peace of Islander's mind, consideration could be given to a programme of strategic testing of tank water.

3.1.5 Consumption of fish (Pathway C)

Many comments provided to the LHI board on the proposed rodent eradication plan expressed concern regarding the potential impact on certain fish populations, particularly in the lagoon, should aerially dispersed bait be deposited onto marine water. While this section contains information relevant to the concern expressed by LHI residents the impact on the marine ecology is not specifically evaluated or discussed, the focus is on potential exposure to humans should fish that have been exposed to rodent bait be eaten by people. The assessment has been undertaken by consideration of the stability of rodent bait in marine water, the likelihood that fish or shellfish will consume bait, the likelihood that a fish that has consumed bait will the caught and eaten, how much fish will be eaten, and assumptions regarding the amount of brodifacoum in edible portions of fish.

Consumption of rodent bait by fish and shellfish

Empson and Miskelly (1999) report on fish feeding trails with Talon® 7-20 pollard baits (12 mm pellets) containing 0.002% brodifacoum, this bait is similar to Pestoff® 20R and made by the same manufacturer. Non-toxic bait dropped into the sea rapidly disintegrated and three species

of fish were observed by divers to feed on the suspended particles. In contrast, in aquarium feeding trials using bait containing brodifacoum with acclimatised marine fish not fed for the previous 24 hours, it was observed the fish were not particularly interested in the bait. They did however eat mussel flesh immediately after the trial. Nonetheless six fish were observed to eat the bait but only one died, two others not observed to eat bait also died of symptoms of brodifacoum poisoning. Although liver concentrations of brodifacoum were measured in this study they unfortunately are not reported by Empson and Miskelly (1999).

This study shows that not all fish presented with the opportunity to consume disintegrating rodent bait will do so.

WHO (1995) consider that because of its very low water solubility brodifacoum in bait formulations is unlikely to be available to fish unless the bait is misused.

Cole and Singleton (1996) investigated the impact on fish at Kapiti Island (off the coast of the North Island of New Zealand) after two aerial applications approximately 4 weeks apart of brodifacoum rodent bait. The monitoring sites, close to steep terrain, were chosen on the likelihood that bait could have found its way into the sea. No evidence was found that the application of bait to the island had resulted in a decline of fish density populations.

Risk to humans

From the above, and if the bait was to find its way into the marine environment, it appears feasible humans could catch and consume marine fish that had eaten non-lethal amounts of particles from Pestoff® 20R.

The likelihood of human exposure, and risk, to brodifacoum via consumption of fish is a combination of the following:

- *The probability that significant amounts of bait will find its way into the marine environment.*

  According to the LHI draft plan, while it is possible small quantities of bait may end up in the sea it is considered unlikely there will be large amounts. Such an outcome is an expensive waste. The plan stipulates aerial baiting will be carefully undertaken and controlled on foreshore areas. Wash-off from land into the sea, or into surface water bodies, is unlikely because brodifacoum is poorly water soluble and binds tightly to soil. The NZ Department of Conservation states “Even when baits were sown directly into streams during pest eradication operations, brodifacoum residues have not been recorded in water” (Fisher and Fairweather 2008). If soil particles with adsorbed

brodifacoum are washed into the sea the brodifacoum will have considerably reduced absorption from the gastrointestinal tract (see Section 2.2.1).

- *The probability that fish will consume the bait.*
  If it is assumed that if Pestoff® 20R is accidently dropped into the marine environment it will most likely be at the water's edge. In shallow water fish of suitable size for human consumption are unlikely to encounter the bait. It is however feasible that in deeper water (e.g. off cliffs) such fish may come across the disintegrating bait and some may eat it; however the availability of particulates from rodent bait to be eaten would only be for a short time before they were dispersed.

- *The probability that a fish which has consumed brodifacoum bait will be caught by an angler.*
  This is possible but unlikely given the small numbers of fish liable to be exposed and the short time bait will be available to fish.

- *The probability that caught fish contains high amounts of brodifacoum in edible portions.*
  The fact the fish is alive to be caught indicates it has either not consumed Pestoff® bait or only small amounts thereof. Consequently there will be no, or only very little brodifacoum in the animal. Of the brodifacoum present, the majority will be in the liver which is not normally consumed by humans. Being fat soluble brodifacoum may also be present in the skin which is also not normally eaten by people. In fatty fish there may be low amounts of brodifacoum in edible flesh.

  Fish, shellfish and other animals were monitored in the immediate area around a very large spill of Pestoff®, approximately 18 tonnes, into the ocean off the coast of New Zealand (Primus et al. 2005). A butterfish sampled 9 days after the spill had liver brodifacoum residues of 0.04 ppm, 0.02 ppm was in the gut but muscle was below detection limits (<0.02 ppm [<0.02 µg/g] muscle). Residues in other fish sampled (a scorpion fish, two herrings, and an unknown species) collected 14 – 16 days after the spill were all less than detection limit. Thirteen crayfish and one crab sampled at the point source 8 – 14 days after the spill had unmeasurable residues, < 0.02 ppm (tissues not specified).

  Primus et al. (2005) also reported on brodifacoum concentrations in mussels after the accidental spill of Pestoff® into the sea. The greatest exposure was observed within 100 m of the spill, there was only minor exposure 100 – 300 m from the epicentre of the

spill. Brodifacoum concentrations in mussels in the vicinity of the spill peaked at 0.41 ppm and averaged just above the detection limit of 0.001 ppm by day 29. However the average of five mussel samples collected at 353 days was 0.002 ppm indicating a slow depuration rate from the organism. The concentrations of brodifacoum occurred in mussels as a result of their filter feeding after a huge spill of rodent bait which caused a cloudy plume over approximately 100 m^2 for 24 hours. Individual pellets dropped into the sea from aerial broadcasting will not cause such concentrations of particulate bound brodifacoum in the water body. The disintegration of individual pellets will be rapidly dispersed as discussed in Section 2.3.2.

- *The probability that high amounts of fish will be consumed by an individual.*
  The average seafood consumption rate for a 2 -3 year old male child reported by Australian Bureau of Statistics (ABS 1999) is 6.9 g/d and the 95th percentile 11 g/d. These consumption rates are for total 'fish and seafood products and dishes' and include fin fish (excluding canned), crustacean and molluscs (excluding canned), packed (canned and bottled) fish and seafood, fish and seafood products, and mixed dishes with fish and seafood as the major component. In estimating the amount of brodifacoum exposure by a 2 year old child for this risk assessment it has been assumed the 'total' seafood consumption at the 95th percentile is all fish, and that 10% of this may contain brodifacoum.

  In screening risk assessments it is a common conservative practice to assume the concentrations of chemical in environmental media may be present at half the analytical detection limit when the actual amount cannot be quantitated by the analysis. Thus the assumed conservative concentration of brodifacoum in edible portions of fish is 50% of 0.02 µg/g fish, i.e. 0.01 µg/g. It should be noted that the analytical detection limit in Primus et al. (2005) for mussels was an order of magnitude less than for fish.

  The daily dose of brodifacoum from high end consumption of fish is potentially estimated to be:

  (11 g fish/d/child x 0.1 x 0.01 µg B/g fish) ÷ (13.2 kg bw) = 0.0008 µg B/kg bw

  This is considerably less (by 6,250 times) than the sub-chronic NOEL for prolongation of prothrombin time (0.005 mg B/kg/d). However there is much uncertainty associated

with the calculation of the dose, nonetheless it is considered to be a 'high end' estimate.

Conclusions:

In considering the above probabilities and the chance they will act in unison, it is concluded the risk to human health from this exposure route is negligible.

Nevertheless for Islanders' peace of mind it may be appropriate and precautionary to advise them not to consume the livers of fish.

3.1.6 Consumption of vegetables (Pathways D1 & D2)

Because brodifacoum is poorly soluble in water and tightly bound to soil WHO (1995) concluded it is not taken up from soil by plants.

There is a possibility that while being hand broadcast in gardens the rodent bait may land on a vegetable plant. If distribution of bait is carefully performed this should be a very infrequent occurrence. Nevertheless if it does occur vigilant washing of vegetables before consumption will remove particles of bait. Due to the physicochemical properties of brodifacoum the chemical will not transfer from the bait matrix onto the surface of the plant.

Exposure to brodifacoum from eating home grown vegetables and fruit is negligible.

3.1.7 Exposure via poultry (pathway E)

This exposure pathway is incomplete because all poultry are to be removed from LHI during the rodent eradication campaign. They will not be reintroduced until after all the distributed bait has fully degraded. Contextual information regarding the distribution and elimination of brodifacoum in chickens is provided below.

Fisher (2009) gave a non-lethal single gavage dose of brodifacoum (0.5 mg/kg) to chickens and measured brodifacoum tissue concentrations at 1, 4, 7 and 14 days after dosing. During this time there were no 'in life' signs of poisoning or evidence of internal bleeding during tissue sampling. The weight of the chickens was ~ 1.25 – 2 kg and did not change during the study.

The liver had approximately 10 – 20 times higher concentration of brodifacoum than muscle (Table 3.1). The liver levels were relatively constant and an elimination half life from this tissue could not be determined. Although plasma concentrations approached those of liver at day 1 they declined to less than detection limit by day 7.

The administered dose (0.5 mg/kg) is equivalent to about 25 g Pestoff® bait per kg body weight (approximately 60 – 100 pellets of the 5.5 mm size bait per chicken).

Table 3.1: Distribution of brodifacoum in chicken [a]

Day	Plasma	Liver	Breast muscle	Abdom fat	Ovary	Faeces
1	0.22	0.66	0.06	0.06	0.13	0.17
4	0.12	0.65	0.03	0.03	0.04	0.018
7	- [b]	0.71	0.015	0.015	0.02	- [b]
14	- [b]	0.62	0.016	0.016	0.005	- [b]
Half life ($t_{½}$) (days)	1.1 d	[c]	5.3 d	2.8 d	3.2 d	[c]

[a] Data is adapted from Fisher (2009). Units are µg brodifacoum/g wet weight.
[b] Concentrations less than detection limit (< 0.001 or 0.005 µg/g depending on tissue).
[c] Half life could not be calculated.

Fisher (2009) also describes a study by Lund (1981) in which four laying hens were fed brodifacoum bait and the eggs fed to a single laboratory rat over 10 days. The four hens died within 10 – 12 days after an average intake of 10.5 mg/kg brodifacoum. After consuming 218 g of eggs the rat showed no sign of toxicity and according to Fisher (2009) it was stated in Lund (1981) that " ..eggs laid during an anticoagulant feeding period contain no toxic residues representing a risk to the consumer".

3.1.8 Meat and dairy products (Pathway E)

Cattle are to be removed from LHI during the eradication campaign and dairy cows will be quarantined from exposure to bait. Therefore the human brodifacoum exposure pathway via meat and dairy products will not occur.

O'Connor et al. (2001) [8] have used sheep as a model to investigate possible contamination of cow's milk after ingestion of brodifacoum. Lactating ewes were given a low and high dose of brodifacoum. Blood and milk were collected at 2, 4, 8, 16, 24 and 32 days. Although the doses

[8] This study is reported in a non-peer reviewed journal.

are not provided the high dose is described as equivalent to a 60 kg sheep eating 3 kg of brodifacoum bait (i.e. about 8 boxes of 150g Talon® bait as sold in hardware stores). The low dose was described as being akin to levels recorded in wildlife around bait lines. Significant concentrations of brodifacoum were found in the blood at 2 and 4 days after the high dose, but at this dose only one milk sample was above the detection limit of 0.01µg/mL. No brodifacoum was detected in milk beyond 4 days. The authors concluded human poisoning through milk was very unlikely.

The study by O'Connor et al. (2001), and the fact that care will be taken to isolate LHI dairy cows from exposure to bait makes human exposure to brodifacoum by consumption of milk very low or incomplete.

3.1.9 Goat produce (Pathway G)

It is anticipated that brodifacoum uptake and distribution in goats will be similar to that in sheep (see Section 3.1.8) and therefore it is possible that if they ate large amounts of rodent bait, some brodifacoum could be in meat and milk. In the draft eradication plan goats on LHI are not intended to be removed but will be kept in isolated areas away from the broadcast rodent bait. These animals are kept as pets and not used for meat, milk or cheese making [9] hence no exposure to brodifacoum will occur.

3.1.10 Consumption of wild ducks (Pathway H)

In the draft LHI rodent eradication plan it is noted that in trials conducted on the Island hybrid mallard/black ducks did eat the baits. Since it may be anticipated the uptake and distribution of brodifacoum may be similar as in chickens (Section 3.1.7) it raises the possibility a recreational duck hunter eating wild birds may be exposed to brodifacoum, especially if the liver was consumed.

Toxikos is advised [9] ducks are occasionally shot by designated licensed fire arm owners on the island as part of a control programme to remove mallards and mallard/pacific black duck hybrids that are non-native. Pacific black ducks are protected and are not shot. There is no hunting on the island that would result in duck consumption as would be the case on the mainland.

[9] Personal communication with Dr Ian Wilkinson, NSW Department of Environment, Climate Change and Water.

It would therefore seem that exposure to brodifacoum by consumption of wild duck is not a significant exposure pathway. Nevertheless it would be prudent to advise those individuals involved with the control of non-native duck populations that they should not consume duck during the eradication programme, and not the liver for perhaps a year after the program has ceased. The time of a year is precautionary because it is unknown how long brodifacoum may remain in the liver of ducks.

3.1.11 Dust inhalation during aerial baiting (Pathway I)

The hypothetical inhalation exposure scenario for LHI residents to fine dust dispersed during the proposed eradication program when the bait is aerially broadcast is summarised in Figure 3.2.

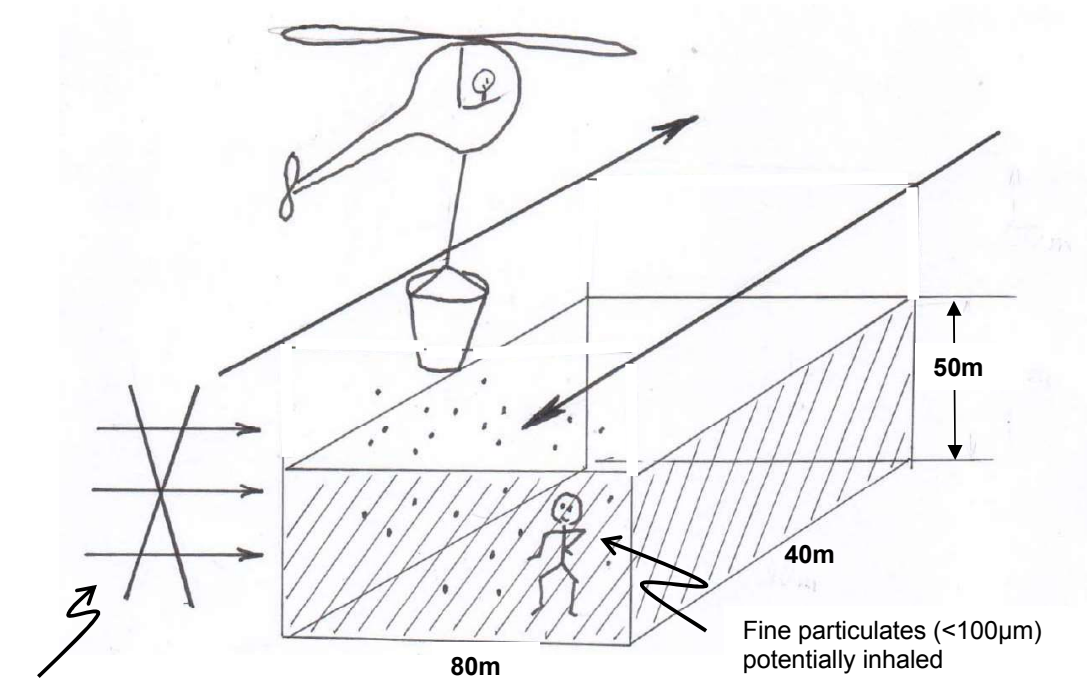


Figure 3.2: Hypothetical inhalation exposure to dust during aerial broadcasting of rodent bait.

The total amount of bait dispersed in two campaigns approximately 14 days apart is 12 and 8 kg/ha. It has been assumed the bait is dropped from a 50 m height along an 80m swath. The amount of inhalable fine particulates in rodent bait dispersed from buckets beneath helicopters has been calculated from data obtained in New Zealand.

In calculating the exposure of a person to brodifacoum it has also been assumed there is no wind or breeze to remove inhalable particulates away from the air space in which they were scattered, that the particulates stay in the air for 8 hours, that a child may be in the impacted air for 8 hours, and all the brodifacoum on dust breathed in will be absorbed into the body.

Exposure assumptions and calculations:

- The bait is to be spread at a total rate of12 kg/ha (i.e.12 kg/10,000m^2) in the first campaign and 8 kg/ha in the second campaign.

- Pellets are released at approximately 50m in a swath 80m wide.
  Over an area 80m x 40m the amount of bait dispersed is:
  (12 kg/10,000m^2) x (80m x 40m) = 3.84kg (say 4kg bait).

- Torr and Agnew (2007) found approximately 130 - 150 g fine material (<2mm size) in a 25 kg bag of 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 – 330g per bag. The maximum amount of fine particles (<2mm [<2000 µm]) in the supplied bait and potentially generated by dispersion machinery is therefore approximately 500 g per 25 kg of bait [10] (i.e. approximately 2% of the total bait).

- The particle size that may be inhaled (i.e. drawn into the mouth and nose during breathing) is 100 µm. Large particles (>10µm) in the inhalable fraction are caught in mucous and subject to expectoration or swallowing. Particles ≤ 10 µm may reach the bronchi where they will be caught in mucous and transported to the throat and swallowed, the very fine particles (≤4 µm) may reach the deep lungs and be phagocytised by macrophages and transported up the ciliary ladder to be swallowed (CEN 1993, ACGIH 2008). Chemicals in, or on particulates of about 100 µm size that are inhaled are potentially absorbed into the body after the particles are swallowed, or after the chemical dissociates from the particle and absorption occurs across the lungs. Particles larger than 100 µm are not inhaled.

  The amount of inhalable particles in the < 2mm fine material measured by Torr and Agnew (2007) is unknown. A conservative assumption would be 25% may be inhalable, if so up to 0.5% (25% of 2%) of the pellet bait could be potentially dispersed as inhalable particulates (i.e. up to 125 g per 25 kg bag bait).

  This means in the 4 kg of bait dispersed into the hypothetical air volume described above there will be:

[10] Maximum amount of fines < 2mm is 150 g as delivered in bags plus 330 g produced during dispersion = 480 g (rounded up to 500 g).

4 kg x (0.5/100) = 0.02 kg (i.e. 20 g of inhalable particulates).

- Assuming the inhalable particles are dispersed in a volume of air 80m x 40m x 50m = 160,000 m^3, and there is no wind or breeze to move them away from this theoretical air volume, and they stay suspended, then the concentration of inhalable particulate in air may be:

  20 g ÷ 160,000 m^3 = 0.000125 g/m^3 (i.e. 0.125 $\mu g/m^3$)

- The amount of brodifacoum in the bait is 0.002%, hence the concentration of brodifacoum in the air could be:

  0.125 $\mu g/m^3$ x (0.002/100) = 0.0000025 µg brodifacoum/m^3
  (0.0000025 µg B/m^3)

  The occupational exposure limit applied to protect workers from the effects of brodifacoum during manufacture of rodent bait is 2 $\mu g/m^3$ (Syngenta 2006). Thus the maximum estimate of brodifacoum in inhalable particulates in air during aerial broadcasting is about eight hundred thousand times (800,000x) lower than the concentration used to protect workers.

  This assumes there is no wind that diluted and dispersed the particulates outside of the theoretical air volume in which they have been scattered.

- A 2 -3 year old child breathes 9.5m^3/d (US EPA 2008) and weighs 13.2 kg (enHealth 2004). If it is assumed inhalable particulates remained suspended for 8 hours, a child spends 8 hours outside in the impacted air, and 100% of the brodifacoum on the particulates are absorbed into the body (bioavailability = 1). Then in these very unlikely circumstances the dose of brodifacoum to a 2 -3 year old child will be:

  [0.0000025 µg B/m^3 x 9.5m^3/d x (8hr/24hr) x 1] ÷ 13.2 kg = 0.0000006 µg B/kg bw/d

  This is significantly less, in fact 250,000,000 (250 million) times less than the NOEL (150 µg/kg bw) for acute effects (single exposure) on PT time.

- The above calculations are for the first baiting programme of 12 kg/ha, a second programme will be undertaken at 8 kg/ha. Following the same steps as above, the dose to a 2 – 3 year old child from inhalation of particulates for the second programme would be 0.0000004 µg B/kg bw/d.

The total dose during the eradication campaign for this inhalation exposure pathway is;

0.0000006 µg B/kg bw/d + 0.0000004 µg B/kg bw/d = 0.000001 µg B/kg bw/d

This is 5,000,000 (5 million) times less than the 42 day NOEL for prolongation of PT (5 µg B/kg bw).

Conclusion

Although fine dust may be released during aerial bait broadcasting, the amount is very small. The maximum dose of brodifacoum to a small child that could occur by inhaling this dust is negligible when compared to the doses that do not have any affect on the body. The dose to a child is about 250 million times less than a single dose of brodifacoum that has no effect, and five million times less than the dose which if taken daily over 42 days has no effect. LHI residents are only likely to be exposed by inhalation twice during the proposed eradication campaign.

The risk to human health from this inhalation exposure pathway is negligible.

4. Existing risk from commercial rodent bait

4.1 Bait constituents

Rodent control on LHI currently consists of baiting with warfarin and commercially available brodifacoum baits (0.005%). As with the proposed use of Pestoff® in the eradication program the human health risks are primarily associated with direct ingestion of bait with the intention of causing self harm. With warfarin the risk is considerably lower than with brodifacoum baits because it is more rapidly cleared from the body and not as strong an inhibitor of vitamin K epoxide reductase (WHO 1995, IPCS 1995).

Since commercial rodent bait sold in Australia has a brodifacoum concentration of 0.005% as compared to 0.002% for Pestoff® there is greater health risk from consumption of commercial bait than there is from an equal weight of Pestoff®20R.

Table 4.1 summarises some of the salient properties of commercial rat bait with those of Pestoff®20R. The greater health risk associated with the higher concentration of brodifacoum in commercial baits is dependent upon the commercial brodifacoum bait used by LHI residents. Some commercial bait (e.g. Talon® and Ratsak) contain bittering agents that act as taste deterrents to incidental ingestion of bait. These are incorporated into the bait on the premise children will quickly spit the bait out of their mouths. Pestoff®20R and some commercial bait (e.g. Bromakil [11]) do not contain taste deterrents and so can be envisaged as presenting a greater risk for incidental ingestion.

The average weight of a small Pestoff®20R pellet is greater than that of both Talon® and Ratsak (see Table 4.1). In the case of Ratsak the amount of brodifacoum per pellet is the same as for the small Pestoff® pellet, while for Talon® there is less brodifacoum compared to Pestoff®20R. Therefore on a per pellet consumption, most likely for incidental ingestion of bait, the health risk associated with Pestoff®20R is the same as Ratsak, but greater than for Talon®.

However, any differences in relative health risk associated with incidental ingestion of small numbers of pellets from different products should be viewed in the context of the negligible health risk posed by such ingestion (see section 3.1.1).

Table 4.1: Comparison of commercial brodifacoum rodent bait with Pestoff®20R

Product	Taste deterrent	Conc[n]	Package	Pellet		
				Diam (mm)	Weight (mg)	Brodifcoum (µg/pellet)
Talon	✓	0.005%	150 g (6 x 25 g prepacked open trays)	~ 4.5	~ 130 [a]	~ 6.5
Ratsak	✓	0.005%	200g (4 x 50 g prepacked open trays)	~ 5	~ 220 [a]	~ 11
Bromakil [b]	✗	0.005%	200 g (bulk, to be dispensed into open trays)	~ 4.5	~ 200 [a]	~ 10
Pestoff® 20R	✗	0.002%	Bulk, to be dispensed into open trays	~ 5.5	~ 500	~ 10
				~ 10	2,000	~ 40

[a] Average pellet weight determined by Toxikos by weighing ~ 50 pellets from product bought in a hardware store.
[b] Does not contain brodifacoum but another second generation anticoagulant, bromadiolone.

[11] Note Bromakil does not contain brodifacoum but another second generation anticoagulant, bromadiolone, at 0.05%.

4.2 Bait stations

Within houses (e.g. roof spaces, under floors and other areas inaccessible to children) open trays, similar to those supplied with commercial bait holding approximately 25 gm of small pellets are intended to be used. These will present the same opportunity for exposure as current practice with commercial baits. The health risks for the duration of the eradication campaign, subject to the considerations in Section 4.1, will also be the same.

Outside of dwellings, T- or J- shaped bait stations purpose made from plastic storm water pipe are currently used (Appendix 1), and these or similar are intended to also be used in the eradication campaign. Again subject to the varying constituents in the commercial baits, the exposure opportunity and health risk for adults and children when using Pestoff®20R will be the same as is the current practice.

A major difference between the health risks associated with the proposed eradication campaign and what is currently practiced is the length of time bait will be used. If the eradication campaign is successful then there will not be a need for continuous rodent control by residents or commercial operations on the island. The long term exposure and health risks are therefore markedly less than if the eradication programme did not proceed and an ongoing need to continue using rat poison remained.

4.3 Conclusions

The relative opportunity for exposure to brodifacoum in bait stations via Pestoff®20R is the same as current practise using commercially available rat bait.

However, for the same number of pellets ingested the health risk may be higher depending on the constituents and pellet size of the commercial product.

Generally for the same weight of bait ingested Pestoff®20R presents a lower risk because it has a lower concentration of brodifacoum than products sold on the domestic market. This is however balanced by the absence of a taste deterrent which is in some, but not all commercial products.

The eradication campaign, if successful in removing rats and mice from LHI, will result in a smaller (zero) ongoing risk of exposure to rodent poisons.

5. General discussion and conclusions

This health risk assessment for human exposure to brodifacoum rodent bait is specific for the Lord Howe Island group and takes into account the bait intended to be used, the method of application, the longevity of the bait in the terrestrial and aquatic environments, and management practices to be undertaken to minimise human exposure to the broadcast bait.

A number of possible theoretical exposure pathways have been considered (Figure 3.1). These include:

- Direct ingestion of rodent bait.
- Inhalation of dust from bait during aerial broadcasting.
- Ingestion of soil contaminated by brodifacoum from bait.
- Dermal exposure to bait and contaminated soil.
- Ingestion of water (ground water and tank water) that may become contaminated by bait.
- Consumption of:
    - vegetables and fruit,
    - poultry produce,
    - fish that have ingested bait inadvertently distributed to shore waters,
    - meat and dairy produce,
    - goat produce,
    - wild ducks.

Many of these exposure pathways will not occur due to pre-emptive management practices that are to be put in place during and after the proposed eradication campaign (e.g. removal of poultry and cattle from the Island, isolating cows and goats from exposure to rodent bait). Consumption of wild ducks is said not to occur on the Island.

Brodifacoum, because of its physical chemical properties, is unable to contaminate groundwater because it doesn't leach from soil. Similarly it does not contaminate vegetables and fruit because it is not transported from water or soil into the plant. In this instance the bait would

have to be physically broadcast onto the plant; this should not occur but if it does bait particles can be easily washed off during food preparation.

An important consideration in estimating exposure to brodifacoum by direct ingestion of bait pellets, or indirectly via potentially contaminated water, soil, and seafood is the stability of the pelletised form of the bait in the environment. The bait completely disintegrates into a few particles of grain within 100 days of being broadcast. It only remains as an entity that can be picked up by children or birds for about 15 – 21 days. Hence with two broadcast campaigns approximately two weeks apart, solid bait may be on the ground in such a form for 4 – 5 weeks. In water bait pellets are reported to disintegrate within 15 minutes, sooner if there is wave action.

Contamination of soil, fish and seafood, and tank water are hypothetical but nonetheless plausible pathways through which LHI residents may become exposed to brodifacoum. Even though it is very unlikely such exposure will occur, conservative (i.e. 'high end') intakes of brodifacoum have been estimated for these pathways. Figure 5.1 shows the theoretical intakes by a 2 year old child and compares them to the 42 day (0.005 mg/kg/d) and 90 day (0.001 mg/kg/d) NOEL for prolongation of prothrombin time. Brodifacoum doses for a two year old were estimated because this is the population sector most at risk from exposure to chemicals in the environment; the behaviour of young children brings them into closer contact with soil and because they weigh less than adults potential doses are higher. It is emphasised there is a lot of uncertainty associated with the intake estimations. Consequently conservative 'high end' estimations have been undertaken so any error is more likely to be on the side of over-estimation rather than under-estimation of intakes.

The probability of seafood being contaminated by brodifacoum is qualitatively discussed in Section 3.1.5. Overall, it is unlikely fish will have much opportunity to eat bait that might fall into the ocean, it is also unlikely humans will catch such fish in numbers where it may become a health issue. The conservative estimations of intake via seafood was undertaken using data from New Zealand for levels of brodifacoum in fish after a very large spill of Pestoff®20R into the sea. Brodifacoum was not measureable in the flesh of fish so potential exposure to brodifacoum in this risk assessment has been done assuming it may be present at half the analytical detection limit. The estimated intake is predicted to be less than both the 42d and 90d NOEL. Despite the low risk a precautionary recommendation for consideration in regard to fish consumption has been made.

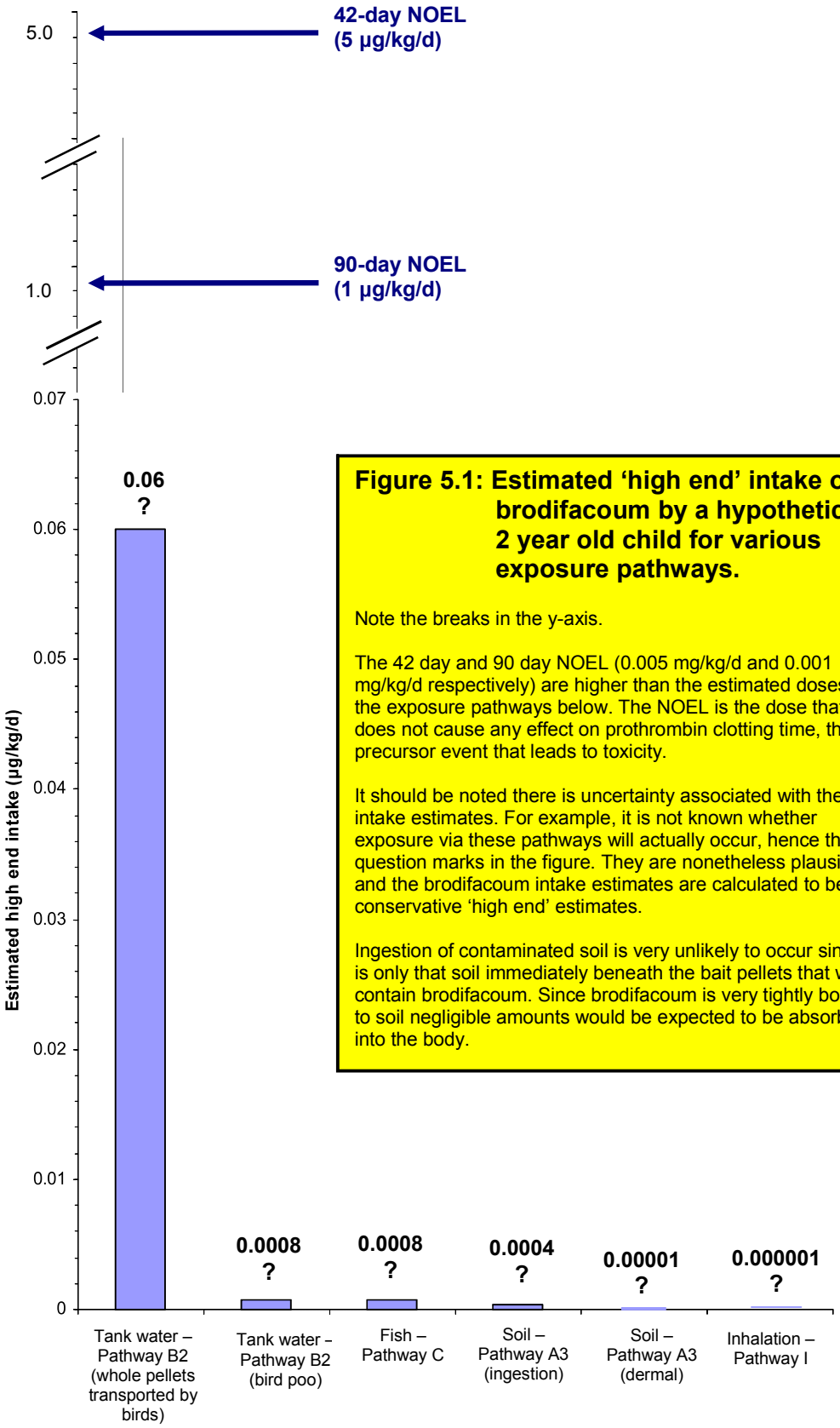


Figure 5.1: Estimated 'high end' intake of brodifacoum by a hypothetical 2 year old child for various exposure pathways.

Note the breaks in the y-axis.

The 42 day and 90 day NOEL (0.005 mg/kg/d and 0.001 mg/kg/d respectively) are higher than the estimated doses in the exposure pathways below. The NOEL is the dose that does not cause any effect on prothrombin clotting time, the precursor event that leads to toxicity.

It should be noted there is uncertainty associated with these intake estimates. For example, it is not known whether exposure via these pathways will actually occur, hence the question marks in the figure. They are nonetheless plausible and the brodifacoum intake estimates are calculated to be conservative 'high end' estimates.

Ingestion of contaminated soil is very unlikely to occur since it is only that soil immediately beneath the bait pellets that will contain brodifacoum. Since brodifacoum is very tightly bound to soil negligible amounts would be expected to be absorbed into the body.

Contamination of tank water may occur if aerial broadcasting of bait accidentally spreads pellets onto roofs. The draft eradication plan has management contingency for this event. Less obvious ways that brodifacoum might get onto roofs is by birds eating bait and depositing droppings on roofs and gutters (brodifacoum is excreted in droppings), or birds picking bait up and discarding it onto roofs. The likelihood of these events is unknown. They are plausible but intuitively unlikely to place significant amounts of brodifacoum onto the roof.

Ingestion of brodifacoum contaminated soil is also considered to be a very minor pathway. It is unlikely all soil incidentally ingested (mostly by hand mouth transfer) will be contaminated soil. Furthermore brodifacoum is tightly bound to organic carbon in soil which significantly lowers the amount that may be absorbed into the body. Indeed swallowing a slurry of charcoal is a treatment option for large amounts of brodifacoum that have been ingested up to 4 hours earlier.

The high end estimation of brodifacoum dose by these exposure routes is less than the 42 day and 90 day NOELs (Figure 5.1). It is concluded there is negligible risk for human health from these exposure pathways.

The most likely and important way that a young child may be exposed to rodent bait during the proposed eradication campaign is by picking the bait up and eating it. Pestoff®20R rodent bait contains a water soluble green dye that will colour the tongue and mouth and thus assist to alert parents if they are vigilant.

Even though brodifacoum is acutely very toxic to a range of species the amount of bait needed to be ingested by a child at one time to cause health effects is quite large. Small bait pellets (5.5mm diameter) are intended to be hand distributed in the settlement and around dwellings. These are therefore the ones most likely to be picked up by a child. The number of pellets required to be ingested to reach the equivalent brodifacoum intake of the acute NOEL (0.15 mg/kg) for prolongation of prothrombin time is approximately 200 which weigh about 100 g. This amount of bait is put into perspective by considering commercial Talon® is sold in 150 g packets containing six prepacked pellet trays of 25 g each. Weight for weight, Talon® also has more brodifacoum than does Pestoff® 20R.

Assuming there will be two bait campaigns about two weeks apart, the time that bait will be in a physical form able to be picked up by a child is about 4 -5 weeks. It will require ingestion of 6 -7 small pellets per day, **each day** by a small child over this period to acquire a dose equivalent to the 42 day NOEL. This is unlikely to occur.

It is a fact that unless it is consumed with the intention of self harm (e.g. suicide attempt) it is quite unusual for a person to suffer toxic effects (anticoagulant symptoms) from incidental ingestion of brodifacoum rodent bait. Even with intentional ingestion most people do not die. This is because there are several days between ingestion and the appearance of toxic effects which allows time to assess the severity of poisoning and administer antidotes (plasma and Vitamin K) which are very efficient in reversing the effects. There are no long term consequences associated with recovery of poisoning by brodifacoum.

Relative to the health risk associated with current household practice of controlling rodents on LHI, the small Pestoff®20R pellets present the same hazard and potential health risk as most commercially available bait. This risk is very low (Section 3.1.1). Compared to Talon®, which has a taste deterrent and less brodifacoum per pellet (Table 4.1), the health risk associated with ingestion of a large number of Pestoff®20R pellets is greater. It is noted however that currently there is an ongoing risk of inadvertent ingestion of rodent bait associated with continuation of the current practice. This long term risk will be removed if rodents are eradicated from the Island. It is also noted health effects from incidental ingestion of any of the rodent baits, including Pestoff® 20R, is very low.

Conclusions:

Although brodifacoum is an acutely toxic substance that has the potential to cause toxicity and possibly death through internal bleeding, the human health risk to Lord Howe Islanders during the proposed eradication campaign is very low, indeed negligible. The most important exposure pathway is direct ingestion of bait picked up off the ground or from bait stations. The draft LHI rodent eradication plan indicates there will be an education campaign targeting children and parents to inform them of the dangers associated with eating the bait. Nonetheless parents will need to be especially watchful of their infant and young children during the 4 -5 weeks bait will be on the ground and able to be picked up. It is noted that with current rodent control practice residents also need to be vigilant, with removal of rodents from LHI the ongoing risk of bait ingestion, albeit low, and vigilance will also be removed.

Even though exposure is unlikely, indirect exposure pathways are managed primarily by removing or isolating human food sources that may become contaminated (e.g. poultry, beef meat and dairy produce). Other human foods (e.g. seafood, vegetables and fruit) are unlikely to be affected.

Tank water may become impacted if bait is strewn over roofs during aerial broadcasting. There are management contingencies to mitigate this if required. Theoretically tank water may also become contaminated with brodifacoum if birds transport pellets onto roofs or, after eating pellets, they leave their droppings on roofs. Both these scenarios are regarded as improbable but if they do occur, are very unlikely to affect tank water to the extent it is unsafe to drink.

Exposure to brodifacoum by indirect pathways (i.e. not direct ingestion of rodent bait) is negligible in comparison to the NOELs.

6. Recommendations

All mitigation measures as outlined in the *Draft Lord Howe Island Rodent Eradication Plan* should be implemented to minimise risks posed by use of rodent bait during the programme.

As a precautionary measure it would be prudent to advise Islanders not to consume the livers of fish that have been caught within 200m of the shore line until 6 months after the last bait broadcast.

Although there are negligible health risks from drinking tank water during the eradication campaign, for peace of Islander's mind, consideration could be given to a programme of strategic testing of tank water.

It would be prudent to advise those individuals involved with the control of non-native duck populations that they should not consume duck during the eradication programme, and not the liver for perhaps a year after the program has ceased.

References

ACGIH (2008). TLVs and BEIs: Threshold limit values for chemical substances and physical agents, biological exposure indices. Appendix C: Particle size-selective sampling criteria for airborne particulate matter American Conference of Governmental Industrial Hygienists, Cincinnati, OH.

ABS (1999). National Nutrition Survey: Foods Eaten. Australia 1995. Report No: 4804. Prepared by McLennan, W. and Podger, A. for the Australian Bureau of Statistics (ABS).

AG (2010). Acceptable Daily Intakes for Agricultural and Veterinary Chemicals. Office of Chemical Safety and Environmental Health, Department of Health and Aging, Australian Government.
http://www.health.gov.au/internet/main/publishing.nsf/content/ocs-adi-list-a-b

Brown, D., Wylie, M. and McClelland, P. (2006). Assessment of Environmental Effects for the eradication of: Ship rats (*Rattus rattus*) from Taukihepa, Pukeweka and Solomon (Rerewhakaupoko) Islands; and Kiore (*Rattus exulans*) from Big Moggy (Mokonui) Island July , 2006. Department of Conservation, New Zealand Government.

Bruno, G. R., Howland, M. A., McMeeking, A. and Hoffman, R. S. (2000). Long-acting anticoagulant overdose: brodifacoum kinetics and optimal vitamin K dosing. Ann Emerg Med. 36 (3): 262-267.

CEN (1993). Workplace atmospheres - size fraction definitions for measurement of airborne particles. CEN EN481:1993. European Committee for Standardization.

Cole, R.G. and Singleton, R.J. (1996). Monitoring of fish populations at Kapiti Island during aerial poisoning for rats, 1996. Unpublished report prepared for Wellington Conservancy, Department of Conservation, Wellington. National Institute of Water and Atmospheric Research, Nelson, New Zealand.

Craddock, P. (2004). Environmental breakdown & soil contamination by Pest-Off® poison bait (20ppm brodifacoum) at Täwharanui Regional Park, North of Auckland. Winter 2003 Trial. *Report prepared for Northern Regional Parks, Auckland Regional Council (unpublished)*. Entomologica Consulting. Auckland, New Zealand.

Eason, C. T. and Ogilvie, S. (2009). A re-evaluation of potential rodenticides for aerial control of rodents. DOC Research and Development Series 312. Department of Conservation, Wellington, New Zealand.

EC (2005a). Competent Authority Report Brodifacoum (PT 14). Doc I.2, Overall Summary and Assessment for the Active Substance Brodifacoum. European Commission, September 2005.

EC (2005b). Competent Authority Report Brodifacoum (PT 14). Doc 1.3, Proposal for Decision Regarding Annex I Inclusion of the Active Substance Brodifacoum.

EC (2005c). Competent Authority Report Brodifacoum (PT 14). Doc 1.3, Document II-A. Effects Assessment for the Active Substance Brodifacoum, European Commission.

EC (2005d). Competent Authority Report Brodifacoum (PT 14). Doc I, Listing of End Points for the Active Substance Brodifacoum. European Commission, September 2005.

enHealth (2004). Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards. Department of Health and Aging, and enHealth Council. Commonwealth of Australia.

enHealth (2010). Australian Exposure Factor Guidance. enHealth Council of Australia (Draft).

Empson, R.A. and Miskelly, C.M. (1999). The risks , costs and benefits of using brodifacoum to eradicate rats from Kapiti Island, New Zealand. New Zealand J. Ecol. 23: 241 – 254.

EWS (2000). Lord Howe Island Groundwater Quality Study and Assessment of Groundwater Quality. Report prepared for the Lord Howe Island Board, June 2000. Environmental Water Monitoring , Water Control Services (Aust.) Pty. Ltd., NSW.

Fisher, P. and Fairweather, A. (2008). Brodifacoum: A review of current knowledge. Part 6 in Department of Conservation Pesticide Information Review Series. Dme No. DOCDM-25436.

Fisher, P.M. (2009). Residual concentrations and persistence of the anticoagulants rodenticides brodifacoum and diphacinone in fauna. PhD Dissertation, Lincoln University, New Zealand http://researcharchive.lincoln.ac.nz/dspace/bitstream/10182/930/3/Fisher_PhD.pdf

Fowler, A. (date unknown). Looking at Bird Poo. http://www.fourthcrossingwildlife.com/LookingatBirdPoo.pdf

FSANZ (2010)., Schedule 1.4.2, maximum Residue Limits, Australia only. Food Standards Australia and New Zealand, http://www.foodstandards.gov.au/_srcfiles/Standard_1_4_2_MRLs_part_2_Sched_1_A-L_v116.pdf (Accessed 22/06/2010).

Harrison, G.J and Ritchie, B.W. (1994). Chapter 8.Making distinctions in the physical examination. In “Avian Medicine: Principles and Application”. Editors B.W. Ritchie, G.J. Harrison and L.R. Harrison, Wingers Publishing Inc, Lake Worth Florida. www.avianmedicine.net/ambook.pdf

Hollinger, B. R. and Pastoor, T. P. (1993). Case management and plasma half-life in a case of brodifacoum poisoning. Arch Intern Med. 153 (16): 1925-1928.

IPCS (1995). Brodifacoum. IPCS International Programme on Chemical Safety, Health and Safety Guide No. 93. United Nations Environment Programme, International Labour Organisation, World Health Organization, Geneva. http://www.inchem.org/documents/hsg/hsg/hsg093.htm

Kruse, J. A. and Carlson, R. W. (1992). Fatal rodenticide poisoning with brodifacoum. Annals of Emergency Medicine. 21 (3): 331-336.

LHI (2009). Draft Lord Howe Island rodent eradication plan. Lord Howe Island Board, Lord Howe Island.

Lund, M. (1981). Hens, eggs and anticoagulants. International Pest Control 23: 126 – 128 (as cited in Fisher 2009).

Morgan, D. R. and Wright, G. R. (1996). Environmental effects of rodent Talon baiting. Part I: Monitoring for toxic residues. Science for Conservation: 38. Department of Conservation, Wellington, New Zealand.

NZFSA (2006). Code of Practice. Aerial and Hand Broadcast Application of Pestoff® Rodent Bait 20R for the Intended Eradication of Rodents from Specified Areas of New Zealand. New Zealand Food Safety Authority, Wellington, June 2006 Revision.

NZFSA (2010). New Zealand (Maximum Residue Limits of Agricultural Compounds) Food Standards 2010. http://www.nzfsa.govt.nz/policy-law/legislation/food-standards/nz-mrl-fs-2010-consolidation.pdf

O'Brien, P. H. and Lukins, B. S. (1990). Comparative dose-response relationships and acceptability of warfarin, brodifacoum and phosphorous to feral pigs. Australian Wildlife Research. 17: 101-112.

O'Connor, C., Milne, L., Wright, G. and Eason, C. (2001). Poison residues in our meat and milk. He Korero Paihama (Possum Research News). 15: 10.

Octapharma (2007). Product Information Sheet for Pronativ® (Human Prothrombin Complex), Octapharma Australia Pty. Ltd. (Regulatory approved 27 September 2007). http://www.octapharma.com/Australia/docs/pronativ_pi_27sept07.pdf

Ogilvie, S. C., Pierce, R. J., Wright, G. R. G., Booth, L. H. and Eason, C. T. (1997). Brodifacoum residue analysis in water, soil, invertebrates, and birds after rat eradication on Lady Alice Island. New Zealand Journal of Ecology. 21 (2): 195-197.

Olmos, V. and Lopez, C. M. (2007). Brodifacoum poisoning with toxicokinetic data. Clinical Toxicology. 45 (5): 487-489.

Pelfrene, A.F. (1991). Synthetic Organic Rodenticides; Chapter 19 in *Handbook of Pesticide Toxicology*, Editors W.J. Hayes and E.R.Laws, Academic Press. Pp 1271 – 1316.

Primus, T., Wright, G. and Fisher, P. (2005). Accidental discharge of brodifacoum baits in a tidal marine environment: a case study. Bulletin of Environmental Contamination and Toxicology. 74: 913-919.

Ross, G. S., Zacharski, L. R., Robert, D. and Rabin, D. L. (1992). An acquired hemorrhagic disorder from long-acting rodenticide ingestion. Arch Intern Med. 152 (2): 410-412.

Samama, C.M. (2008). Prothrombin complex concentrates: a brief review. Eur. J. Anaesthesiology 25: 784–789.

Shapiro, S.S. and Martinfz, J. (1969). Human prothrombin metabolism in normal man and hypocoagulable subjects. J. Clin. Invest. 48: 1202 – 1298.

Spahr, J. E., Maul, J. S. and Rodgers, G., M. (2007). Superwarfarin poisoning: A report of two cases and review of the literature. American Journal of Hematology. 82 (7): 656-660.

Spiller, H. A. (2005). Brodifacoum. In Encyclopedia of Toxicology (Second Edition), pp. 335-337. Elsevier.

Toor, N. and Agnew, D. (2007). Trial to determine differences in bait fragmentation in various spreader bucket designs used during aerial application of toxic bait. Department of Conservation, New Zealand Government. February 2007.

Travis, S. F., Warfield, W., Greenbaum, B. H., Molokisher, M. and Siegel, J. E. (1993). Spontaneous hemorrhage associated with accidental brodifacoum poisoning in a child. The Journal of Pediatrics. 122 (6): 982-984.

US EPA (1998). Reregistration Eligibility Decision (RED) Rodenticide Cluster. United States Environmental Protection Agency. EPA738-R-98-00.

US EPA (2008). *Child-specific exposure factors handbook. Final report*. National Center for Environmental Assessment, Office of Research and Development, United States Environmental Protection Agency, Washington, DC.

Vandenbroucke, V., Bousquet-Melou, A., De Backer, P. and Croubels, S. (2008). Pharmacokinetics of eight anticoagulant rodenticides in mice after single oral administration. Journal of Veterinary Pharmacology and Therapeutics. 31 (5): 437-445.

Weitzel, J. N., Sadowski, J. A., Furie, B. C., Moroose, R., Kim, H., Mount, M. E., Murphy, M. J. and Furie, B. (1990). Surreptitious ingestion of a long-acting vitamin K antagonist/rodenticide, brodifacoum: clinical and metabolic studies of three cases. Blood. 76 (12): 2555-2559.

WHO (1995). Anticoagulant Rodenticides. Environmental Health Criteria document 175. International Programme on chemical Safety, World Health Organization, Geneva.

Appendix 1: Design of bait stations

T- and J- shaped bait stations to be deployed when necessary around the settlement and dwellings are depicted below. The stations are made from plastic storm water pipe with cross wires at the entrance.

SOUTH EASTERN SYDNEY
ILLAWARRA
NSW HEALTH
DIVISION OF POPULATION HEALTH
PUBLIC HEALTH UNIT
Director's Office

9 December 2010

Mr Stephen Wills
Chief Executive Officer
Lord Howe Island Board
PO Box 5 Lord Howe Island NSW 2898

Email: stephen.wills@lhib.nsw.gov.au

Dear Mr Wills

RE: Human Health Risk Assessment on the Use of Brodifacoum for the Lord Howe Island Rodent Eradication Plan

I refer to my letter of 24 November 2009 concerning the South Eastern Sydney Illawarra Public Health Unit's assessment of the 'Draft Lord Howe Island Rodent Eradication Program' and my request for a human health risk assessment to be undertaken of the program by an independent expert in health impacts and for the recognized Health Risk Assessment framework to be used for the assessment. I also refer to a meeting held with the Public Health Unit and the NSW Food Authority to discuss aspects of the proposal as addressed by Dr Ian Wilkinson.

It was understood from the original request that it is the intention to conduct a one off aerial spraying and hand broadcasting of the bait Pest Off20R, which contains broadifcoum. It was also advised that there would be a 30 metre buffer around all dwellings and that hand broadcasting will be undertaken in the residential areas of the Island.

Human Health Risk Assessment

In October 2010 the Public Health Unit was emailed a copy of the report "Human Health Risk Assessment on the use of Brodifacoum for the Lord Howe Island Rodent Eradication Plan' undertaken by Toxikos Toxicology Consultants and signed off by Dr Roger Drew, Toxicologist and Health Risk Assessor. I am pleased with the report and its inclusions and that a suitable independent assessor has been engaged to undertake the assessment.

In detail all potential exposure pathways, indirect exposure pathways and health risk from current practice have been explored and examined. I would fully support and agree with all of the following recommendations as outlined in the Executive Summary of the report:

South Eastern Sydney and Illawarra Area Health Service
Public Health Unit - Director's Office
Locked Mail Bag 88, Randwick NSW 2031, Australia
(Hut "U" Easy St, Randwick Hospitals Campus)
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- All mitigation measures as outlines in the *Draft Lord Howe Island Rodent Eradication Program* should be implemented to minimize risks posed by use of rodent bait during the program

- As a precautionary measure it would be prudent to advise Islanders not to consume the livers of fish that have been caught within 200m of the shore line until 6 months after the last bait broadcast

- Although there is negligible health risk from drinking tank water during the eradication campaign, for peace of mind of the Island residents, consideration could be given to a program of strategic testing of tank water

- It would be prudent to advise those individuals involved with the control of non-native duck populations that they should not consume duck during the eradication program, and not the liver for perhaps a year after the program has ceased

- If the program goes ahead, during the operation the Public Health Unit will be available for health advice if required.

I advise that the Public Health Unit is able to provide comment on any intended strategic sampling program for the tank water and would be pleased to provide comment on the health component of the education program for the residents.

Yours sincerely

Professor Mark J Ferson MPH MD FRACP FAFPHM
Director & Medical Officer of Health

Government of South Australia
SA Health

COPY

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Threatened Fauna Ecology
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Locked Bag 914
COFFS HARBOUR NSW 2450

Dear Dr ~~Wilkinson~~ Ian

Re: The Draft Lord Howe Island Rodent Eradication Plan

You emailed Dr Lewis, while I was on annual leave, the draft *Lord Howe Island Rodent Eradication Plan* (the Plan) and a toxicology health risk assessment of the plan carried out by *Toxikos Consultants* (Toxikos), and you asked that the South Australian Department of Health review these documents. This we have done.

The draft plan indicates that there will be an intentional exposure of the environment to brodifacoum by distributing 42,000 kg of edible bait containing 840,000 mg of brodifacoum as a 0.002% pellet (20 mg/kg active ingredient) as *PestOff Rodent Bait 20R* (Animal Control Products Ltd) at a rate of 20,000 g per hectare (or 2 g bait/m^2 equating to 4 µg of active ingredient/m^2) by hand or mechanical or aerial broadcasting over a total of 2100 ha. These criteria are modified by various factors including a 50% higher rate when applied by air in certain circumstances (pg 27), with at least one large bait every 2 square metres but at least one small bait every half square metre in the 'settlement area' (pg 28), and the use of bait trays. Toxikos advises that each bait pellet contains 10 or 40 µg of brodifacoum. A map of the various broadcast methods and likely density would have better illustrated the Plan especially in relation to domestic dwellings, and where children are likely to frequent.

We agree that there is a potential risk for humans being exposed to the chemical. This Toxikos has summarised well. We also agree with the assessment that the most likely route of exposure is direct oral ingestion of the bait by children. Indirect exposure via the poison partitioned into liver of animals etc was rightfully included. The plan includes mitigation strategies to deal with this and other exposure pathways.

As with any risk management prevention of exposure is the best course of action. Within the hierarchy of controls for risk management the Plan considers *elimination* and concludes that a chemical method is the most appropriate. We make no comment on this. *Substitution* of the long acting highly lipophilic and therapeutically active brodifacoum with another less toxic, perhaps shorter acting poison, could be considered. Notwithstanding, the risk controls are likely to be similar. The following text assumes *fait acompli* and hence an *engineered solution* is required.

In this case, eliminating or reducing the risk that children: (1) are able to gather sufficient baits and (2) have a desire to consume them appears to be the best solution. There are a number of drivers that can increase the likelihood of a child gathering and consuming baits. Of concern is the lack of data on how palatable and attractable the pellets are to children. The palatability in some cases can be directly proportional to the risk of consumption. The pellets are manufactured from a cereal based flour and coloured green. The binders are unknown, but any binder or other excipient that sweetens the pellet is likely to increase the

probability of consumption, especially repeat consumption. The green colour is unlikely to be a deterrent and indeed it may be an attractant.

Recommendation: Ensure pellets are not likely to be attractive for consumption, especially multiple doses, due their taste or colour.

Of concern is a lack of bittering agent (taste deterrent) irrespective of whether the pellets are palatable. The presence of a taste deterrent should increase the chance of a child spitting out pellets and not ingesting them (*European Commission 2009 report p25)* or would perhaps limit repeated episodes of ingestion.

Recommendation: Give consideration to rendering the pellets unattractive to consumption by adding a bittering agent.

The number of doses a child may consume is proportional to the child's gathering ability. The further apart the baits the lower the chance a child of consuming multiple pellets. The report gives no indication on the success of otherwise of the various broadcast methods in uniformly distributing the baits. It is apparent that "lumps" of pellets, where more than one pellet is placed in close proximity to another, will elevate the risk markedly. These data are essential to inform the broadcast methods and ensure that they place the nominated concentration of pellets per unit area of soil.

Recommendation: the broadcast methods are evaluated and appropriately modified to ensure that multiple pellets are not placed within close proximity to each other (this risk is missing from "poor aerial bating application") in the risk – mitigation matrix.

The toxicological outcome of brodifacoum is well defined and described by Toxikos. However, there are sensitive subpopulations for which exposure has a higher risk of morbidity. These individuals are most likely easily identifiable which will allow greater precautions to be applied either by care givers or authorities laying the baits.

Recommended: That consideration is given to preparing a specific risk management plan for the highly sensitive subpopulation or at least identifying whether such a sub-population exits. These may include those with coagulopathies (whether genetic, drug induced or some other reason) and those with potential vitamin k deficiencies such as children with cystic fibrosis etc.

There was some concern that the Plan implies that because the chemical is sold as baits for domestic purposes, from which few poisonings are recorded, the risk of exposure on Lord Howe Island from this proposal is low. The deliberate mass distribution of 42,000 kg of bait over a wide area cannot be compared with the use of baits in the domestic situation. Therefore, the risks created by the proposal need to be managed, not ignored. Furthermore, historic use of such baits (pg 80), although it may create familiarity among adults (who may or may not respond appropriately) does not impinge the child – whether or not such baits have been used in the past does not alter the risk to children in any way, for a child does not learn from such events, unless perhaps they are actually involved.

Recommendation: That the information packages do not under estimate the familiarity of the use of brodifacoum containing baits, and that their effectiveness in communicating the essential information is tested before utilising.

The calculation of the risk that exposure may occur cannot be drawn from the fact that the product is sold in various jurisdictions (page 79). The distribution and exposure pathways are too different in this proposal to allow a sensible comparison. However, knowledge that exposure is measurable and can usually be successfully managed, especially if treated early, is comforting. The literature has many case reports on this topic.

In terms of the risk management of the project, prevention of exposure is the key. Whether a 30 m buffer zone around dwellings is suitable (pg 27) needs to be assessed on a case by

case basis. I am not confident that a helicopter will accurately disperse pellets boarded by a 30 m buffer zone, and there is an issue of overlap increasing the density of the pellets. There also is no mention of avoidance of children's play areas, walkways or road-side verges frequented by children or areas where children play or congregate.

Recommendation: The plan elaborates on means by which land which is frequented or may be frequented by children is not contaminated with baits.

The numeration of the residual risk is problematic. The best data would be from human studies that measure dose against, say, change in prothrombin time. However, these data seem to be absent or too uncertain to be useful (such as data from poisoning cases). Therefore, the numeration of the lowest dose that would cause an effect needs to be extrapolated from animal data. For anticoagulants it is more useful to use the anticoagulant effect rather than death as the endpoint. This is because death is a manifestation of a range of physiological failures and not the primary response to the brodifacoum. Toxikos used the effects on the prothrombin complex, but quoted data from the European Commission 2005 report – a more recent 2009 report exists.

Recommendation: It is suggested that perhaps Toxikos re-examines its recommendations in light of the European Commission 2009 report.

What is interesting is that Toxikos did not apply an "uncertainty factor" but rather used the actual No Effect Level (NOEL) of the rat to derive the dose that may produce an effect. This inherently limits the usefulness of the derived value (page 29 & 30 Toxikos).

The literature indicates that there is a difference in responses (LD50) between sexes of a species, within a species, and between species, and most likely between laboratories. For instance pigs may be more sensitive than rats based on LD50. One then can presume that the underlying physiological response may be somewhat variable as well. Hence there is always some uncertainty as to the actual dose that may cause an effect in a generic animal and furthermore, given the range of values, it is likely the human will respond differently from some animals. These uncertainties are usually accounted for by dividing the lowest observable effect level (LOEL) or NOEL by some factor that ensures the criteria value will fall within a 'safe' range for humans. This the European Commission 2009 did in their deliberations.

Toxikos pointed out that the therapeutic index is very small – that is, the difference between the dose that causes an effect and the dose that causes death is small. Therefore other end-points may be more pertinent (although I would argue the PT is the most fundamental). The European Union "Directive 98/8/EC" for brodifacoum (2009) utilized a different endpoint. This organisation suggested that the effect of brodifacoum found in a study examining whether the chemical caused teratogenic effects was more appropriate. In this study the mothers suffered effects from which the lowest observable effect was found to be 0.001 mg/kg, somewhat lower than the 0.15 (acute) or 0.005 (chronic) mg/kg bw /day used by Toxikos. Although the effect was from pregnant females, who may not behave the same as children, the effect warrants consideration. Using the EU 2009 figure and not applying a safety margin and using the same method as Toxikos (page 29) the maximum number of pellets a child could consume without an effect is less than two pellets based on:

(0.001 mg/kg bw x 13.2 kg)/0.01 mg brodifacoum per pellet = 1.3 pellets.

These data indicate there is some uncertainty in calculating a "safe" level for the consumption of these pellets.

Toxikos rightly indicates that a chronic dosing regime may be appropriate (pg 30) hence uses a 42 day no effect level on prothrombin time from a rat study, also without a safely margin, to arrive at a maximum dose of 0.005 mg/kg bw/day or about 6-7 pellets per day.

The assumption the Plan seems to take is that the child is unlikely to dose multiple times. This needs better argument: to my mind it is plausible unless the pellets are extremely hard to forage, or unpalatable, or distasteful (the emerald green colouring may not be a detractive). For instance, the foraging of pellets from a bait tray is a real and measurable risk. Such risks need numeration. Of note is the fact that water soluble dyes in some cases can colour the urine – this may be an avenue of surveillance for care-givers.

Recommendation: The risk from consuming pellets multiple times is assessed and numerated, if possible, to ensure that mitigation strategies can be built into the plan if needed. And in particular of a child consuming brodifacoum from single or multiple bait trays or due to pellets being poorly spread.

On purely clinical basis, the 2 mg dose that Toxikos derived from acute (NOEL) appears to be somewhat high. Warfarin is purported to be less pharmacologically active than brodifacoum (eg Gill JE, Redfern R, 1883, J Hyg 91(2), 351). To achieve anti-coagulation in a human a "loading" dose is usually given (5-10 mg in an adult or 0.2 µg/kg/day in a child) followed by 2-10 mg/day in an adult or 0.1- 0.4 mg/kg/day for a child (eg *Martindale, The Complete Drug Reference*, or *Australian Therapeutic Guidelines: Cardiovascular* 2008). These doses, albeit for warfarin, appear to be very close to the calculated maximum allowable dose for a child with brodifacoum. The mitigating factor is the very long half-life of brodifacoum and the need for chronic dosing.

Recommendation: It may be prudent to ensure Toxikos is comfortable with the value they derived, given no safety margin has been allowed for, and that fact that rats may be somewhat different from humans, with pigs perhaps more sensitive (their LD50 was reported to be less than rats in a study) and in light of the EU 2009 report.

The toxicology of the dye in the pellet is not discussed, but was raised with you by phone. I understand that Tokicos has considered its toxicity.

Recommendation: The Plan mentions the dye and the out-come of Toxikos's deliberations as to its risk as a toxicant.

In terms of the Plan itself:

The Plan unfortunately simplifies the treatment of an exposure to brodifacoum; treatment can be considered relatively simple provided no sequelae to the exposure occurs. The Plan also makes no assessment on the ability to actually assess and treat paediatric or adult patients. Other factors such as the ability to measure the INR, which is a prerequisite in management of vitamin k antagonist ingestions, need consideration.

Recommended: if not already performed, a management plan for the accidental exposure to brodifacoum needs to be considered, especially for the paediatric patient.

The Plan erroneously states that warfarin is less toxic than brodifacoum (pg 12): it is not (as pg 21 indicates). In the illustrated case (pg 12) the controlling factor is dose (as concentration) not toxicity. On page 31 (6.1 Human Health) the Plan incorrectly states that "Brodifacoum at the low concentrations specified for this operation is of low toxicity to humans...." This statement is misleading; caregivers reading this may reasonably and incorrectly assume that low levels of vigilance are required when supervising young children during the baiting program; dose matters more. The statement also contradicts the logic of statements that follow on page 31 indicating that parents will need to be 'vigilant'.

The Plan uses the term 'small children': it is presumed that 'young' children is the subject of observation in these cases.

It appears that the Plan does not account of differences in the community in terms of parenting skill nor capacity of parents to adequately prevent children from engaging in behaviours that may increase the risk of ingesting baits; some parents may be sight impaired,

intellectually disabled or infirmed or otherwise unable to provide the necessary level of supervision. Developing a means for providing assistance for such parents needs to be considered.

Recommended: if not already performed, a management plan for providing assistance to parents with additional needs and challenges to be considered.

I hope this has been of use. Should you require further discussion please don't hesitate in calling me (08 8226 7100 or email david.simon@health.sa.gov). I also acknowledge the help of my toxicology section for providing useful and critical advice.

Yours sincerely

David Simon

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19/11/2010

\Letter eA482376 NSW gov re Lord Howe Island rodent eradication plane with brodifacoum - LETTER.doc

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Toxikos response to SA Health comments on the Human Health Risk Assessment for Rodent Eradication on LHI

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Toxikos document: TR020311-RF2
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Toxicologist and Health Risk Assessor

1. Risk assessment methodology

SA Health indicates the quantitation of the risks from exposure to brodifacoum is difficult due to imprecise determination of critical doses for adverse effects in humans. Toxikos agrees with this, it is however no different from many other chemicals to which humans are exposed. In these circumstances it is usual to use information for the most sensitive effect observed in experimental animals which have been given defined doses of the chemical. In agreement with the Lord Howe Island (LHI) risk assessment, SA Health notes the anticoagulant effect, rather than death, is the more useful and appropriate end point to use in the risk assessment. This is because anticoagulation is the primary response to brodifacoum, uncontrolled bleeding and subsequent death are consequences of anticoagulation. There are no other effects that occur from exposure or poisoning with brodifacoum. An effective measure of anticoagulation is prolongation of prothrombin time (PT). In the LHI risk assessment Toxikos used experimental doses in rats that have no-effect on PT (i.e. no observed effect levels, NOELs) for comparison with conservative estimations of human exposure on the Island should the rodent eradication plan for LHI proceed.

SA Heath comment Toxikos did not apply uncertainty factors to the NOEL and hence the "*usefulness of the derived value"* is limited. It is apparent that SA Health have expected, or interpreted the risk assessment to have been undertaken using a toxicity reference value (TRV) that reflects an acceptable or safe dose. This was purposefully not done due to the difficulty in applying a TRV across different exposure pathways, particularly the direct ingestion of pesticide pellets where an estimated reliable exposure dose cannot be calculated for comparison with the TRV (see below for more comments on this exposure pathway). In addition the endpoint of interest used in the risk assessment is a biochemical response rather than a toxicological outcome, such as bleeding, which is usually used in setting a TRV. The biochemical action is however a necessary event for toxicity to occur.

Although it is not explicitly stated in the risk assessment Toxikos utilized the margin of exposure (MOE) method for characterizing risk from exposure to brodifacoum. In this technique an estimation of dose is compared with the appropriate NOEL, i.e. the highest dose that has no effect on the endpoint of interest. It is worth noting Toxikos has not "*derived"* a value for characterizing the risk. The NOEL used in this method is the unmodified value directly taken from experimental data with no uncertainty (safety) factors applied. This is a well recognized option, recommended by the World Health Organization (WHO 2005, 2008), the International Life Sciences Institute (ILSI 2008) and used by WHO bodies (e.g. JECFA 2005) and Australian authorities (e.g. NICNAS 2007, 2010a, 2010b), for characterizing public health risk from exposure to chemicals.

The larger the MOE the lower is the health risk; the rule of thumb is MOEs>100 are generally regarded as indicative of low health risks. In the risk assessment the calculated MOEs were not specifically described as margins of exposure; they were presented as the number of fold the estimated exposure was less than the NOEL. On reflection Toxikos acknowledges it could have been made more explicit what method of risk characterization was being applied. However there was a desire to limit the extent of technical jargon in the risk assessment. The lack of categorical reference to MOE terminology does not detract from, or compromise the LHI risk assessment.

The table below shows the MOEs calculated in the LHI the risk assessment. It should be noted MOEs were not calculated for direct ingestion of bait because the potential dose is not easily enumerated as it is patently dependent upon the behaviour of the child. This is discussed later in this document.

Ingestion of potentially contaminated soil	12,500
Dermal exposure after handling bait	500,000
Ingestion of tank water contaminated by bird droppings	6,250
Consumption of fish	6,250
Dust inhalation	5,000,000

The MOE method for risk characterization is more transparent than comparing exposure estimations with a TRV because the uncertainty factors embedded within a generic TRV, and hidden during risk characterization using the TRV, are not part of the situation specific assessment. While there are broad international guidelines on how to choose the size of the uncertainty factors, in actuality they are markedly influenced by the science policy and regulatory risk assessment framework of an authority, level of concern for the health endpoints, study interpretation, agency expertise, extent and product use patterns in the country, and exposure circumstances. Thus different authorities may develop different TRVs for a substance even though they are using the same study upon to which to base the TRV derivation. The MOE avoids these issues and allows the risk manager to choose the margin of safety to fit the situation circumstances before concern and/or management action is required.

2. The no observed effect level (NOEL)

Toxikos has used three NOELs in characterizing the human risk from ingestion of brodifacoum depending on the length of time it is assumed the pellets may be available for consumption after they have been broadcast on the island. These are:

- 0.15 mg/kg body weight for a single episode of eating bait,
- 0.005 mg/kg/d assuming bait is eaten every day for 42 days, and
- 0.001 mg/kg/d if bait is eaten every day for 90 days.

The NOELs used by Toxikos are consistent across a number of studies. A brief description is below.

Pelfrene (1991) reported a 42 day rat feeding study in which there were no adverse effects at 0.005 mg/kg/d. However the details of the study were not provided. The European Commission (2005a, b, c) describe an unpublished confidential 90 day feed study in rats which included an interim assessment of haematology parameters; the NOEL after 45 days was 0.004 mg/kg/d and at the end of 90 days was 0.001 mg/kg/d. The same description of the study is provided in 2009 (EC 2009) as is in EC (2005a, b). Another proprietary repeat dose study (Hodge et al. 1980), in fact a study designed to investigate developmental effects in the foetus, is described by US EPA (1998). Groups of 10 pregnant rats were administered brodifacoum dissolved in ethanol/water at 0.001, 0.01 or 0.02 mg/kg/d by gavage on days 6 – 15 of gestation (i.e. 10 days exposure); the NOEL for equivocal haemorrhagic effects was judged to be 0.001 mg/kg/d (US EPA 1998). This study is described in more detail below as it the one used by EC (2009) for setting a TRV which SA Health suggested might be used for the LHI risk assessment.

Thus two studies indicate a NOEL of 0.005 (0.004) mg/kg/d) after 42 (45) days of daily exposure. A traditional 90 day feed study gave a NOEL of 0.001 mg/kg/d). Although the 10 day gavage rat developmental study of Hodge et al. (1980) also produced a NOEL of 0.001 mg/kg/d, as discussed below the effect was marginal (US EPA 1998) and may have been affected by the physiological changes that occur in gravid animals.

After reviewing the information from the European Commission (EC 2009) the NOELs used by Toxikos remain the most appropriate for determining the MOE after 45 or 90 days of potential exposure to brodifacoum on LHI.

3. The European Commission assessment (EC 2009)

SA Health have pointed out that Toxikos has partly relied upon an European Commission review of brodifacoum that was conducted in 2005 (EC 2005 a, b, c), they have suggested the evaluation undertaken in 2009 by the Commission (EC 2009) is more appropriate as in the latter a toxicity reference value (TRV) has been derived that perhaps should be used in the risk assessment. As described above the methodology applied by Toxikos did not use TRVs, and we consider the TRV from EC (2009) to be inappropriate for the risk assessment.

With regard to toxicological information and description of studies, the EC (2009) review does not contain any additional information than is in EC (2005). The European Commission (EC 2009) established an "*acute*" TRV from the rat developmental study of Hodge et al. (1980). SA health acknowledged the effect was from pregnant females who may not behave the same as children but nonetheless suggested the effects warranted consideration. It is well known a number of physiological changes occur during pregnancy that can affect the absorption, metabolism and distribution of drugs. Toxikos' consideration follows.

EC (2009) does not describe any of the experimental details of the Hodge et al. (1980) study, not even the dose levels used, not the mode of administration, not the evaluation techniques, or findings at each dose level. Reported in EC (2009) is a single sentence in which it is stated maternal haemorrhages at doses >0.01 mg/kg (NOEL 0.001 mg/kg) occurred and that there were no effects on the foetus at any dose.

Note this is a repeat dose study and the dose should be described as mg/kg/d as is convention and in US EPA (1998). For a more comprehensive description of the Hodge et al. (1980) study one must go to US EPA (1998). The dose details are as described in Section 2 above, but it should be appreciated the dosing method was bolus gavage of dissolved brodifacoum directly into the rat forestomach which is different from the mode of administration (dietary) in the rat 90 day study. Quite apart from the animals being pregnant, compared with dietary administration, gavage studies often yield different results for acutely toxic substances due to faster absorption of the bolus dose causing a blood-time curve with a sharper peak. The brodifacoum to be used on LHI is mixed with a cereal base to form pellets and potential exposure from direct ingestion of pellets is more similar to the exposure in the rat feed studies than to a bolus dose in ethanol/water.

SA Health suggests that the European Commission (EC 2009) in setting their TRV have used a "*different*" end point that is more appropriate than the one used by Toxikos. In fact both have used haematological events that are related; the EC (2009) bleeding and Toxikos prolongation of PT.

The endpoint used for determining the maternal NOEL in the developmental rat study of Hodge et al. (1980) was blood in the uteri observed when the animals were sacrificed at the end of the gestation period (day 21). The incidence was 0.001 mg/kg/d (0%), 0.01 mg/kg/d (1%) and at 0.02 mg/kg/d (30%). At the mid dose the US EPA (1998) considered the effect equivocal, but for conservatism and because the observation was possibly related to brodifacoum administration (and consistent with the mode of action) considered the NOEL was 0.001 mg/kg/d. It should be noted there is a 10x difference between the NOEL (0.001 mg/kg/d) and the next dose (0.01 mg/kg/d) in which the response was equivocal, but just a 2x dose difference between the mid dose and the top dose (0.02 mg/kg/d) in which the effect was unambiguous. The large dose difference between the low and mid dose strongly suggests the 'true' NOEL in this study is somewhat higher than the experimental dose of 0.001 mg/kg/d.

EC (2009) applied a composite 300 fold safety factor to the rat maternal NOEL to establish the TRV (10x interspecies, 10x intraspecies differences and 3x for concern for suspected developmental effects). In fact EC (2009) states "*no significant effects on litters were observed*", US EPA (1998) states "*there were no indications of any dose related developmental effects".* Similarly a rabbit study was negative for developmental effects (EC 2005 b, 2009, US EPA 1998). There is also no indication of adverse effects on the human foetus after exposure to high intake of brodifacoum such as after suicide attempts (e.g. Zurawski and Kelly 1997). It is therefore odd that EC (2009) have used an additional safety factor of 3x for developmental effects when the available data for brodifacoum indicates it does not cause this effect. The perceived concern, contrary to experimental evidence, arises by analogy with warfarin which is known to induce a range of developmental outcomes which are unlikely to be due to its anticoagulant effects as a rodenticide. Warfarin and brodifacoum are different molecules. It should also be noted the brodifacoum concern regarding developmental effects is a provisional decision in EC (2009). It is doubtful whether authorities in the US or Australia would establish an 'acute' TRV in this manner. A TRV based on the maternal effects in a rat developmental study would more likely be established with a safety (uncertainty) factor of 100 (see the discussion on MOE above).

SA Health intimates the EC (2009) evaluation is more up to date and therefore greater weight should be given to it rather than the EC (2005) evaluation. While it is certainly more recent it does not invalidate or replace the information in EC (2005). Indeed the EC (2009) document contains far fewer study details than EC (2005) or US EPA (1998). Frustratingly EC (2009) does not even identify the studies from which it cites information. After carefully considering the information in EC (2009), it is Toxikos' conclusion the EC (2009) evaluation does not improve or overturn the methodology, or alter the outcome of the risk assessment for LHI.

4. Species differences

Based on differences in LD_{50} values cited in the LHI risk assessment SA Health argues the underlying physiological response between species may be somewhat variable and it is likely humans will respond differently from animals. This is the basis for SA Health to suggest uncertainty factors should have been applied to the NOEL in order that exposures could be compared to a 'safe' dose. If the risk assessment had been performed using a "*criteria*" value Toxikos agrees with SA Health that uncertainty factors applied to the toxicological NOEL should be sufficient to ensure the "*criteria value"* (TRV) would fall within a safe range for humans. As described above this was not the method used to characterise the risk of brodifacoum exposure at LHI and it is not necessary that it be used.

Toxikos has used doses in the rat that do not prolong PT as the NOELs to calculate margins of safety. The risk manager can decide what MOE should generate concern, i.e. in effect determine a safety margin with which they are comfortable. The underlying question from SA Health is whether the rat is the most sensitive species from which to obtain the NOEL used in the calculations. The literature searches undertaken by Toxikos indicate investigation of brodifacoum induced changes in PT have not been conducted for a wide range of species. However all species have the same effect of death if uncontrolled bleeding occurs. Since this occurs by the same mode of action in all species (i.e. inhibition of coagulation as measured by PT) the LD_{50} provides a means to judge the relative sensitivity of different species to the anticoagulant effects of brodifacoum.

In the LHI risk assessment information on LD_{50} was obtained from reviews, the specific study from which the data was reported was not sought. For non-ruminant mammals the single dose LD_{50}'s were:

- Overall in rats from four reviews 0.27 mg/kg.
- In dogs 0.25 – 1.0 (Pelfrene 1991) and 0.25 – 3.56 mg/kg (Eason and Ogilvie 2009).
- In guinea pig, mouse and rabbit 0.28 – 0.4 mg/kg (Pelfrene 1991).
- In pigs O'Brien and Lukins (1990) reported 0.52 mg/kg, but Eason and Ogilvie (2009) gave a value of 0.1 mg/kg.

Thus, apart from the information for pigs reported in Eason and Ogilvie (2009), the lowest LD_{50} was about the same for rat, dog, guinea pig and rabbit at approximately 0.25 mg/kg/d. It is therefore not unreasonable to assume that humans would also be similarly as sensitive to the effects of

brodifacoum. Indeed the World Health Organisation (IPCS 1995) estimated the average fatal dose for an adult (60 kg) to be approximately 15 mg brodifacoum (i.e. 0.25 mg/kg), or 300 g of 0.005% bait. Note in the LHI risk assessment Toxikos has also contextualised direct ingestion of brodifacoum relative to the amount of bait that would need to be consumed.

SA Health considered the 0.1 mg/kg LD_{50} data for pigs from Eason and Ogilvie (2009) indicated this species was more sensitive than others and hence it was likely humans may respond differently from other animals. Toxikos has sought to verify this LD_{50} data for pigs.

- Eason and Ogilvie (2009) cite two references as the source for the low LD_{50} value for pigs, Godfrey (1985) and Eason and Spur (1995). Both these papers are not the original source of the data.
- Eason and Spur (1995) cite Godfrey (1994), which is a study in wallabies, and Godfrey (1985).
- Thus it would appear that Godfrey (1985) is the primary source of the 0.1 mg/kg LD_{50} for pigs reported by Eason and Ogilvie (2009). However this paper is also not the original source of the data, it nevertheless cites the LD_{50} as 10 mg/kg raising the possibility that perhaps Eason and Spur (1995) have misquoted the value in their review.
- Godfrey (1985) cites four papers as the source of the 10 mg/kg LD_{50} in pigs.
    - Bull (1976), a review that does not mention brodifacoum.
    - Duback (1979), the proceedings of a scientific conference that were not available to Toxikos in the time available for this response.
    - Godfrey (1981a), publication not available but from the title is a study in rabbits.
    - Godfrey (1981b), publication not available but from the title is a study in dogs.

It is Toxikos' conclusion that the concern regarding demonstrable species differences in response to brodifacoum based on the lethality data for pigs cannot be sustained, and that the assumption by Toxikos that humans are likely to be as equally sensitive as rats is valid, indeed it is same assumption as that made by the World Health Organization.

5. Clinical considerations of anticoagulant therapy

SA Health have suggested "*the 2 mg dose Toxikos derived from acute (NOEL) appears somewhat high"* and have cited clinical loading doses for children of warfarin are about 0.2 µg/kg/d (this is a typographical error by SA Health and 0.2 mg/kg/d is meant) and maintenance doses are 0.1 – 0.4 mg/kg/d. Toxikos presumes the reference to a 2 mg dose refers to calculations in the risk

assessment pertaining to an acute, single ingestion of rat bait. The acute (single dose NOEL) is 0.15 mg/kg, thus for a 13.2 kg child consumption of 1.98 mg of brodifacoum would equate to the NOEL. This is approximately 200 pellets or about 100 g.

We consider the analogy with warfarin loading doses is not appropriate because it occurs over a number of days and is followed by a lower maintenance dose regime, whereas the scenario in the risk assessment commented upon by SA Health is for a single ingestion. Nevertheless comments are provided below.

Achieving the desired level of anticoagulant therapy in patients with warfarin is not straight forward; there have been many algorithms for warfarin loading and determination of maintenance doses (e.g. Desai and Farrington 2000, Bauman et al. 2006, Heneghan et al. 2010). The loading dose of warfarin to children is 0.2 – 0.5 mg/kg/d for 2 – 4 days (maximum 10 mg/d for any given individual), over this period the loading doses are adjusted to achieve the desired target level of anticoagulation as judged by INR (International Normalised Ratio)[1] measurements for the PT measurement technique being used. Maintenance doses of warfarin, usually 0.1 – 0.4 mg/kg/d, are aimed at keeping the INR within the target range for the condition for which anticoagulant therapy is being undertaken. For such repeat dose exposure the risk assessment for LHI has used a NOEL of 0.005 mg/kg/d to characterise the risk from ingesting brodifacoum rather than the single dose NOEL of 0.15 mg/kg.

The acute, single dose brodifacoum response for prolonged PT in rats is no effect at 0.15 mg/kg/d, 0.2 mg/kg reduced activity to 7% of normal values, and 0.33 mg/kg to 4% of normal (Pelfrene 1991). Given that warfarin loading doses occur over 2 – 4 days and are followed by maintenance doses to achieve the desired level of anticoagulation (note, not bleeding), the brodifacoum dose response in rats is consistent with the clinical anticoagulant objective in humans and the repeat dose NOEL's of 0.005 mg/kg/d and 0.001 mg/kg/d used in the risk characterisation for LHI.

In making its comments SA Health expressed concern that warfarin is less pharmacologically active than brodifacoum, this was probably why the issue of the warfarin loading dose was raised. With equivalent doses, more brodifacoum is found in the target tissue (the liver) and for longer than with warfarin. This is because brodifacoum is more lipid soluble and its metabolism much slower.

[1] Prothombin time is determined by adding a standardised thromboplastin reagent (phospholipid and tissue factor) to the patient's citrated whole blood. Citrate removes calcium from the blood to prevent clotting. When excess calcium is added after the reagent the blood begins to clot and the time taken recorded. It ios common to relate the patients clotting time to that of a control (i.e. 'normal clotting'). However the ratio of patient to control is influenced by both the laboratory method and the source of the thromboplastin reagent. To allow cross laboratory and international comparisons the PT results are standardised according to the reactivity of the particular thromboplastin preparation, the results is expressed as the INR.

These are the major reasons why brodifacoum is more effective than warfarin as a rodenticide, although different binding to serum albumin affecting the free fraction of the compounds may also play a role. The suggestion that brodifacoum is more pharmacologically active than warfarin is really a question of whether brodifacoum is a more potent inhibitor (i.e. has a lower inhibition constant, Ki) of vitamin K epoxide reductase (VKOR), however Toxikos has been unable to locate information to address the relative specific activities of brodifacoum and warfarin towards VKOR.

SA Health cites Gill and Redfern (1983) to support greater pharmacological action of brodifacoum compared to warfarin. This is an *ad libitum* feeding study in *Meriones shawi* (Shaw's gerbil) that incorporates all the differences in rodenticide metabolism and disposition that contribute to the greater field effectiveness of brodifacoum over warfarin as a rodenticide, it does not address the innate pharmacodynamic properties of the two compounds. In this paper the basic measure of rodenticide effectiveness was the number of feeding days required to cause mortality. We also note the test species is somewhat unusual and that the study was undertaken to find an effective control for gerbil population outbreaks in North West Africa.

Regarding the clinical outcome of single unintentional ingestion of brodifacoum rat bait, Su and Hoffman (2006) describe a compilation of 145 paediatric cases. Prolongation of INR occurred in only 8 (5.2%) and only one was reported to have abnormal prolonged bleeding but this did not require medical intervention. Su and Hoffman (2006) stress the majority of patients (usually children) are entirely asymptomatic and have normal coagulation profile after unintentional exposure. Knowing clinical effects are rare they point out most clinicians endorse supportive care without PT measurements, they however recommend unintentional exposure should be considered a potentially significant exposure and prothrombin time monitored daily for at least 2 days.

The situation regarding multiple exposures is different; Su and Hoffman (2006) indicate clinically significant anticoagulation can occur in children following small repeated ingestions of bait. This is recognised in the risk assessment, and is the reason why, for any exposure other than a single ingestion, the 42 day NOEL of 0.005 mg/kg/d was used to characterise the risk of potential prolongation of PT (note not necessarily cause bleeding). The amount of bait that needs to be ingested daily over this time to meet or exceed the NOEL is relatively small, just 6 -7 pellets. The risk assessment for LHI rodent eradication and SA Health highlight this potential. Furthermore SA Health and the LHI eradication plan both discuss mitigation strategies. Related discussion is in the next section.

6. Direct ingestion of rodent bait

SA Health rightly direct attention to the potential risk associated with multiple ingestion of rodent bait pellets. This is consistent with the deliberations in the LHI risk assessment. Due to the uncertainty in predicting how many pellets a child may pick up and consume per day at no time has Toxikos suggested there is a 'safe' number that can be consumed. What the risk assessment attempts to provide to the risk manager is contextual information relative to the dose that needs to be ingested for the NOEL to be exceeded. For a single ingestion episode quite a large number of pellets need to be eaten, if the pellets are eaten on a daily basis a much smaller number of pellets are required to reach and possibly exceed the NOEL for prolonged PT. The LOEL that Toxikos has used for these considerations has been chosen after deliberation of the bait's environmental degradation and the ability of children to pick it up as a pellet to eat, this is less than 4 – 5 weeks, therefore the 45 day NOEL of 0.005 mg/kg/d was used and not a NOEL of 0.001 mg/kg/d, sourced either from the 90 day rat feed study or the Hodge et al. (1983) gavage developmental study, as suggested by SA Health.

SA Health are concerned that the bait may be attractive to children and that the target distribution may not be achieved, perhaps there will be a greater density of pellets on the ground and a child will more easily be able to gather them. An increased amount of pellets on the ground is contrary to the operational information in the LHI rodent eradication plan that Toxikos has assumed will be able to be met. SA Health has appropriately indicated the risks will increase if what is said to occur in the plan does not occur. Toxikos agrees with this, but in conducting a risk assessment for a proposed activity one has to assume the activity will be carried out as described.

It is simply not possible to achieve the outcome of ridding LHI of rats and mice and at the same time guarantee it will be risk free to residents. The plan has a number of operational mitigation strategies. If the broadcasting of pellets is undertaken as described in the plan Toxikos considers it unlikely, but nonetheless feasible, that a child may ingest pellets on multiple days during the 45 days that pellets may be able to be picked up and swallowed. Therefore the risk assessment indicates the key to ensuring small children are not exposed is educating children and parents about the bait, and close vigilance by parents during the eradication campaign. If the education/communication is not robustly conducted then its ability to mitigate the risk from incidental direct ingestion of bait by young children may be compromised. In this Toxikos and SA Heath are in broad agreement.

Taking into consideration the operational aspects of the LHI eradication plan (assuming these are achieved), the stability of the bait, the fact that the vast majority of cases of accidental ingestion of brodifacoum do not require medical intervention, signs and symptoms of poisoning occur before serious outcome is imminent, and the availability of very effective antidote and treatment, Toxikos has concluded the overall risk of health effects is low and negligible.

In retrospect perhaps a better description of the probability of health effects would be, the likelihood of health effects is low and of serious outcome negligible.

7. Summary response to SA Health recommendations

The following (in italics) are recommendations from the SA Health peer review that pertain to the conduct and outcome of the LHI health risk assessment.

- *It is suggested that perhaps Toxikos re-examines its recommendations in the light of the European Commission 2009 report.*

Toxikos has read and examined the European Commission 2009 report (EC 2009) in detail. The methodology used by Toxikos for characterising the risk is an approved international and national approach that is more appropriate for the circumstances of exposure at LHI than that undertaken by EC (2009). The margin of exposure (MOE) approach taken by Toxikos is transparent and allows greater appreciation of the risks than comparison with a toxicity reference value ('safe' dose) as suggested by SA Health. It is acknowledged it was not made explicit in the risk assessment that a MOE method was being used, the MOE being articulated as the number of times the estimated exposure from different potential exposure routes was less than the no effect level identified from experimental animal studies.

From the EC (2009) evaluation SA Health has raised a number of risk assessment aspects that have been examined by Toxikos. For each of these it has been found the information in the LHI risk assessment is appropriate and the outcomes and recommendations of the risk assessment have not been changed. The EC (2009) report, although more recent than the EC (2005) report referenced in the risk assessment, does not add to, or alter the information in the risk assessment.

- *The risk from consuming pellets multiple times is assessed and numerated, if possible, to ensure that mitigation strategies can be built into the plan if needed. And in particular of a child consuming brodifacoum from a single or multiple bait trays or due to pellets being poorly spread.*

The risk assessment has considered the potential health risks should pellets be consumed multiple times by a child. Assuming pellets may be eaten on a single occasion or consumed every day for 45 days, the risk has been contextualised and enumerated by estimation of the number of pellets required to be consumed to achieve the no effect dose. The actual number of pellets that could be eaten by a child, hopefully none if the information and education strategy of the eradication plan is effective, is not possible to enumerate since it is highly dependent upon the behaviour of the child. The risk assessment indicates only a small number of pellets (about 6 – 7) need to be eaten over multiple days before the no effect level for increasing prothrombin time is exceeded. With respect to targets of 'on-ground' bait density or the bait being poorly spread, Toxikos has assumed the operational aspects of the eradication plan are achieved. Thus the risk assessment reflects health risks according to the plan.

- *It may be prudent to ensure Toxikos is comfortable with the value they derived, given no safety margin has been allowed for, and that fact rats may be somewhat different from humans, with pigs perhaps more sensitive (their LD_{50} was reported to be less than rats in a study) and in the light of the EU 2009 report.*

Toxikos has investigated this recommendation in detail. The risk characterisation method used in the risk assessment does not require the use of a safety margin; an appropriate safety margin can be identified by the risk manager by choosing the margin of exposure above which health concern may be raised. Examination of the toxicological information has not identified data to suggest humans may be different from rats with respect to response to brodifacoum, on the contrary the information indicates there are no material differences between non-ruminant mammals. Scrutiny of the pig LD_{50} data has found the suggestion that pigs are more sensitive is not sustainable. As indicated above the EC (2009) report does not alter the information or outcome of the LHI risk assessment. Toxikos is comfortable with the risk assessment and its recommendations, detailed reasoning is found in the technical commentary accompanying this response to the SA Health recommendation.

- *The plan mentions the dye and the out-come of Toxikos's deliberations as to its risk as a toxicant.*

Toxikos has not investigated the toxicology of the dye used in the rodent bait pellets. It is identified as a food approved dye, and *inter alia* it has been assumed if safe for food use its toxicity is negligible, and health effects from the dye after pellet ingestion also negligible.

References

Pertaining to MOE:

ILSI (2008). Appication of the margin of exposure approach to compounds in food which are both genotoxic and carcinogenic. International Life Sciences Institute. http://www.ilsi.org/Publications/MOE%20WS%20Report.pdf.

JECFA (2005). Summary of evaluation performed by the Joint FAO/WHO Expert Committee on Food Additives: Acrylamide. Report TRS 930-JECFA 64/8. http://www.inchem.org/documents/jecfa/jeceval/jec_41.htm.

NICNAS (2007). Interim public health risk assessment of certain PBDE congeners. National Industrial Chemical Notificiation Assessment Scheme. http://www.nicnas.gov.au/publications/car/other/final%20interim%20report%20-%20march.pdf.

NICNAS (2010a). Priority Existing Chemical Assessment Report No. 32: diethylhexyl phthalate. National Industrial Chemical Notificiation Assessment Scheme. http://www.nicnas.gov.au/publications/car/PEC/PEC32/PEC_32_Full_Report_PDF.pdf.

NICNAS (2010b). Priority Existing Chemical Assessment Report No. 30: triclosan. National Industrial Chemical Notificiation Assessment Scheme. http://www.nicnas.gov.au/publications/car/PEC/PEC30/PEC_30_Full_Report_PDF.pdf.

WHO (2005). Harmonization Project Document No. 2: Chemical-specific adjustment factors for interspecies differences and human variability: guidance document for use of data in dose/concentration response assessment. World Health Organization (IPCS). http://www.inchem.org/documents/harmproj/harmproj/harmproj2.pdf.

WHO (2008). Harmonization Project Document No. 6: Part 1: Guidance document on characterising and communicating uncertainty in exposure assessment. World Health Organization (IPCS). http://www.who.int/ipcs/methods/harmonization/areas/uncertainty%20.pdf.

Pertaining to LD_{50}

Bull, J. O. (1976). Laboratory and field investigations with difenacoum, a promising new rodenticide. In Proceedings of the 7th Vertebrate Pest Conference, University of Nebraska, Lincoln. http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1004&context=vpc7.

Dubock, A. C. (1979). Alternative strategies for safety and efficacy of rodenticides. In Proceedings of the 5th British Pest Control Conference, Vol. 14, pp. 1-15, Stratford-upon-Avon.

Eason, C. T. and Ogilvie, S. (2009). A re-evaluation of potential rodenticides for aerial control of rodents. DOC Research and Development Series 312. Department of Conservation, Wellington, New Zealand.

Eason, C. T. and Spurr, E. B. (1995). Review of the toxicity and impacts of brodifacoum on non-target wildlife in New Zealand. New Zealand Journal of Zoology. 22 (4): 371 - 379.

Godfrey, M.E.R., Reid, T.C. and McAllum, H.J.F. (1981a). The oral toxicity of brodifacoum to rabbits. New Zealand Journal of Experimental Agriculture. 9: 23-25.

Godfrey, M.E.R., Reid,T.C. and McAllum, H.J.F. (1981b). The acute oral toxicity of the anticoagulant brodifacoum to dogs. New Zealand Journal of Experimental Agriculture. 9: 147-149.

Godfrey, M.E.R. (1984). Acute toxicity of brodifacoum to wallabies (Macropus rufogriseus). New Zealand Journal of Experimental Agriculture. 12: 63-64.

Godfrey, M.E.R. 1985. Non-target and secondary poisoning hazards of "second generation" anticoagulants. Acta Zool. Fennica 173:209-212.

O'Brien, P.H. and Lukins, B.S. (1990). Comparative dose-response relationships and acceptability of warfarin, brodifacoum and phosphorous to feral pigs. Australian Wildlife Research. 17: 101-112.

Other references

Bauman, M. and Massicotte, M.P. (2006). Chapter 31: Thromboembolic complications in children. I "Pediatric Hematology" 3rd Edition. Eds R,J, Arceci, I.M. Hann and O.P. Smith. Blackwell Publishing. Pp 672 – 686.

Desai, H. and Farrington, E. (2000). Anticoagulation with warfarin in pedictarics. Paediatric Nursing, March (http://findarticles.com/p/articles/mi_m0FSZ/is_2_26/ai_n18609982/?tag=content;col1)

EC (2005a). Competent Authority Report Brodifacoum (PT 14). Doc I.2, Overall Summary and Assessment for the Active Substance Brodifacoum. European Commission, September 2005.

EC (2005b). Competent Authority Report Brodifacoum (PT 14). Doc 1.3, Proposal for Decision Regarding Annex I Inclusion of the Active Substance Brodifacoum.

EC (2005c). Competent Authority Report Brodifacoum (PT 14). Doc 1.3, Document II-A. Effects Assessment for the Active Substance Brodifacoum, European Commission.

EC (2009). Directive 98/8/EC concerning the placing of biocidal products on the market. Inclusion of active substances in Annex I to Directive 98/8/EC. Assessment Report. Brodifacoum Product-type 14 (Rodenticide), 7 September 2009. Annex I – Italy.

Gill, J.E. and R. Redfern (1983). Laboratory tests of seven rodenticides for the control of *Meriones shawi*. J. Hyg., Camb. 91: 351-357.

Heneghan,C., Tyndel, S., Bankhead, C., Wan,Y., Keeling, D., Perera, R., and Ward, A. (2010). Optimal loading dose for the initiation of warfarin: a systematic review. BMC Cardiovascular Disorders 10:18 (doi:10.1186/1471-2261-10-18).

Hodge, M.C.E. et al. (1980). Brodifacoum: Teratogenicity Study in the Rat. ICI Central Toxicology Laboratory Report No: CTL/P/437. GLP, unpublished. (As described in US EPA 1998, also briefly described in EC 2009, but not in by Ec 2005a, b).

IPCS (1995). Brodifacoum. IPCS International Programme on Chemical Safety, Health and Safety Guide No. 93. United Nations Environment Programme, International Labour Organisation, World Health Organization, Geneva. http://www.inchem.org/documents/hsg/hsg/hsg093.htm

Pelfrene, A.F. (1991). Synthetic Organic Rodenticides; Chapter 19 in *Handbook of Pesticide Toxicology*, Editors W.J. Hayes and E.R.Laws, Academic Press. Pp 1271 – 1316.

Su, M. and Hoffman, R.S. (2006). Chapter 57: Anticoagulants. In "Goldfrank's Toxicologic Emergencies" 8th Edition. Eds Flomenbaum, Goldfrank, Hoffman, Howland, Lewin and Nelson. McGraw Hill Publishers. Pp 891 – 893

US EPA (1998). Reregistration Eligibility Decision (RED) Rodenticide Cluster. United States Environmental Protection Agency. EPA738-R-98-00.

Zurawski, J.M. and Kelly, E.A. (1997). Preganancy outcome after maternal poisoning with brodifacoum, a long acting warfarin-like rodenticide. Obstetrics and Gynaecology 90: 672 – 674.

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Report

REPORT

LORD HOWE ISLAND RODENT ERADICATION PROGRAM – RESPONSE TO LETTER

David Kelly - Lord Howe Island Board

Job No: 20113

5 March 2015

PROJECT TITLE:	Lord Howe Island Rodent Eradication Program – Response to Letter
JOB NUMBER:	20113
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1 EXECUTIVE SUMMARY

Pacific Environment – Toxikos has conducted a review of the 2010 Toxikos (Report TR010610-RF2 dated 15 September 2010) and considered the issues raised Mr Rathgeber in his letter to the Lord Howe Island Board. Although some errors were found in the original Toxikos report, they do not affect the overall findings that the proposed rodent eradication plan is appropriate and would not pose a risk to the health of the residents of Lord Howe Island.

Some of the issues raised by Mr Rathgeber, although relevant considerations, are in some cases based on a misunderstanding of the toxicological information and the application of workplace and environmental standards.

The findings of this review are that the proposed rodent eradication plan involving the use of brodicafoum will not pose a risk to the health of the residents of Lord Howe Island. The risk management processes included in the plan will mitigate any possible risks posed by the use of brodicafoum.

2 INTRODUCTION

The Lord Howe Island Board, has requested Pacific Environment – Toxikos to review the issues raised in a letter by Mr Rathgeber on the proposed use of Brodifacoum for pest eradication on Lord Howe Island. In 2010 Toxikos (Report TR010610-RF2 dated 15 September 2010) conducted a toxicological assessment on the use of brodifacoum for the eradication of rodents on Lord Howe Island and concluded that the proposed plan for the application of brodifacoum on Lord Howe Island would not pose a risk to the local human population. Mr Rathgeber questioned some of the findings of the Toxikos report and raised concerns about the potential health effects that the use of brodifacoum may have on the health of the Lord Howe Island residents. He has asked that the eradication program be put aside.

Pacific Environment – Toxikos has reviewed the original Toxikos report and the issues raised by Mr Rathgeber and the findings are presented in Section 3 of this report. It should be noted that the people that have undertaken this current review were not involved in the preparation of the original Toxikos report and the findings can be considered as independent.

3 RESPONSE

3.1 Review of the 2010 Toxikos report

Format: The 60 page report presents a conventional screening human health risk assessment which discusses the usual steps of issue identification, hazard identification and dose response leading to hazard characterization, exposure assessment and finally risk characterization. References are provided, all calculations are shown in full and all assumptions are transparently discussed and of a conservative nature. A formal sensitivity analysis is not provided presumably because the calculated Margins of Exposure between likely exposure levels and harmful exposure levels were so large.

Comment - This is an appropriate approach to the brief given to Toxikos.

Issue identification: as stated by Toxikos, the Health Risk Assessment (HRA) only deals with public health risks and theoretical pathways for human exposure to Brodifacoum during the eradication program and does not address OHS issues nor risk to non-target species. Throughout the report the 2-year old child is considered to be the most sensitive receptor.

Comment - This is an appropriate approach to the brief given to Toxikos.

Hazard identification: The Toxikos report presents a summary of the Physical and chemical properties (Sect. 2.2.1), Toxicology (Sect. 2.2.2), and Human signs and symptoms (Sect. 2.2.3). The provided detail is adequate and relevant to the HRA. A search of current international reports and publications did not find any significant new information sources. The European Commission published an updated 'CLH report - Proposal for Harmonised Classification and Labelling[a]' for Brodifacoum in 2013 but this does not contain significant new toxicological information.

A review of the toxicological profile of Brodifacoum as reported by Toxikos did not find any errors or omissions. Toxicokinetic studies indicate that Brodifacoum has almost complete oral absorption (range >75-100%) and is widely distributed, bioaccumulating mainly in the liver with lower concentrations in the kidney. Elimination from the liver is biphasic, with half-life in the range of 282-350 days. The excretion after oral administration is very slow (11–14% in 10 days), occurring via the

[a] http://echa.europa.eu/documents/10162/13626/clh_proposal_brodifacoum_dd006368-57_en.pdf,

urine and the bile, both as polar metabolites (glucuronide) and parent compound. The metabolism of Brodifacoum is limited and the toxicologically relevant chemical species is the parent compound.

The Toxikos report identified the high acute toxicity of Brodifacoum with oral LD_{50}s in rats ranging from 0.17-0.9 mg/kg bw); slightly lower acute toxicity levels are reported for the inhalational (3.05 mg/kg bw, 4h) and dermal routes (3.16 – 7.48 mg/kg bw)[b]. Brodifacoum is not a skin or eye irritant. Brodifacoum showed no skin sensitizing potential in a LLNA study in mice, but did cause skin sensitization in guinea pig indicating that Brodifacoum has potential for skin sensitization and thus fulfils the EU criteria for classification as a skin sensitizer[c]. The mode of action of Brodifacoum is unequivocally identified as impairment of the clotting cascade and increased prevalence of haemorrhage leading to death. Repeated dose oral studies show that in the rat and in the dog, the clinical signs, haematological and post mortem data were consistent with this mode of action and there are no indications of other secondary toxicities. Reports of human intoxication by Brodifacoum show toxic responses consistent with the animal studies. The dermal absorption value quoted in the Toxikos report (1.87%)[d] requires a minor change as the recent EC report recommends a value of 5% for pellet/grain bait formulations.[e]

Comment - The toxicological information provided in the Toxikos report is appropriate

Dose response: The Toxikos report identifies the following endpoints from the animal studies.

No Observed Effect Level (NOEL) for affecting prothrombin clotting time (PT)

- Rat – acute single oral dose, 0.15 mg/kg bw
- Rat – 42 day feeding study, 0.005 mg/kg bw
- Rat – 90 day feeding study, 0.001 mg/kg bw

Australian acceptable daily intake (ADI) 0.0000005 mg/kg bw

Comment - These values are appropriate and supported by the available studies

General comment on the risk assessment approach

Although the approach taken by Toxikos is supportable and understandable in the absence of exposure information, a more conservative approach is recommended using Acceptable Exposure Levels (AELs) rather than NOELs to compare to the crude estimates of exposure. In brief, quantitative risk assessment normally relies on firstly identifying a critical effect for a threshold-based toxicant and secondly having reliable exposure data. Risk characterization then involves comparing the estimated/measured exposure to a derived Acceptable Exposure Level (AEL). The term AEL resembles the AOEL (Acceptable Operator Exposure Level) used in OHS risk assessments. The omission of the term operator underlines that the AEL is the reference value for the human

[b] ibid

[c] ibid

[d] Toxikos report, pg 15

[e] http://echa.europa.eu/documents/10162/13626/clh_proposal_brodifacoum_dd006368-57_en.pdf, pg 28.

population as a whole. This is an analogous approach to deriving a Margin of Exposure (MOE) or Margin of Safety (MOS).

In brief, systemic AELs should be derived for acute, medium-term, and long-term exposure via all routes applicable, based on the systemic toxicity of the active substance using appropriate Assessment Factors (AFs). To derive an AEL, the selected NOEL is divided by the AFs to give the AEL. For Brodifacoum, the chosen endpoint is PT which is a threshold response, there are no complicating secondary toxic effects and there are available animal studies of different durations supported by human poisoning cases. The normal AF is 100 (10 fold for human variability, 10-fold for animal to human extrapolation). The literature suggests that humans are less sensitive than rats to Brodifacoum and the mode of action in both species is identical. The estimated average fatal dose for a 60 kg bw human male is 15 mg[f] which using allometric scaling (¾ power) is equivalent to a dose to a rat of 1 mg/kg; as this is ca. 4 times the rat LD50 it appears that humans are indeed less sensitive to the acute toxicity of Brodifacoum and hence it is considered reasonable to remove the 10-fold AF for animal-human extrapolation. The retention of the 10-fold AF for human variability is a conservative approach allowing for the potential increased sensitivity of a young child when compared to an adult. The derived AEL is thus the NOEL/10. Using the NOELs listed above, the AELs for use in risk assessment are shown below.

	Study	NOEL mg/kg bw	AEL mg/kg bw
Rat	acute single oral dose	0.15	0.015
Rat	42 day feeding study	0.005	0.0005
Rat	90 day feeding study	0.001	0.0001

Exposure assessment: The Toxikos report presents a thorough and relevant discussion of the properties and fate of the applied bait in the environment. Section 2.3 'Properties of the rodent bait' describes the physical properties of the intended bait formulation and its stability in soil and water; these are important considerations for the human exposure scenarios described and modelled in the report. In brief, Brodifacoum binds strongly to soil and doesn't leach, it does not volatilise, it has very low water solubility and is fat soluble. These properties determine the relevance of the exposure scenarios discussed in Sect. 3 'Exposure and Risk' in the Toxikos report.

Sect.3.1.1 Direct ingestion of bait is considered the most likely and important pathway. Toxikos identifies that a 2 year old child would have to consume 200 pellets all at once to reach the rat (and assumed human) acute toxicity NOEL of 0.15 mg/kg bw. If the child consumes smaller quantities each day for the possible 4-5 weeks the pellets are available, then to achieve the rat 42 day NOEL of 0.005 mg/kg bw, the child would have to consume 6-7 pellets per day. A recalculation using the AEL changes these estimates to 20 pellets/day for the single acute exposure and <1 pellet per day, every day, for the repeated exposure. These are conservative calculations and give a 10-fold safety margin when compared to the NOELs. As noted by Toxikos, while intoxication seems unlikely, the presence of an indicator dye in the bait which will stain lips and mouth, in conjunction with an education campaign and parental supervision will minimise risk from the direct ingestion of bait.

[f] "Brodifacoum (HSG 93, 1995)". Inchem.org

Notably, human studies have demonstrated the complete efficacy of antidote treatment (Vit K) for cases of human intoxication by Brodifacoum.

Sect.3.1.2 Ingestion of soil (Pathway A3). Toxikos uses conservative assumptions of soil ingestion and soil concentration and estimates that a child might ingest 0.0000004 mg/kg bw/d of Brodifacoum. This is insignificant when compared to the 42-day AEL of 0.0005 mg/kg bw/d.

Sect. 3.1.3 Dermal exposure (Pathway A4). Toxikos uses conservative assumptions of soil contamination of the hands of a child and estimates that a child might absorb 0.00001 µg/kg bw/d. Applying the recommended 5% dermal absorption factor from the EC instead of 1.8%, the calculation yields 0.00003 µg/kg bw/d which is insignificant compared to the42 day AEL of 0.5 µg/kg bw/d.

Sect. 3.1.4 Ingestion of water (Pathways B1 & B2). Using a conservative set of assumptions about bird defecation, dropping size and Brodifacoum concentration, Toxikos estimates that a child might ingest through drinking tank water 0.0008 µg/kg bw/d of Brodifacoum which is insignificant compared to the 42 day AEL of 0.5 µg/kg bw/d.

In a separate calculation for pellets dropped on roofs by birds, Toxikos calculates a child might absorb 0.06 µg/kg bw/d of Brodifacoum which is about 12% of the 42 day AEL of 0.5 µg/kg bw/d. As Toxikos states, this scenario is highly unlikely and of little concern to the risk manager.

Sect. 3.1.5 Consumption of fish (Pathway C). After a review of the available studies on fish consumption of Brodifacoum baits in the marine environment, Toxikos discusses the possible scenarios whereby humans could catch and eat fish that had eaten non-lethal amounts of particles from Pestoff 20R under the following headings:

- the probability that significant amounts of bait will find its way into the marine environment
- the probability that fish will consume the bait
- the probability that a fish which has consumed Brodifacoum bait will be caught by an angler
- the probability that caught fish contains high amounts of Brodifacoum in edible portions
- the probability that high amounts of fish will be consumed by an individual

All the assumptions in the analysis are conservative and appear reasonable. The estimated daily dose of Brodifacoum from high end consumption of fish is potentially estimated to be 0.0008 µg/kg bw/d which is insignificant compared to the 42 d AEL of 0.5 µg/kg bw/d

Sect.3.1.6 Consumption of vegetables (Pathways D1 & D2). Uptake into plants is considered to be neglible.

Sect. 3.1.7 Exposure via poultry (Pathway E). As noted in the report, this exposure pathway is incomplete.

Sect 3.1.8 Meat and dairy products (E). As noted in the report, this exposure pathway is incomplete.

Sect 3.1.9 Goat produce (Pathway G). As noted in the report, this exposure pathway is incomplete.

Sect. 3.1.10 Consumption of wild ducks (Pathway H). As noted in the report, this exposure pathway is incomplete.

Sect. 3.1.11 Dust inhalation during aerial baiting (Pathway I). This is a potentially important pathway for human exposure as inhaled Brodifacoum is assumed to be 100% absorbed. A series of assumptions based on trial applications is presented to allow for calculation of exposure. e.g. bait is dropped from 50 m height along an 80 m swathe (at the rate of 12 kg/hectare. Dust generation during loading and dispersion is estimated at 500 g per 25 kg of bait. A reasonable assumption is made that up to 25% of the dust may be inhalable yielding 125 g of inhalable dust per 25 kg of bait. The 4 kg of bait released over a 40 m length will thus yield 20 g of inhalable particles. The 2 year old receptor is then assumed to be in the impacted zone for 8 hours, breathing suspended particulates which remain suspended for the entire exposure time; these are very conservative assumptions. Toxikos then calculates the concentration in air as:

20 g/160,000 m^3 = 0.000125 g/m^3 = 125 µg/m^3, **not** 0.125 µg/m^3 as reported by Toxikos.
Pellets contain 20 µg Brodifacoum/g of pellets
hence 125 µg/m^3 of pellet dust contains 0.0025 µg Brodifacoum/m^3.

Comment – a 1000 fold error occurs in the Toxikos calculations.

Toxikos quotes an occupational exposure limit for Brodifacoum as 2 µg/m^3 (8 h TWA) (Syngenta 2006 MSDS). No alternative occupational exposure limits were found. The estimated exposure (0.0025 µg Brodifacoum/m^3) is thus 800 times less than the only published OHS limit of 2 µg/m^3.

Using the assumptions in the Toxikos report and the correct value for Brodifacoum concentration in air, the estimated exposure to a 2-3 year old child would be 0.0006 µg Brodifacoum/kg bw/d. This is 25000 times less than the acute AEL of 0.015 mg/kg bw.

Comment: Toxikos concludes that the risk to human health from the inhalation pathway is insignificant, and despite the 1000-fold error in one of the Toxikos calculations the conclusion is considered correct.

<u>Conclusion:</u> The Toxikos report is a comprehensive scoping human health risk assessment for the proposed Lord Howe Island rodent eradication plan. The basic methodology is sound although this reviewer would prefer exposure estimates to be compared to AELs rather than NOELs. There is little available information to update this assessment other than a revision of the dermal absorption factor. The analysis of the toxicology data otherwise remains sound and well utilised. The exposure scenarios used are complete and the assumptions used in the exposure calculations are uniformly conservative. The only significant pathway of potential human exposure during the application of Brodifacoum is the oral pathway through ingestion of pellets, as identified by the Toxikos report. The risk management procedures proposed for the program, especially the education program for parents, will mitigate this risk. The conclusions of the Toxikos report are sound and the recommendations should remain unchanged.

Recent publication

Bryce M. Masuda, , , Penny Fisher, Brent Beaven Ecotoxicology and Environmental Safety Volume 113, March 2015, Pages 1–8

The second-generation anticoagulant rodenticide brodifacoum is an effective tool for the eradication of invasive rodents from islands and fenced sanctuaries, for biodiversity restoration. However, broadcast application of brodifacoum bait on islands may expose non-target wildlife in coastal marine environments to brodifacoum, with subsequent secondary exposure risk for humans if such marine wildlife is harvested for consumption. We report a case study of monitoring selected marine species following aerial application of brodifacoum bait in August 2011 to eradicate Norway rats (Rattus norvegicus) from Ulva Island, New Zealand. Residual concentrations of brodifacoum were detected in 3 of 10 species of coastal fish or shellfish sampled 43–176 d after bait application commenced. Residual brodifacoum concentrations were found in liver, but not muscle tissue, of 2 of 24 samples of blue cod (0.026 and 0.092 µg/g; Parapercis colias) captured live then euthanized for tissue sampling. Residual brodifacoum concentrations were also found in whole-body samples of 4 of 24 mussels (range=0.001–0.022 µg/g, n=4; Mytilus edulis) and 4 of 24 limpets (range=0.001–0.016 µg/g, n=4; Cellana ornata). Measured residue concentrations in all three species were assessed as unlikely to have eventually caused mortality of the sampled individuals. We also conducted a literature review and determined that in eleven previous accounts of residue examination of coastal marine species following aerial applications of brodifacoum bait, including our results from Ulva Island, the overall rate of residue detection was 5.6% for marine invertebrates (11 of 196 samples tested) and 3.1% for fish (2 of 65 samples tested). Furthermore, our results from Ulva Island are the first known detection of brodifacoum residue in fish liver following an aerial application of brodifacoum bait. Although our findings confirm the potential for coastal marine wildlife to be exposed to brodifacoum following island rodent eradications using aerial bait application, the risk of mortality to exposed individual fish or shellfish appears very low. There is also a very low risk of adverse effects on humans that consume fish or shellfish containing residual concentrations in the ranges reported here. Furthermore, any brodifacoum residues that occur in marine wildlife decline to below detectable concentrations over a period of weeks. Thus potential human exposure to brodifacoum through consumption of marine wildlife containing residual brodifacoum could be minimized by defining ‘no take’ periods for harvest following bait application and regular monitoring to confirm the absence of detectable residues in relevant marine wildlife.

3.2 Response to issues raised by Mr Ratheburger

In your last email you provided a copy letter from former chairman Alistair Henchman which advised that the dust levels from Pestoff20R were 0.6%, countering my stating that the dust levels were of the level of 2% going up to 5% after exiting the aerial distributing arm on the helicopter.

I said I would go back into my 'bunker' to check this as I had recalled a verbal statement that it was indeed of the level of 5%, and went to look for any written record……..alas I found none, but I did find the overheads Dr Wilkinson had shown where the level of dust sampled from trials in NZ was 1.8%, with a 'rider' to say most were 0.8%....a very strange 'rider', but never mentioned the 0.6% suggested by Mr Henchman.

Anyway in the absence of evidence I will concede the figures of Dr Wilkinson, although there has been a lot of water-under- the-bridge since, yes?

In the course of my going through my hardcopy and computer files looking for the information I came across my Letter-to-the-Editor, No.6 dated 28/8/2008, not sure what Signal edition it was published in, in which I state that the level of dust would exceed the permissible levels for industrial dusts by many-fold, like 43.2 times. Wilkinson in his overheads had shown, we have hard copy, the standard for toxic dusts as 0.0005mg/litre which translates into 0.5mg/m3 for a 4 hour exposure, yet he stated that the fallout of dust particles over Lord Howe Island would be 216g/ha or 21.6 mg/m3, which is 43.2 times the safe limit. Wilkinson talks about the level of brodifacoum in the dust, well toxic dust is toxic dust and the authorities do not adjust, without specific knowledge, the criteria between one toxic dust and another for reasons of simplicity, not knowing the relative toxic intensities of the toxins included in the dust particles. For example we know that the same mass of warfarin and brodifacoum enclosed in the same sized dust particles will have extraordinarily different levels of toxicity…..for brodifacoum is at least 200 times more toxic than warfarin. See further clarification below.

I also looked into the Toxikos Report and analysed the data in Section 4., Existing risk from commercial rodent bait. It is on page 47. Interestingly it states in the first para. 'With warfarin the risk is considerably lower than with brodifacoum baits because it is more rapidly cleared from the body…..'…..This is one of the points we have been making about brodifacoum and its potential adverse impact on the human body, is the residual time it remains in the body, first thought to be 9 months and now 24 months, and likely for considerably longer as scientific detecting equipment is capable of detecting smaller and smaller levels of contamination.

Comment: In humans, the half-life of Brodifacoum in plasma is about a month while in liver it is about a year. Nanogram quantities detected by improved analytic techniques are not relevant to the toxicologically significant concentrations.

Anyway back to the 'figures' in the Toxikos Report, and Section 3.1.11. Dust inhalation during aerial baiting. It starts on page 44. It discusses, as the title states the ingestion of dust particles in a given 'corridor' along which the helicopter might traverse, releasing 12kg per ha(10,000m2) in the first campaign and 8kg per ha in the second campaign, and in the sample swath 4kg of bait would be dropped.

The amount of dust in the sample according to Torr and Agnew in 2007, as the Toxikos Report says, found there was 130-150 g of fine material in a 25kg bag of bait as delivered. Using abrasive tests etc., they determined that the amount of fines produced from different designed distribution hoppers would range from 50g to 330g per bag, and the maximum amount of fines in the supplied

bait and potentially generated by dispersion machinery would approximate 500g per 25kg of bait, that is 2%.

The amount of inhalable particles as determined by the scientists, Torr and Agnew is admitted by Toxikos as unknown ??, but then in the absence of data, Toxikos assumed that 25% may be inhalable, ie 25% of the 2%, or 125gm of the 25kg bag.

Therefore of the 4kg of bait dropped in the 'corridor', there would be 20g of inhalable material(dust).....or given the speculation above, it could be 40g or even 60g, but we'll go with 20g.

Now the above inhalable material would be contained in the corridor 'volume' of 80m x 40m x50m or 160,000m3, and Toxikos determined by deduction, 20g divided by 160,000m3 would be 0.000125g/m3...which they erroneously further translate as 0.125mcg/m3(mcg = microgram, ie., a millionth of a gram). The translation more correctly should have been either 0.125mg/m3(mg = milligram, ie., a thousandth of a gram) or 125mcg/m3. Yes, indeed, it all can be very confusing.

Comment: this observation is correct, there is a 1000-fold error in the calculations. However this has importance only for the calculation of inhalational exposure. The margin of exposure is sufficiently large that reducing it by a 1000-fold does not change the conclusion that this exposure pathway is insignificant.

Toxikos goes on to then determine the actual amount of brodifacoum in the dust, as being 0.0000025mcgB/m3, the 'B' meaning brodifacoum.....but in fact being 'out' by a factor of one thousand, the level is 0.0025mcgB/m3, an acceptable exposure according to Toxikos, BUT in accordance with the regulations of dust measurement it is the dust particle itself that is measured, not the amount of toxin within, as mentioned above. See further clarification below.

Toxikos relate the occupational standard limit of exposure to protect workers from the effects of brodifacoum during manufacture of the rodent bait as 2mcg/m3, giving a reference to Syngenta 2006, indeed the manufacturers of Talon, so it is its own standard.

Therefore by more correct analysis of the 'accepted' earlier assumptions, the amount of exposure in the corridor would be 125mcg/m3 of dust containing brodifacoum and with the manufacturer of Talon's self-imposed regulation as 2mcg/m3, it is 60 times greater, and this correlates to my work in the Letter-to-the-Editor on 28.8.'08, which spoke of us residents being exposed to 43.2 times above the permissible limit for toxic dust exposure levels,working off data provided by Dr Wilkinson. I quote again from my above 'letter', ' Dr Wilkinson produced data on Toxic Dusts and expressed that the acceptable safe limit was 0.5mg/m3. The toxic dust fallout he projected for Pestoff 20R would be 216gm/hectare(in a 10cm thick band) and this would then, from our maths, translate into a dust density of 21.6mg/m3, which is 43.2 times greater than this safe limit.

Dr Wilkinson was talking, as the standard states in terms of toxic dusts, that is, of the dust (containing brodifacoum) in Pestoff20R bait,. Now, as indeed Toxikos did, he went on to discount the dust level relative to the amount of actual brodifacoum contained, however that is not the way to apply the regulation.

Indeed the following extract from the Australian workplace 'Guidance on the Interpretation of Workplace Exposure Standards for Airborne Contaminants', see the link below, clarifies the issue on page 19 under INHALABLE DUST; 'Inhalable dusts that are toxic have an exposure standard based upon the substance of concern. Where the toxic component of the dust is measured, this is satisfactory as long as the exposure standard for dusts not otherwise classified is not exceeded.' In

other words the discounting of the dust hazard to the level of brodifacoum contained in the dust is WRONG.

Comment: The above interpretation of the Workplace Exposure Standards is misguided. It is the contaminant level in the dust that drives the risk management not the concept of 'toxic dust'.

Safe Work Australia[g] Guidance on the Interpretation of Workplace Exposure Standards for Airborne Contaminants recommends that "Where no specific exposure standard has been assigned and the substance is both of inherently low toxicity and free from toxic impurities, exposure to dusts should be maintained below 10 mg/m^3, measured as inhalable dust (8 hour TWA)." There are workplace exposure standards (WESs) for the various components of dust, such as respirable crystalline silica, and dusts and fumes containing toxins, such as lead.

This 10 mg/m^3 is the upper limit for 'Dust, not otherwise specified'. Where there is a contaminant such as crystalline silica or lead or Brodifacoum, then a WES can be developed for that contaminant and this value drives the monitoring and risk management as long as the total dust level does not exceed 10 mg/m^3.

The text below from SWA[h] (pg 26) clearly indicates that the concentration of the toxic substance is the driving factor for the risk assessment.

> 'Where no specific exposure standard has been assigned and the substance is both of inherently low toxicity and free from toxic impurities, exposure to dusts should be maintained below 10 mg/m3, measured as inhalable dust (8-hour TWA). However, the exposure standard for dusts not otherwise classified should not be applied where the particulate material contains other substances which may be toxic or cause physiological impairment at lower concentrations. **In these circumstances, the exposure standard for the more toxic substance should be applied.** For example, where a dust contains asbestos or crystalline silica, like quartz, cristobalite or tridymite, exposure to these materials should not exceed the appropriate value for these substances.'

e.g. with respect to the eradication plan, the total dust level from the helicopter pellet drop is expected to be 0.125 mg/m^3 - this is well below the 10 mg/m^3 general standard. The calculated concentration of Brodifacoum in the dust is 0.0025 µg/m^3 and this is well below the adopted WES of 2 µg/m^3.

As said, I have accepted Toxikos' assumptions of the amount of 'fines' contained in the distributed bait, for I have no other information to go by, but given even that, rather than its incorrect analysis giving 'clearance' to the air conditions above us during the 'drops', a correction of its mathematics shows our exposure to be 60 times the occupational health regulations, and then not to mention

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[g] Guidance on the Interpretation of Workplace Exposure Standards for Airborne Contaminants. Safe Work Australia, Canberra, April 2013. http://www.safeworkaustralia.gov.au/sites/swa/about/publications/pages/workplace-exposure-standards-airborne-contaminants

[h] ibid

that the workers in the manufacturing plant would likely have breathing regulators and full body coverage during manufacturing and packaging of the pesticide, Pestoff20R.

As said earlier, I had not made a specific hand note of the 5% dust level of which I had 'heard', so I have accepted Toxikos's figures of 2%, but then at that level of 2%, the exposure of us residents under the corridor would be 60 times the maximum occupational health levels, which would suggest any wind-shear would be quite detrimental to our health only 40m away and certainly all the birds under and around the drop zones…..just from inhalation, and not including additional fallout on birds feathers, our hair and skin, crops, grass etc.

And as I acknowledged to your concern in my recent email, where I said, 'I appreciate your acknowledgement of the high toxicity of brodifacoum-based products, in your concern for inhaling dust within less than 1 meter of the open packet of Talon.....but hardly would handling a packet of Talon compare to the much greater exposure from Pestoff20R dust floating down on us from aerial baiting.'

For all the 'clearance' Toxikos gave to the eradication programme, albiet a very limited study in our opinion, from the Toxikos Report, page 9, the Recommendations state, we quote;

'Recommendations:

- All mitigation measures as outlined in the draft Lord Howe Island Rodent Eradication Plan should be implemented to minimise risks posed by use of rodent bait during the programme.

- As a precautionary measure it would be prudent to advise islanders not to consume the livers of fish that have been caught within 200m of the shoreline until 6 months after the last bait broadcast.

- Although there is negligible health risk from drinking tank water during the eradication campaign, for peace of islander's mind, consideration could be given to a programme of strategic testing of tank water.

- It would be prudent to advise those individuals involved with the control of non-native duck populations that they should not consume duck during the eradication programme, and not the liver for perhaps a year after the programme has ceased.'

These words seem to convey a lot of unassuredness on the part of Toxikos. I have always contended that their brief should have included micro-studies of the human reproductive organs, endocrinological studies, and specific studies on the likely impact on the brains of the very young, of such a powerful toxin as brodifacoum.

Comment: No effect has been demonstrated with technical brodifacoum in long term carcinogenicity tests. Studies in rats and rabbits have demonstrated no fetotoxic, embryotoxic or teratogenic effects[i].

Further,the Australian dust regulators web site, http://www.safeworkaustralia.gov.au/sites/SWA/about/Publications/Documents/680/Guidance_Interpretation_Workplace_Exposure_Standards_Airborne_Contaminants%20.pdf, on page 11, section 4.2

[i] World Health Organization/International Programme on Chemical Safety; Poisons Information Monographs 77 Brodifacoum pp.1-22 (1990)]

Skin Absorption, refers to the greater implications of toxins which are absorbed into the skin, as distinct from inhalation. We all know that brodifacoum whilst it slowly dissolves in water, is readily dissolved in our body oils and fats, therefore our skin, yet neither Wilkinson nor Toxikos examined the implications of absorption in their respective studies…..a potentially tragic oversight.

Comment: The dermal absorption of Brodifacoum has been considered in the HRA. Toxikos suggests 1.8% while the very conservative value of 5%[i] for the pellet formulation has been used in the current review of the HRA. The dermal pathway leads to insignificant systemic absorption irrespective of which value is used.

Hank, it's just simply NOT WORTH THE RISK on our INHABITED island.

Rob Rathgeber.

[i]http://echa.europa.eu/documents/10162/13626/clh_proposal_brodifacoum_dd006368-57_en.pdf