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

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Table 1. Numbers of trapping days, trap nights, area of trapping grid, numbers of rats and mice caught and marked, and estimates of the density of each species.

Grid	Days grid trapped	Trap nights	Area of grid (ha)	Mice marked	Mice/ha	Rats marked	Rats/ha
1	7	1372	0.36	29	80.6	11	30.6
2	7	1372	0.36	24	66.7	23	63.9
Totals		2744		53		34	

Table 2. Estimates of rates of uptake of small and large non-toxic baits, as indicated by pyranine fluorescence.

Species	Consume small bait (Grid 1)		% Positive	Consume large bait (Grid 2)		% Positive
	No	Yes		No	Yes	
Mouse - adult	1	27	96.4	0	17	100.0
Mouse - Juvenile	0	1	100.0	1	0	0.0
Rat – Adult	0	4	100.0	0	17	100.0
Rat - Juvenile	0	5	100.0	3	14	82.4

Table 3. Estimates of rates of uptake by marked rodents of small and large non-toxic baits, as indicated by pyranine fluorescence.

Species	Consume small bait		% Positive	Consume large bait		% Positive
	No	Yes		No	Yes	
Mouse	0	16	100.0	0	9	100.0
Rat	0	0	0.0	0	5	100.0

Captions for figures

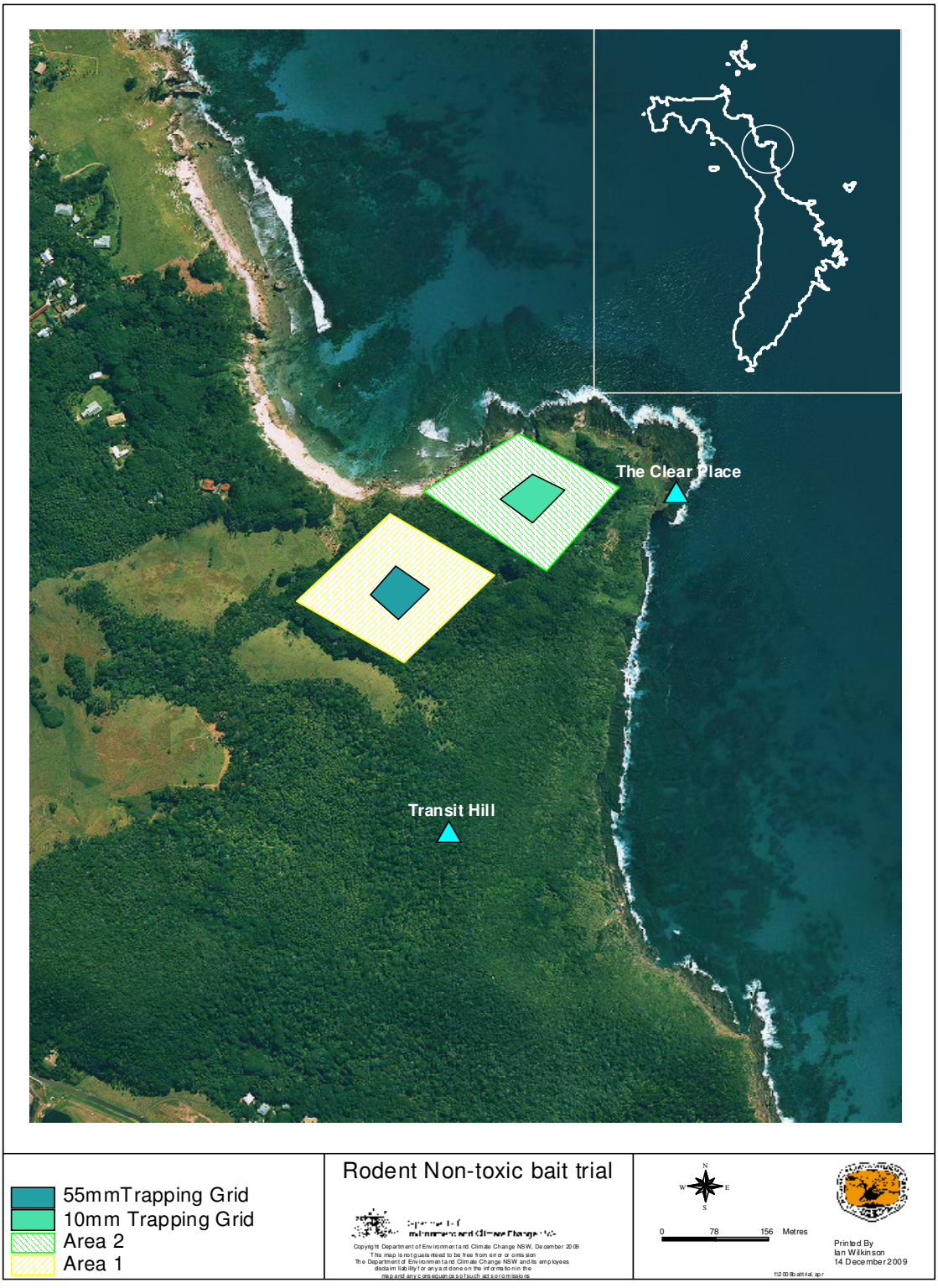
Figure 1: Map of Lord Howe Island showing the locations of baiting areas and trapping grids for the non-toxic bait trial at the Clear Place.

Figure 2. Cumulative numbers of mice marked on trapping grids prior to baiting.

Figure 3. Cumulative numbers of rats marked on trapping grids prior to baiting.

Figure 4.. Daily cumulative captures of adult and juvenile rats and mice.

Figure 5. Juvenile rats captured in the same snap trap.



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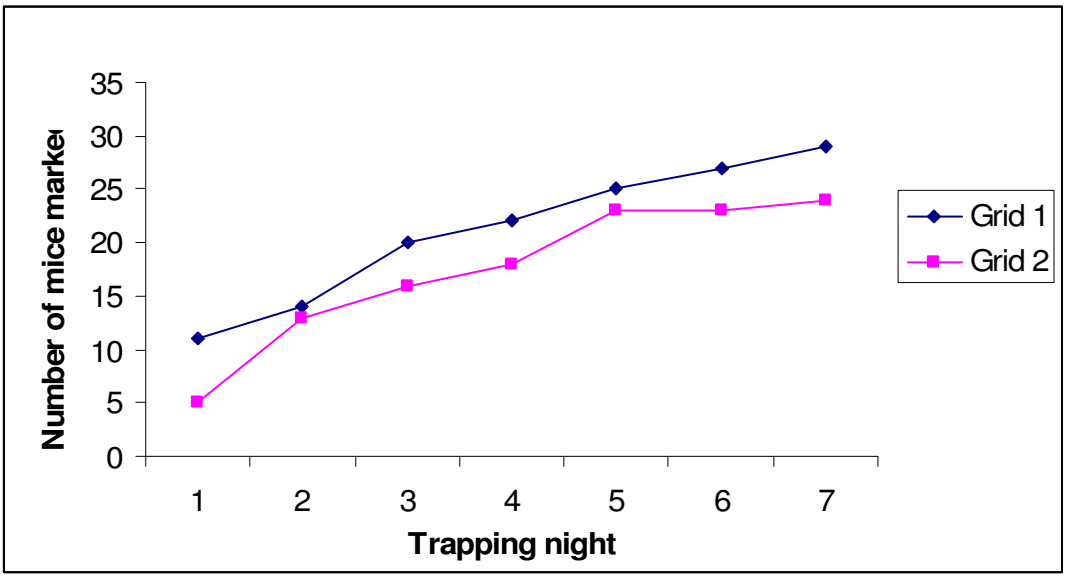

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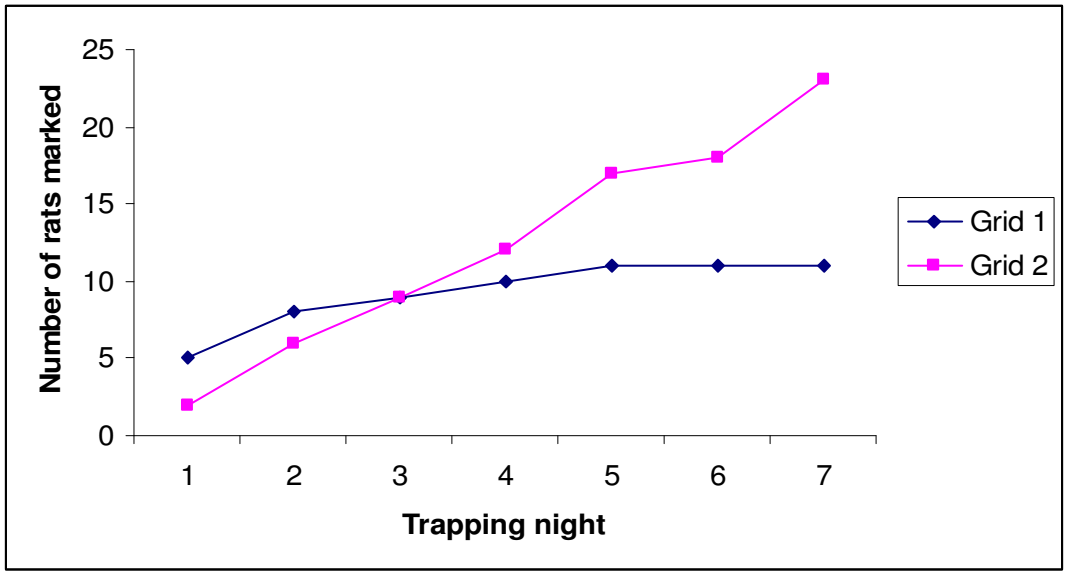

Figure 3. Cumulative numbers of rats marked on trapping grids prior to baiting.

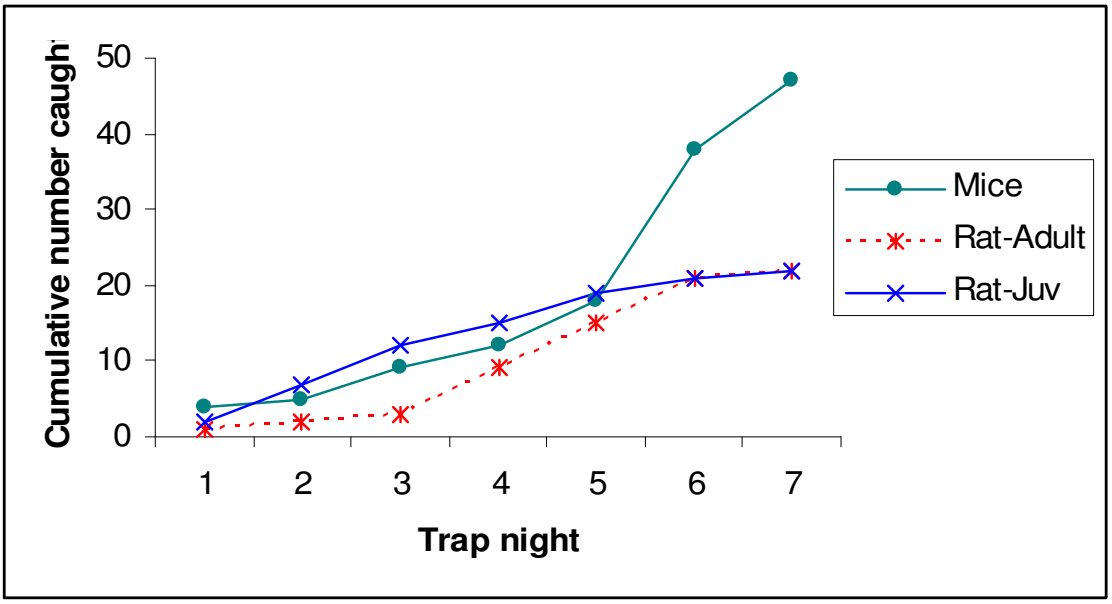

Figure 4. Cumulative captures of adult and juvenile rats and mice.

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