1993). The highly successful captive breeding and release program resulted in the release of 82 birds bred from just three breeding pairs originally captured (NPWS, 2002). Prior to the commencement of the program it was estimated that only 37 individuals remained in the wild.

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

	
Figure 8 Woodhens in 2013 Captive Trial	**Figure 9 Currawongs in 2013 Captive Trial**
	
Figure 10 Woodhen Aviary in 2013 Captive Trial	**Figure 11 Currawong aviaries in 2013 Captive Trial**

2.2.1 Bird capture

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

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

2.2.2 Captive Housing Design and Location

The design plans for the holding pens used for each species during the 2013 trial were prepared by an experienced team of aviculturists from Taronga Zoo considering knowledge gained from previous facilities built to house these birds (both at Taronga Zoo and on LHI) as well as advice from New Zealand where the Weka, a species similar to the woodhen, had been kept in captivity during rodent-eradication operations undertaken in that country. These, together with recommendations from the pilot study will be used to inform the detailed design of the larger facility needed during the REP. Woodhens will be held in enclosed paddocks 14 m by 14 m (see Figure 12), holding approximately 20 birds each. For the currawongs, aviaries 1.5m wide x 3m high x 6m long aviaries, will be constructed, holding 2 birds per aviary (see Figure 13). Indicative plans from the 2013 pilot study are shown below.

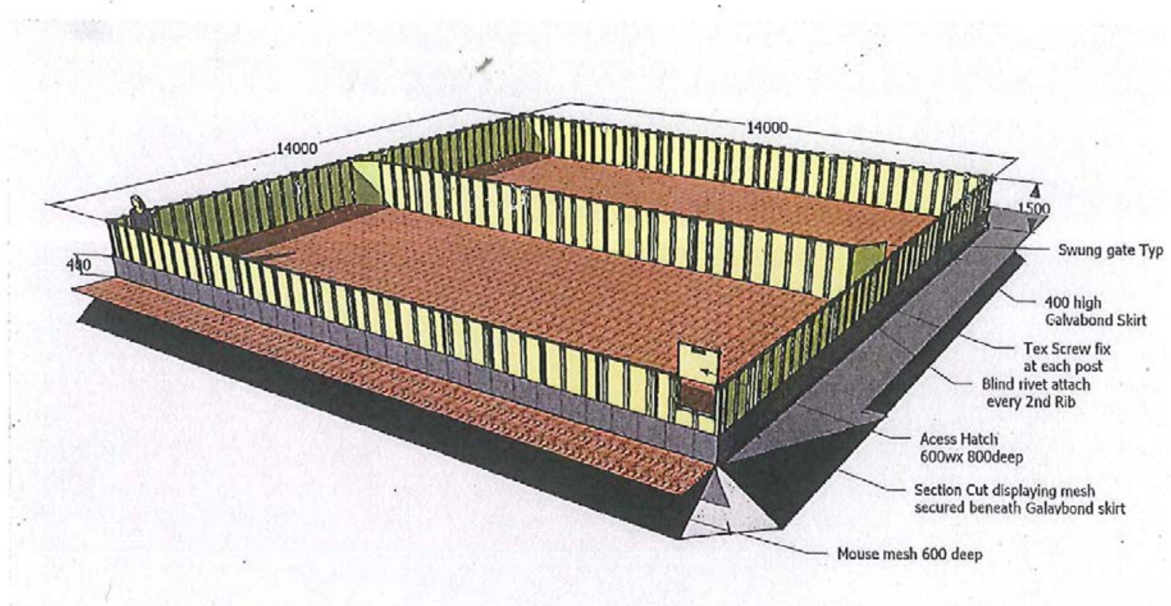


Figure 12 Indicative Woodhen Aviary

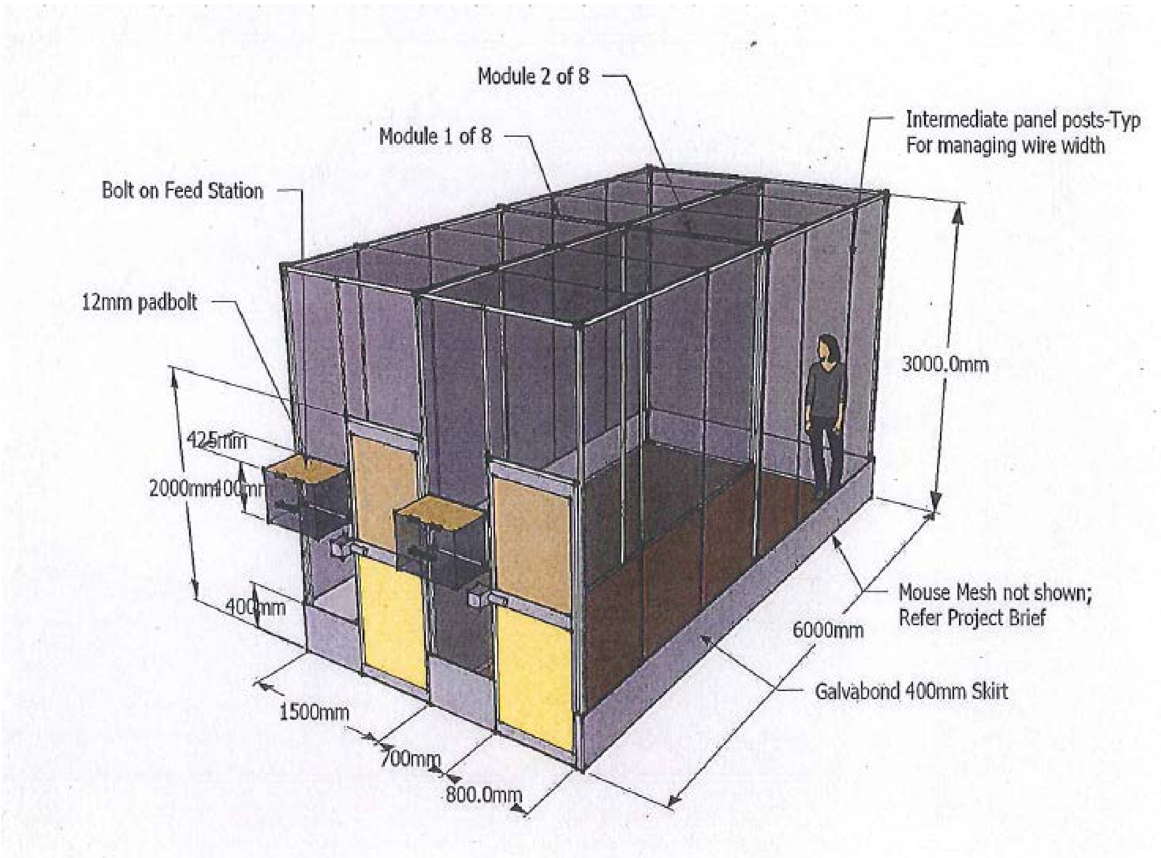


Figure 13 Indicative Currawong Aviary

The required number of aviaries will be accommodated for by reuse of the 2013 aviaries that are still in place at the Nursery site and through modifying existing greenhouses at the Nursery site used in 2013. The existing footprint of the 2013 aviaries and greenhouses should prove sufficient space (see Figure 14). In the unlikely event that additional space is required, expansion may occur on previously cleared and grassed land at the nursery site. No additional vegetation clearing would occur.

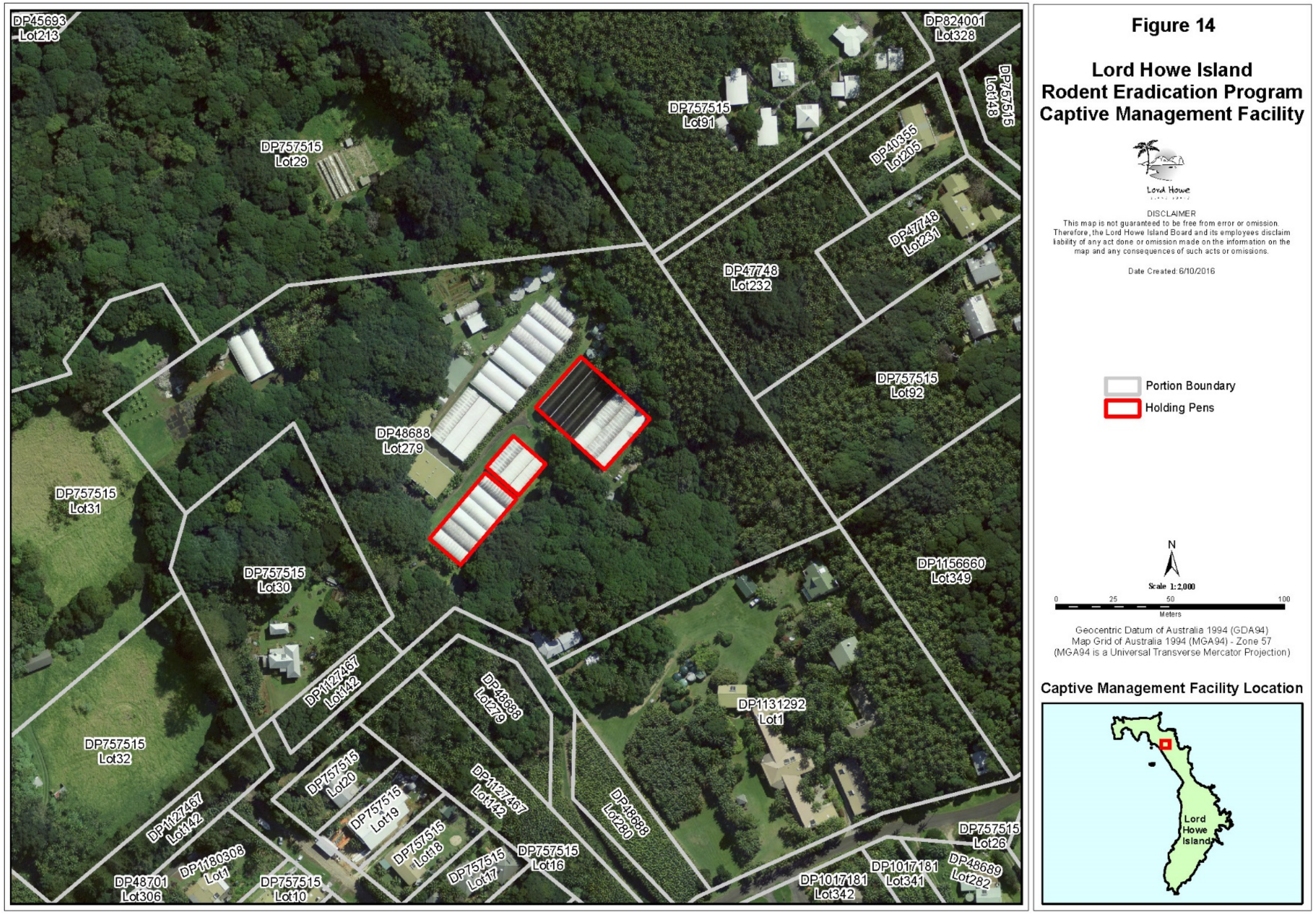


Figure 14 Captive Management Facility Location

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

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

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

2.2.3 Captive Husbandry and Disease Management

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

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

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

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

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

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

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

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

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

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

2.2.4 Mainland Populations

Given the success of the 2013 trial on LHI, establishing temporary or permanent captive populations of either woodhen or currawongs on the Australian mainland has not been proposed. A captive colony of woodhen could be established on the Australian mainland, subject to finding a zoo that is interested. Discussions with Taronga Zoo and Melbourne Zoo have indicated that they do not have available space or interest in establishing a LHW population.

2.3 Bait Application

The method chosen for the LHI REP is to eradicate rats and mice by distribution of the toxin Brodifacoum at a concentration of 20 ppm in the cereal based product Pestoff 20R. Justification for this methodology, toxin and bait is provided in Section 3.

2.3.1 Baiting Protocol

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

2.3.2 Area to be baited

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

2.3.3 Number of bait drops

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

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

2.3.4 Timing

The operation is programmed to take place in winter 2017 (June-August), when the availability of natural food for rodents is low, rodent breeding is greatly reduced or absent and the rodent populations are likely to be at their seasonal lowest. This is also a period when most non-target seabirds are absent from the LHIG. Bait drops will be timed to avoid periods of predicted heavy rainfall (as this may prematurely dissolve the bait) and cannot take place in high winds or in the presence of low cloud. Therefore weather will influence the actual timing of the two bait drops. Weather forecasts of rainfall and wind speeds will be obtained from the Bureau of Meteorology station on LHI from June onwards. A forecast of less than 15 knots and four fine days (three fine nights) without significant rainfall (less than 6 mm daily) is preferred for each drop but the decision to apply bait will be taken by the operations manager at the time when all relevant factors are known.

Given the possibly limited operational window, approval is sought for at least a three year period to account for unforeseen delays beyond winter 2017, however the operation would only occur once during that period.

2.3.5 Aerial baiting

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

The bait will be dispersed using a purpose built spreader bucket (see Figure 15) slung below a helicopter. A rotating disc typically throws the bait 360º to 35 m (note outlier pellets may be thrown to 45 m); enabling a swathe of up to 70 m to be baited in a single pass.

Overlapping (50%) each swathe will ensure that there are no gaps in the distribution of baits (see Figure 16). Application rates out of the bucket are calculated to account for the 50% overlap (i.e. for the first drop 6 kg/ha on each swathe with 50% overlap will be applied to achieve a 12kg/ha application rate on the ground). Each bait drop will take approximately two days to complete dependant on weather.

Figure 15 Custom built spreader bucket being prepared and in use on LHI during 2007 trials.

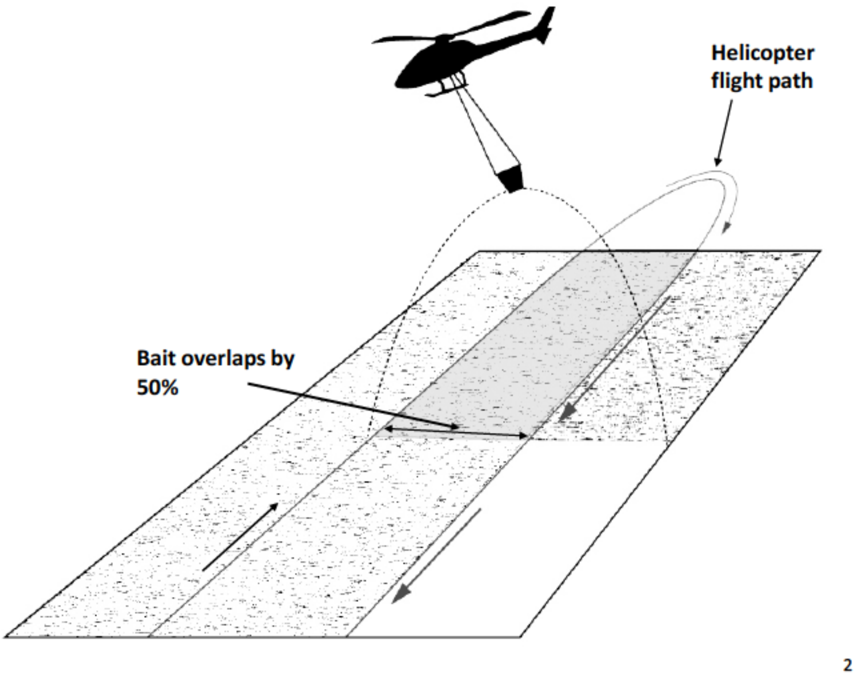


Figure 16 Aerial Application Method

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

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

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

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

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

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

2.3.6 Hand broadcasting of bait

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

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

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

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

2.3.7 Bait stations

Commercially available or specifically designed bait stations (see Figure 17) will be used where aerial or hand broadcasting cannot be undertaken. Bait stations will also be placed within all areas containing livestock (i.e. dairy herd, horses and goats). The bait stations used in livestock areas will be designed specifically to be able to withstand interference and trampling by stock. Where practicable, and with the agreement of householders, small amounts of bait in open containers (‘bait trays') similar to commercial products currently available, will be placed within buildings including kitchens, pantries, pet food storage areas etc. Where possible, bait trays will also be put in accessible roof spaces and under-floor cavities.

Note: there is a potential for currently registered Brodifacoum products to be used in accordance with label conditions by residents in some dwellings. This will be considered on a case by case basis assessing higher palatability of pellets vs. higher dosage, quality control and resident acceptability.

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

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

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

Indicative areas to be treated using the three methods above are shown in Figure 18 and Figure 19.

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

Figure 17 Bait Station Examples

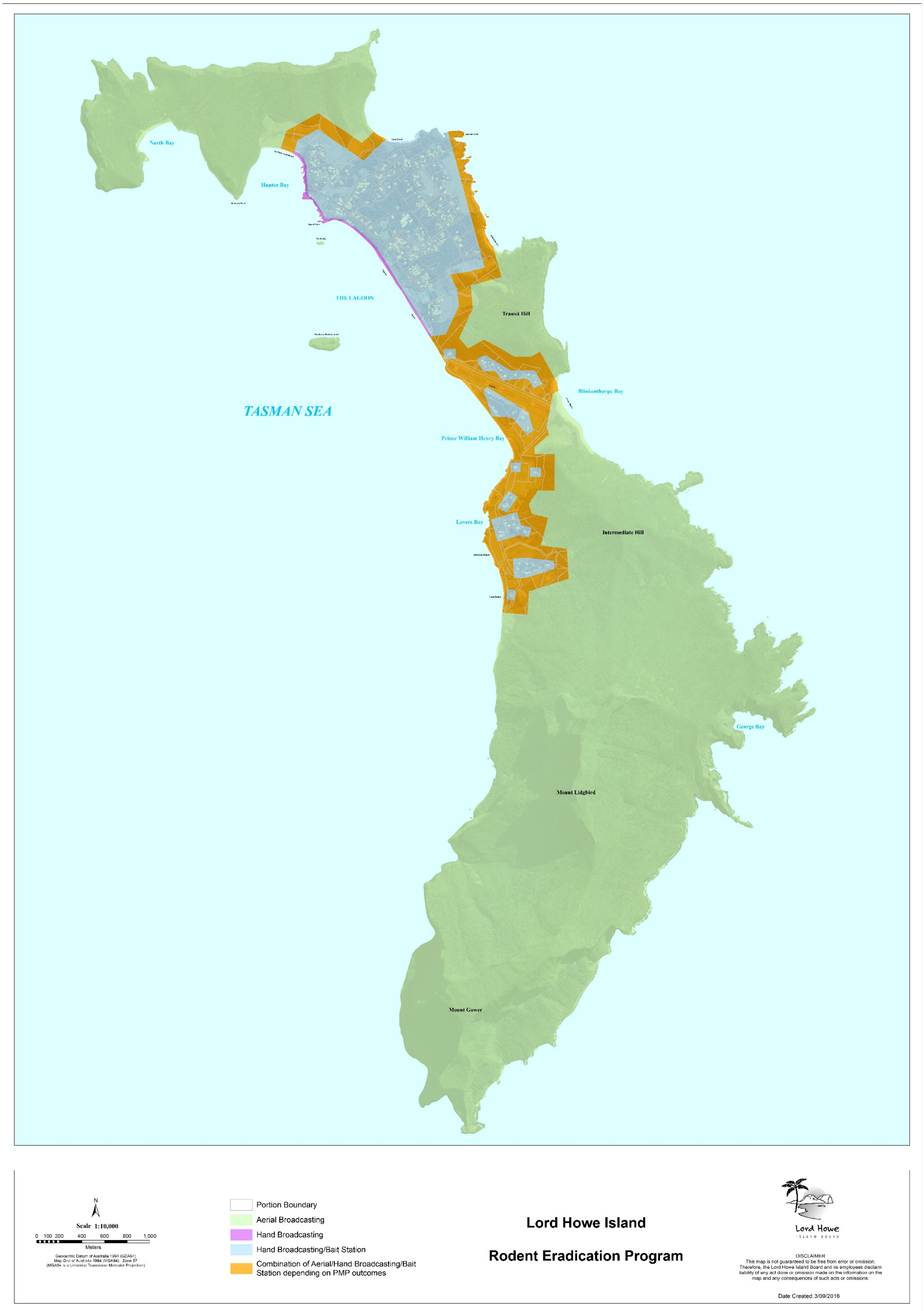


Figure 18 Indicative Treatment Areas by Method

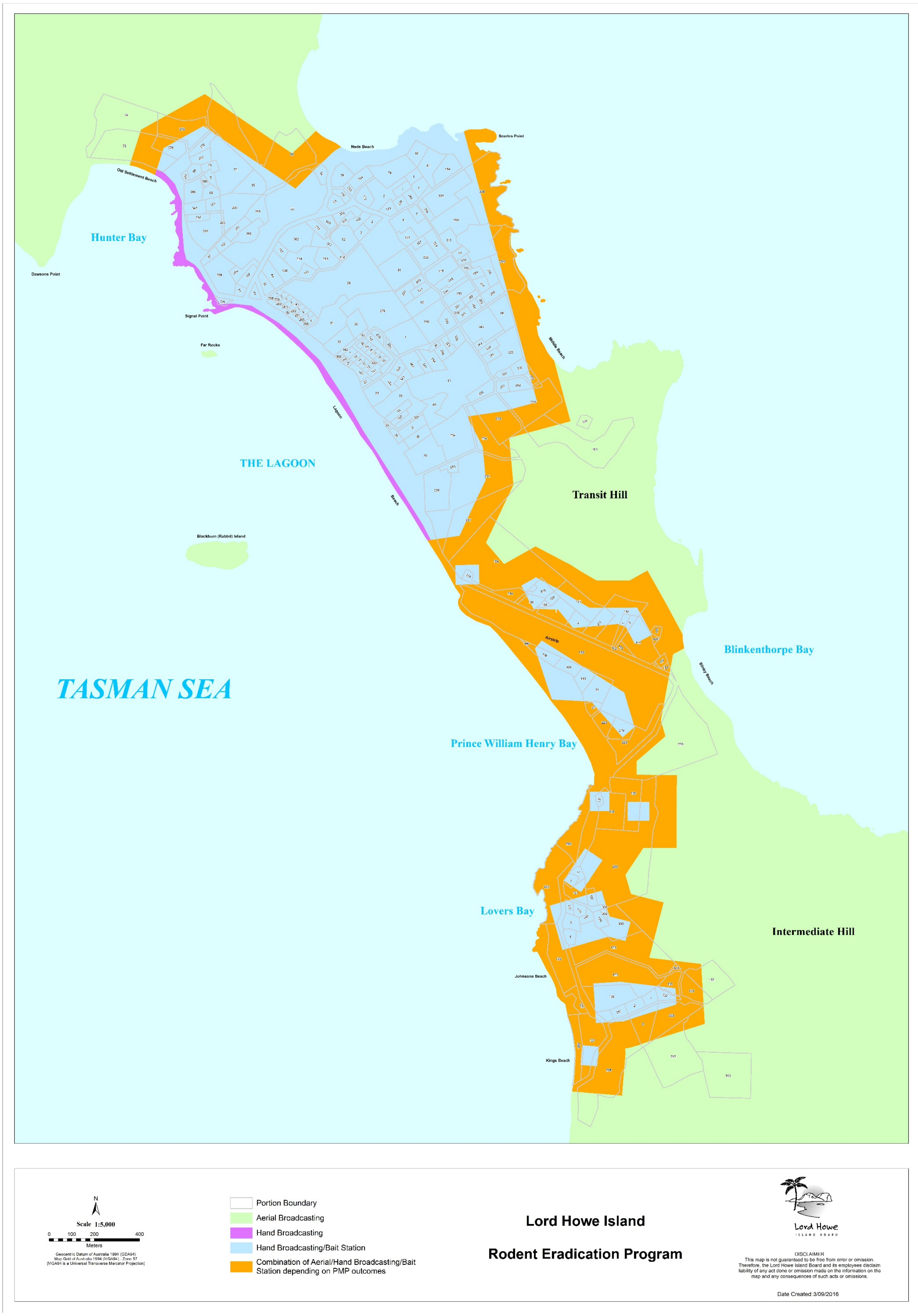


Figure 19 Indicative Treatment Areas by Method - Settlement Area detail

2.3.8 Property Management Plans

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

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

2.3.9 Product storage

At the manufacturing plant in New Zealand, the bait will be packaged into 25 kg bags and loaded in approximately 1 tonne weatherproof bait pods for transport by ship to mainland Australia. After customs and quarantine clearance in Australia, the bait will be 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.

Product Disposal

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

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

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

2.3.10 Accidental Release

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

2.4 Environmental and Impact Monitoring

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

- Monitoring of weather in the lead up to and during the REP.
- Monitoring breakdown of baits after distribution. Bait breakdown will be monitored at random sites using the Craddock Condition Index described below in Section 5.2.1 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 (if required, dependant on results). All tests will be conducted at a NATA accredited analytical laboratory. Rain water tanks and groundwater bores will be sampled if requested by residents.
- Monitoring for sick and dead non-target species. All individuals will be treated with Vitamin K where possible. Carcasses of rodents and non-target species will be collected if found, however previous

studies have shown that the vast majority of rodents that are poisoned die in burrows underground (Vercauteren et al.2002). No analysis of non-target carcasses is proposed.

- Analysis of milk samples pre and post baiting.

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

2.5 Masked Owl Eradication

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

A recent study (Milledge, 2010) has shown that rodents currently 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 of solely native species in the absence of rodents, it is proposed to eradicate remaining owls via hunting or trapping before, during and after the baiting proposal.

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

2.5.1 Pre- and Post-REP Population Estimates

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

Acoustic Monitoring

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

Timing and Personnel

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

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

2.5.2 Masked Owl Eradication Methods

Secondary Poisoning and Trapping Programme

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

Timing and personnel

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

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

Shooting programme

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

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

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

Timing and personnel

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

Firearms

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

Translocation

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

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

2.6 Rodent Detection Monitoring

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

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

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

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

A range of tools are available for trying to detect rodents at low density however they all have their limitations so in order to maximise the chances of detecting any survivors it is desirable to use a mixture of techniques. Details of these tools are provided in Section 2.6.5.

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

2.6.1 Initial Follow up Monitoring

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

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

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

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

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

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

2.6.2 Declaring Eradication Success

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

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

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

2.6.3 Ongoing Rodent Detection Monitoring

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

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

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

2.6.4 Detection Response

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

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

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

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

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

2.6.5 Detection Tools

Bait stations

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

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

Rodent Detection Dogs

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

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

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

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

- Ability to identify target scent and avoidance of non-target species and scent
- High level obedience and control
- Good temperament around people and other dogs

- Initial and ongoing assessment and certification of dog and handler

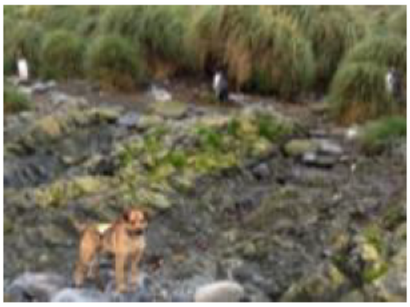
		
Rodent Detection Dog Gadget on Ulva Island Photo: detectorgadget.blogspot.com	Rodent Detection Dog Cody on Macquarie Island Photo: Meg McKeown	Dog trainer Steve Austin with Rabbit Detection Dogs Gus and Ash Photo:K9 Wildlife Conservation

Figure 20 Rodent Detection Dog Examples

Trail Cameras

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

Chew blocks / Wax tags

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

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

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

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

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

Figure 21 Chew Block

Figure 22 Examples of Chew Cards and Evidence of Rodent Damage

Traps

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

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

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

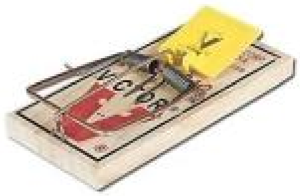


Figure 23 Example Snap Trap

Figure 24 Example Live Traps

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

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

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

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

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

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

Tracking tunnels

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

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

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

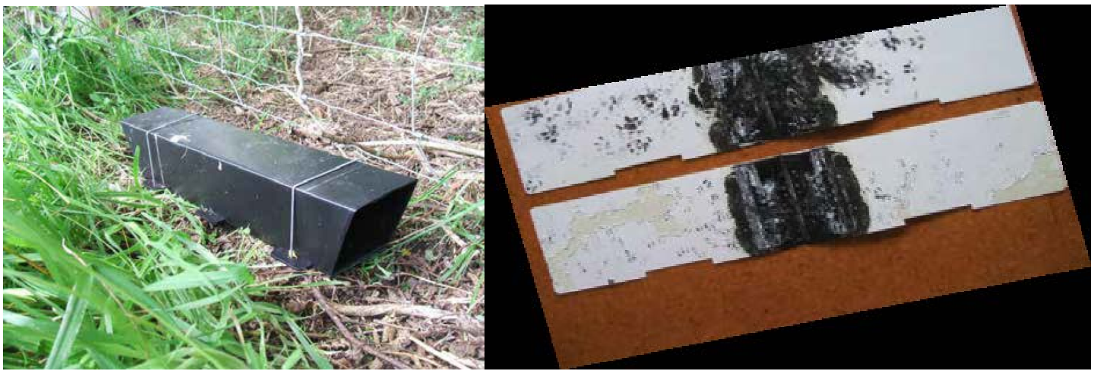


Figure 25 Example Tracking Tunnel and Foot Print Evidence

2.6.6 Implementation

Trials

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

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

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

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

Timing

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

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

Training and Data recording

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

2.7 Improved Biosecurity

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

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

Specifically in relation to rodents and in addition to the ongoing rodent detection measures described in Section 2.6.3, the following measures will be applied:

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

2.8 Biodiversity Benefits Monitoring

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

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

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

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

2.8.1 LH Pied Currawong

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

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

2.8.2 Land birds

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

2.8.3 Seabirds

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

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

2.8.4 Reptiles

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

2.8.5 Land snails

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

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

2.8.6 Other invertebrates

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

2.8.7 Big and Little mountain palms

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

2.8.8 Fruiting plants

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

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

2.8.9 Woodhen

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

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

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

3 Alternatives Considered

3.1 Alternative Scenarios

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

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

3.1.1 Do Nothing Scenario

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

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

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

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

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

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

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

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

Rats are voracious predators of invertebrates. The loss of invertebrates on LHI is particularly significant because invertebrates play an important role in maintaining natural ecological functions, such as nutrient cycling, pollination, pest control and decomposition. Documented impacts to invertebrates include the loss of two endemic land snails (Ponder 1997) – *Epiglypta howinsulae* and a sub-species of *Placostylus bivaricosus* and 11 beetles. These beetles, that were present on LHI prior to the introduction of rats, have not been recorded since. This is despite significant effort including a systematic invertebrate survey by the Australian Museum between 2002 and 2004 (C. Reid unpublished data). Rats are also responsible for the local extirpation of Wood-feeding

Cockroach *Panesthia lata* which now only occurs on offshore islands including the Admiralty Group. Rats are also widely believed to be responsible for the elimination of the endangered LHI Phasmid from the main island. The only remaining wild population of phasmid occurs on rat-free Balls Pyramid (Priddel *et al.* 2003).

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

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

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

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

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

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

In summary, continued impacts to matters of NES; 10 bird species, two reptile species, six invertebrate species and two plants species (Table 4) are unacceptable in a do nothing scenario. Consequences of failing to proceed with the REP are detailed in section 1.9.1.

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

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

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

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

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

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

3.1.2 Continuing the Rodent Control Scenario

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

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

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

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

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

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

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

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

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

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

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

Continued impacts to matters of NES; 10 bird species, two reptile species, six invertebrate species and two plants species (Table 4) are unacceptable in the current scenario. Consequences of failing to proceed with the REP are detailed in section 1.9.1.

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

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

3.1.3 Preferred Scenario - Eradication

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.2 Selection of Eradication Technique

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

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

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

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

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

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

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

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

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

3.2.1 Alternative Eradication Techniques Assessed as Unsuitable

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

Disease

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

Trapping

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

Biological

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

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

Fertility Control

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

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

- The product is not currently registered in any country. While SenesTech hope to have it registered in the USA next year it is likely to be some time before it is registered in Australia.
- The product, Contrapest, aims to *reduce* rat populations through sterilisation, by reducing fecundity but leaving some animals to defend territories i.e. ongoing **control not eradication**.
- It requires every female to be dosed with the product i.e. it needs to be regularly dispensed as there is no inherited or contagious transmission of the reduced fertility.
- The fertility control compounds (VCD and Triptolide) are not species-specific and could affect other mammals including humans.
- Currently the product is designed for rats although the developers state that it has the potential to be modified to target mice, along with other species, although dispensing the appropriate dosage is problematic at this stage.

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

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

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

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

3.2.2 Preferred Technique – Use of Toxicant

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

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

3.3 Selection of Toxicant

3.3.1 Mortality Agents Assessed as Unsuitable

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

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

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

Cholecalciferol

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

Sodium monofluoroacetate

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

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.

Other agents

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

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

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

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 including Brodifacoum, bromadiolone and difethiolone are more toxic, require lower concentrations and only a single feed to kill rodents and are thus preferred for use in eradications. However they do present a greater non-target risk.

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

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

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

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

Diphacinone

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

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

Toxicological Properties of diphacinone

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

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

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

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

3.3.2 Preferred Toxicant – Brodifacoum

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

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

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

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

- Brodifacoum has proven to be successful in over 226 eradications including all 14 eradications on islands greater than 500 ha in size.
- Brodifacoum has proven to be successful in a variety of climatic conditions including those similar to LHI.
- Brodifacoum is highly toxic to both rats and mice in minute quantities, allowing a lethal dose to be consumed in a single feed, thus avoiding the consumption of sub-lethal doses and the associated risk of bait shyness/avoidance.

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

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

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

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

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

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

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

3.3.3 Detailed Brodifacoum Information

Overview

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

Chemical name

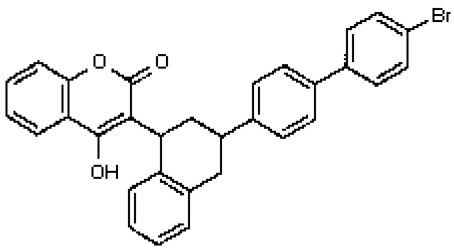
3-[3-(4'-bromo-[1,1'-biphenyl]-4-yl)-1,2,3,4-tetrahydro-1-naphthalenyl]-4-

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

Chemical and physical properties

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

This section is from Eason and Wickstrom (2001)



Synonyms

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

Mode of Action

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

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

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

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

This section is from Eason and Wickstrom (2001)

Pathology

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

This section is from Eason and Wickstrom (2001)

Absorption, metabolism, and excretion

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

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

This section is from Eason and Wickstrom (2001)

Antidote

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

Treatment

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

3.4 Selection of the Preferred Bait

3.4.1 Bait Description

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.4.2 On Island Trials

Efficacy Trials

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

Palatability and Uptake Trials

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

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

3.4.3 Options for distribution

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

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

Bait stations.

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

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

Hand Broadcast

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

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

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

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

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

Aerial Broadcast

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

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

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

3.5 Summary Comparison of Alternatives

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

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

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

Table 11 Assessment of Eradication Options

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

3.6 Likelihood of Success

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

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

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

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

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

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

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

3.7 Alternative Locations and Timeframes

Alternative locations were not considered.

The baiting is planned to occur in winter (June - August) of 2017 but may extend into September if there are problems such as unfavourable weather conditions. June- August is preferred because this is the time of the year when the rodents are at their most vulnerable due to the relatively low abundance of natural food. Many of the seabird species are also absent from the island at this time of years. This is also the low season for tourists on LHI. The operation will take place in a single year sometime between 2017 and 2019. Uncertainty remains concerning the year because there are a number of approvals that have not yet been obtained.

4 Description of the Environment

4.1 General Environment

4.1.1 Flora and fauna

The LHIG supports a diverse terrestrial flora and fauna with a high degree of endemic species and communities. Many biogeographical relationships are discernible, with components of the terrestrial flora and fauna exhibiting affinities with eastern Australia, New Zealand, Norfolk Island and New Caledonia (DECC, 2007). The biodiversity of the island has been well studied over a long period of time. A summary of relevant studies is found in section 11.1.1 and Appendix L – LHI Ecological Studies Summary.

Flora

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

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

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

Fauna

Birds

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

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

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

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

Mammals

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

Reptiles

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

Invertebrates

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

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

There are more than 50 endemic species of land snails found in the island group. One large species, *Epiglypta howinsulae*, has already become extinct and another large species, the Lord Howe placostylus (*Placostylus bivaricosus*), is endangered with one of its subspecies presumed extinct (DECC, 2010). A new species of Phasmid *Davidrentzia validus* was discovered in 1988, with only 12 records of the species been detected since then. The species is considered at risk from predation by rodents.

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

Freshwater Fishes

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

4.1.2 Hydrology

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

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

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

4.1.3 Soil and Vegetation

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

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

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

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. It is considered unlikely that the proposal would impact plants.

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

4.1.4 Remnant native vegetation

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

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

4.1.5 Gradient

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

4.1.6 Current State of the Environment

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

- habitat clearing and modification particularly for accommodation and farmland in the settlement area
- vegetation windshear and associated canopy dieback
- trampling, browsing and grazing from introduced cattle and horses and historically goats
- weed invasion from 270 plant species that have become naturalised including 68 declared noxious weeds
- predation by rodents
- predation and competition from other introduced animals including:
- 18 land bird species and five sea bird species that have established populations on the LHIG since human settlement
- Cats, goats and pigs that have now been eradicated
- African Big-headed Ant *Pheidole megacephala*. Number on the island have been significantly reduced and an eradication program is well commenced (expected eradication 2018)
- Approximately 100 other species of introduced invertebrates
- Bleating Tree Frog *Litoria dentata* and Grass Skink *Lampropholis delicate*

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

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

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

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

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

4.1.7 Commonwealth Heritage Places

The LHIG is not a Commonwealth Heritage Place.

4.1.8 Indigenous Heritage Values

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

4.1.9 Other Important or Unique Values of the Environment

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

4.2 Listed Threatened Species

There are no EPBC Listed Threatened Ecological Communities on the LHIG.

A Protected Matters Search undertaken on 21/12/15 and combined with Island flora and fauna records has identified 23 birds, 1 fish, 1 shark, 4 marine mammals, 5 invertebrates, 5 marine reptiles, 2 land reptiles and 6 plant species listed as threatened under the EPBC Act, occurring or with the potential to occur in the project area. These are described in Table 12 below.

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

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

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

Species	EPBC Act Status	Type of Presence	Distribution, Abundance and Diet relevant to the LHI REP
Birds			
Australasian Bittern *Botaurus poiciloptilus*	E	Recorded Vagrant	Only one verified record for LHI (1888) (McAllan *et al.* 2004). Recorded elsewhere feeding on freshwater crayfish, fish as well as frogs and tadpoles.
Black-browed Albatross *Thalassarche melanophris*	V	Recorded Vagrant/irregular visitor; seabird	Only three records of occurrence in the LHIG, and all were at sea (McAllan *et al.* 2004). Feeds on fish and squid.
Buller's Albatross *Thalassarche bulleri*	V	Rare visitor; seabird	Low numbers occasionally recorded at sea during winter around LHIG but not recorded on land (Hutton pers comms, 2016). Feeds mainly on squid, supplemented by fish and krill
Campbell Albatross *Thalassarche melanophris impavida*	V	Rare visitor; seabird	Low numbers occasionally recorded at sea during winter around LHIG but not recorded on land (Hutton pers comms, 2016). Feeds on krill and fish, with some cephalopods, salps and jellyfish.
Chatham Albatross *Thalassarche eremita*	E	Recorded Vagrant/irregular visitor; seabird.	Extremely rare in Australian waters. Known to forage over deep water in the area on probably eats fish and cephalopods.
Curlew Sandpiper *Calidris ferruginea*	CE	Recorded Vagrant/irregular visitor; seabird.	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. Forage on tidal flats for worms, molluscs, crustaceans, insects, small fish and seeds.
Eastern Curlew *Numenius madagascariensis*	CE	Recorded Regular visitor; seabird	Records of the Eastern Curlew on LHI are from autumn (March and April), spring (September and November) and summer. There is no indication that the species is on LHI in June- August. The Eastern Curlew is carnivorous, mainly eating crustaceans (including crabs, shrimps and prawns), small molluscs, as well as some insects
Fairy Prion *Pachyptila turtur Subantarctica*	V	Recorded Vagrant/irregular visitor;	A single record of Fairy Prion exists for the LHIG. The individual was seen at sea in September of 2011. Fairy Prions usually eat mostly euphausiids and other small

		seabird.	crustaceans, but also eat small quantities of fish and pteropods
Gould's Petrel *Pterodroma leucoptera*	E	Recorded Vagrant; seabird	Only two at-sea records and one beach-wash record for this species in LHIG. Diet of the species includes squid and fish.
Kermadec Petrel *Pterodroma neglecta*	V	Recorded Regular visitor; seabird	Breeds on Ball's Pyramid from November to May (Hutton 1991), and may been seen flying around Mt. Gower during summer. Feeds on squid, fish, crustaceans and, during the breeding season, insects.
Lord Howe Island Currawong *Strepera graculina crissalis*	V	Recorded Endemic; land Bird	This bird is a sub-species of the mainland Pied Currawong, and is endemic to the LHIG. The entire population of the Lord Howe Island Currawong is restricted to LHI and the nearby islets (Mayr and Greenway 1962; Schodde and Mason 1999). The current population is 215 ± 11 birds (Carlile and Priddell, 2007) and appears to be stable as there is no empirical evidence of an historical decline (DEWHA 2009a). The Lord Howe Island Currawong is widespread on LHI, occurring in lowland, hill and mountain regions. It mainly inhabits tall rainforests and palm forests, especially besides creeks or in gullies, but it also occurs around human habitation, and forages amongst colonies of seabirds on offshore islets (DEWHA 2009a). It breeds in the forested hills of LHI, particularly in the south (Hutton 1991, McFarland 1994). Highest densities of nests are on the slopes of Mt Gower and in Erskine Valley (Garnett and Crowley 2000). Its breeding sites are located close to water in gullies (Garnett and Crowley 2000; Hindwood 1940; Hutton 1991). The currawong occurs singly, in pairs and family groups and, in the non-breeding season, in small flocks of up to 15 birds (DEWHA 2009a). It has been recorded breeding from October to December although breeding may commence in September (McAllan *et al.* 2004). During the breeding season breeding pairs and offspring probably occupy strongly-defended territories (Knight 1987). Data from a recent mark-recapture programme undertaken by the OEH suggests that not all currawongs are able to establish a breeding territory due to the lack of appropriate habitat (Carlile and Priddel 2007). In autumn and winter the species forms flocks and can be found in the settlement area (DEWHA 2009a). No information is available on the ages of sexual maturity or life expectancy, but it is probably capable of surviving to more than 20 years of age (Higgins *et al.* 2006). Breeding success appears to be relatively low; the only available, though limited, data suggests that less than 42% of nests produce fledglings (DEWHA 2009a). The Lord Howe Island Currawong is omnivorous; its diet consisting of fruits, seeds, snails, insects, the chicks of other bird species, and rodents (Garnett and Crowley 2000; Hull 1910; Hutton 1991; McFarland 1994).
Lord Howe Woodhen	V	Recorded Endemic; land	The Lord Howe Woodhen is a flightless bird endemic to LHI. Annual surveys of bird

Hypotaenidia sylvestris		bird	number are conducted in November- December since the 1980s. The population estimate in 1997 was 220-230 individuals and 71-74 breeding pairs (NPWS 2002). The population of woodhen has been increasing steadily over the last ten years (LHI Board unpubl. data. 209 birds were recorded as part of the annual population survey conducted in 2015. The 2015 survey data is still being analysed to produce a total population estimate using the methodology in Harden (1999). It is expected that the population estimate will be approximately 240-300 individuals (unpublished data). Woodhens usually lay eggs from August until January (NPWS 2002) or February (Gillespie 1993) and continue raising young until April (NPWS 2002). However, the start and finish dates of breeding can vary between years and there are breeding records for much of the year (Miller and Mullette 1985). Pairs have multiple broods during the breeding season (Gillespie 1993). Juveniles can breed at nine months of age (Marchant and Higgins 1993) but juveniles that do not establish a territory by the breeding season immediately following their own hatching generally do not survive (Harden and Robertshaw 1988, 1989). About 60% of juveniles die in their first year (Harden and Robertshaw 1989) possibly due to limited high-quality habitat (NPWS 2002). Breeding success is greater in the settlement area than in the southern mountains (Marchant and Higgins 1993, Harden and Robertshaw 1988, 1989). The species is currently impacted by rodents on LHI. The woodhen occurs predominately in three vegetation types: 1) Megaphyllous Broad Sclerophyll Forest (mainly palms), which covers 19% of the island; 2) Gnarled Mossy-Forest, which covers 2% of the island; and 3) Gardens around houses. About 40 % of the population lives in the settlement area of the island (NPWS 2002). Over 80% of the woodhen's diet is comprised of earthworms (Miller and Mullette 1985). The bulk of the remaining 20% is made up of grubs, typically found in rotting logs. Snails, arthropods, seabird chicks, rodents, plant shoots, lichen and fungi are also eaten (NPWS 2002). Woodhen were observed eating non-toxic pellet baits during a trial conducted on LHI to gauge what species may eat the Pestoff 20R baits. Blue-coloured faeces have also been seen when handling some birds, indicating they had been consuming Brodifacoum wax blocks (Harden 2001). These blocks are widely dispersed around the settlement by residents. Further evidence of woodhens consuming Brodifacoum baits has come from its detection in the internal organs of several woodhens found dead along roadsides and recovery of ill birds that have been captured and treated with Vitamin K.

Northern Giant Petrel *Macronectes halli*	V	Rare visitor; seabird	Low numbers occasionally recorded at sea during winter around the LHIG but not recorded on land (Hutton pers comms, 2016). The Northern Giant-Petrel eats seal, whale, and penguin carrion, and seal placentae. It also eats substantial quantities of krill and other crustaceans, octopus, squid and fish. It will kill and eat immature albatross and a variety of other seabirds, including individuals captured at sea.
Northern Royal Albatross *Diomedea sanfordi*	E	Rare visitor; seabird	Low numbers occasionally recorded at sea around the LHIG during winter but not recorded on land (Hutton pers comms, 2016). Feeds primarily on cephalopods, fish, crustaceans and salps.
Australian Painted Snipe *Rostratula australis*	E	Recorded Vagrant; seabird	There has only been one record on LHI, and that was in February 1990. Feeds on vegetation, seeds, insects, worms and molluscs, crustaceans and other invertebrates.
Salvin's Albatross *Thalassarche cauta salvini*	V	Rare visitor; seabird	Low numbers occasionally recorded at sea during winter around the LHIG but not recorded on land, (Hutton pers comms, 2016). Feeds on squid and fish.
Shy Albatross *Thalassarche cauta*	V	Rare visitor; seabird	Low numbers occasionally recorded at sea during winter around the LHIG but not recorded on land (Hutton pers comms, 2016). Feeds on fish, squid, crustaceans and tunicates.
Southern Giant Petrel *Macronectes giganteus*	E	Recorded Vagrant; seabird	Only four confirmed records for the LHIG; all prior to 1965, three of which were beach-cast specimens. There are reports of sightings at Ball's Pyramid between 1978-1980 (McAllan *et al.* 2004). The Southern Giant-Petrel is an opportunist scavenger and predator. In summer at least, it will scavenge primarily penguin carcasses, although it will also feed on seal and whale carrion. It catches and kills live birds. It is also recorded consuming octopus, squids, krill other crustaceans, kelp, fish, jellyfish, and rabbit.
Southern Royal Albatross *Diomedea epomophora*	V	Rare visitor; seabird	Low numbers occasionally recorded at sea during winter around the LHIG but not recorded on land (Hutton pers comms, 2016). Feeds primarily on squid and fish.
Swift Parrot *Lathamus discolor*	E	Recorded Vagrant; landbird	One record only from LHI and that is of a dead bird found in 1968. Feeds on nectar, mainly from eucalypts, but also eats psyllid insects and lerps, seeds and fruit.
Wandering or Snowy Albatross *Diomedea exulans (sensu lato)* Amsterdam Albatross *Diomedea amsterdamensis*	V E	Recorded Vagrant/irregular visitor; seabird. Subspecies not identified	Irregular visitor to the LHIG Group. Occasionally seen at sea during winter, autumn and spring. This species feeds on fish and squid.

Antipodean Albatross *Diomedea antipodensis* Tristan Albatross *Diomedea dabbenena* Gibson's Albatross *Diomedea antipodensis gibsoni*	E E V		
White-bellied Storm-petrel *Fregetta grallaria gallaria*	V	Recorded Regular visitor; seabird	The White-bellied Storm-petrel is present on the LHIG from September to May. It feeds at sea on feeds on small crustaceans and squid, and visits its nesting burrows on islets within the LHIG only during the night.
White-capped Albatross *Thalassarche cauta steadi*	V	Rare visitor; seabird	Low numbers occasionally recorded at sea during winter around the LHIG but not recorded on land (Hutton pers comms, 2016). The White-capped Albatross probably has a diet of inshore cephalopods (squid) and fish.
Fish			
Black rock Cod *Epinephelus daemelii*	V	Recorded	The Black Rock Cod is recorded from warm temperate and subtropical waters of the south western Pacific, including off south eastern Australia, Lord Howe Island, Norfolk Island, the Kermadec Islands and northern New Zealand. It is a large reef-dwelling grouper. Adult Black Rockcod are known to occur in caves, gutters and on rocky reefs from near shore environments to depths of at least 50 m (Heemstra and Randall 1993). Recently settled small juveniles are occasionally found in intertidal rock pools along the NSW coastline and larger juveniles are generally captured by anglers on rocky reefs in estuary systems. It is likely that they are epibenthic predators feeding on macroinvertebrates (mainly crustaceans) and fishes on or near the bottom.
Sharks			
Great White Shark *Carcharodon carcharias*	V	Recorded with the LHI Marine Park	Occasionally recorded in waters around the LHIG

Mammals			
Blue Whale *Balaenoptera musculus*	E	Species or habitat likely to occur	May transit waters around the LHIG
Southern Right Whale *Eubalaena australis*	E	Species or habitat likely to occur	May transit waters around the LHIG
Humpback Whale *Megaptera novaeangliae*	V	Recorded Vagrant/irregular visitor; Marine Mammal	May transit waters around the LHIG in early and late winter.
Sperm Whale *Physeter macrocephalus*	V	Recorded Vagrant/irregular visitor; Marine Mammal	May transit waters around the LHIG
Invertebrates			
Magnificent Helicarionid Land Snail *Gudeoconcha sophiae magnifica*	CE	Recorded	A large shelled endemic snail, previously recorded from upper slopes and summits of both Mt Lidgbird and Mt Gower (a total of 18 specimen records from between 1914 and 2002). No live animals were found despite extensive surveys conducted by the Australian Museum in 2001 and 2002 and was not recorded during a targeted 2016 Australian Museum survey on Mt Gower despite considerable efforts (Kohler *et al.,* 2016). This lack of positive records suggest that the species is absent from or rare in the surveyed area of the summit of Mt Gower. Very little is known about the biology and ecology of this endemic snail. The nominate form of G. sophiae has been reported to be crawling on the ground during wet nights (I. Hutton pers. comm.) and the subspecies magnifica is postulated to have the same behaviour. Rats are regarded as a significant threat to this snail (Beeton, 2008a and, Kohler *et al.,* 2016) and are possibly driving this species towards extinction, if they have not done so already. Largely unprotected from rodent predation due to inaccessibility of its range. Continuing decline expected in the absence of rodent eradication, as rodent control is not practicable throughout most of its extant range (Kohler *et al.,* 2016).
Masters' Charopid Land Snail *Mystivagor mastersi*	CE	Recorded	This minute snail, endemic to LHI, is only known from a few sites, including the summit of Mount Lidgbird, Mount Gower, and lowlands sites; Blinky Beach and Boat Harbour (Beeton 2008b), (a total of 10 specimen records from between 1887 and 2002). Specimens from Mt Lidgbird and Mt Gower differ in shell morphology from lowland forms and may represent a distinct, undescribed species. The lowland form has last been recorded in 1971 near Old Settlement Beach and has not been recorded during

			the comprehensive surveys between 1999 and 2002, or during the 2016 survey. Therefore, the lowland form may be very rare or possibly extinct. By contrast, there are several more recent records of *Mystivagor* from the summit of Mt Gower, including one specimen found during the 2016 survey. The population has probably declined, due initially to pigs and goats, then later to predation by the introduced rat (Beeton 2008b). The size of the current population is unknown. Largely unprotected from rodent predation due to inaccessibility of its range. Continuing decline expected in the absence of rodent eradication, as rodent control is not practicable throughout most of its extant range (Kohler *et al.,* 2016). Charopid species generally favour moist forests where they live in leaf litter and feed on decaying plant matter or biofilm. They have a very small range of activity as they attach themselves to the underside of leaves, bark etc. Because of their small size and lifestyle, charopids have a limited dispersal capacity (Kohler *et al.,* 2016).
Lord Howe Flax Snail, Lord Howe *Placostylus bivaricosus*	E	Recorded	The Lord Howe Placostylus is a large land snail; the shell of a mature specimen can be up to 8 cm long. It is endemic to LHI with three sub-species recognised. *Placostylus bivaricosus* is the only sub-species of this snail known to be extant; other sub-species are either listed as extinct (*P.b. cuniculinsulae*) or have not been recorded in over 30 years (*P.b. etheridgei*). It has close relatives in New Zealand (*P. ambagiosus, P. bollonsi and P. hongii*). Other members of the genus occur in the Solomon Islands, Fiji and New Caledonia. Once rather common throughout much of the lowland, the decline of the species was first noted in the 1940s. Recently live individuals of this species have been recorded in targeted surveys at 14 out of selected 20 sites in 2006/2007 and in seven out of 21 selected sites in 2010. During the 2016 survey this species was only found at one site from which it had previously been reported (near Old Settlement Beach). Live animals could not be found in Stephen's Reserve in 2007, 2010 or 2016. Altogether these negative records indicate that the species is probably extinct in Steven's Reserve, where it once was very common (Kohler *et al.,* 2016). Hutton & Hiscox (in Kohler *et al.,* 2016) concluded that the greatest density of live *Placostylus* snails appear to be where the practice of a good rat baiting program is exercised and where dense, heavy leaf litter exists that precludes the snails from predation by introduced birds, which have been identified as a second probable threat. The 2016 survey at Old Settlement Beach indicates that the species is still relatively abundant at this site, but overall the species is considered to be in decline. Animals are rather long-lived (5 to 10 years). Adults are ground dwelling and aestivate, inhabiting the leaf litter of rainforest areas, burying into the sand during drier periods. They are nocturnal and crawl on the ground during humid or wet nights in the leaf litter in moist forests. Juveniles are arboreal (Kohler *et al.,* 2016).

			The Ship Rat identified as a major predator of the species and posing a significant threat to the Placostylus, (NPWS 2001). Continuing decline is expected in the absence of rodent eradication as current rodent control practices are not preventing decline (Kohler *et al.,* 2016). The removal of predators from all its current and previous occurrences is necessary to ensure its long-term survival.
Mount Lidgbird Charopid Land Snail *Pseudocharopa ledgbirdi*	CE	Recorded	This snail, endemic to LHI, is now thought to be confined to Mount Gower although its distribution, prior to 1945, also included Mount Lidgbird and Erskine's Valley (Beeton 2008c). From 1887 until 2002, 239 specimens have been collected for museums. However, the number of snails found has declined markedly since 1981, with only six specimens being recorded for the period 1981 to 2002 (none alive). Because the effort to find snails has increased since 1925, the decline in finds has been interpreted as reflecting a severe drop in the snail's population (Beeton 2008c). Recorded during the recent survey in 2016 (1 specimen on Mt Gower). The decline in the snail's population is likely to be due to damage done to its environment by pigs and goats, then subsequently to predation by the introduced rat (Beeton 2008c). The size of the current population is unknown. Largely unprotected from rodent predation due to inaccessibility of its range. Continuing decline expected in the absence of rodent eradication, as rodent control is not practicable throughout most of its extant range (Kohler *et al.,* 2016). Charopid species generally favour moist forests where they live in leaf litter and feed on decaying plant matter or biofilm. They have a very small range of activity as they attach themselves to the underside of leaves, bark etc. Because of their small size and lifestyle, charopids have a limited dispersal capacity (Kohler *et al.,* 2016).
Whitelegge's Land Snail *Pseudocharopa whiteleggei*	CE	Recorded	Previously recorded from upper slopes and summits of both Mt Lidgbird and Mt Gower (a total of 14 specimen records from between 1887 and 2002). Two specimens recorded during a 2016 survey on Mt Gower. This species is probably uncommon and has a restricted distribution at high altitudes of Mt Gower and Mt Lidgbird (Kohler *et al.,* 2016). The key threat to this snail is predation by introduced rats (Beeton 2008d). Largely unprotected from rodent predation due to inaccessibility of its range. Continuing decline expected in the absence of rodent eradication, as rodent control is not practicable throughout most of its extant range (Kohler *et al.,* 2016). Charopid species generally favour moist forests where they live in leaf litter and feed on decaying plant matter or biofilm. They have a very small range of activity as they attach themselves to the underside of leaves, bark etc. Because of their small size and lifestyle, charopids have a limited dispersal capacity (Kohler *et al.,* 2016).

Reptiles			
Loggerhead Turtle *Caretta caretta*	E	Recorded Vagrant/irregular visitor; Marine Reptile	Occasionally recorded in waters around the LHIG as a visitor in the park during trans-Pacific migrations. Loggerheads are carnivorous, eating shellfish, crabs, sea urchins and jellyfish. No nesting recorded on the LHIG.
Green Turtle *Chelonia mydas*	V	Recorded Vagrant/irregular visitor; Marine Reptile	In the LHIG, Green turtles regularly occur from the sheltered habitats of the lagoon through to the offshore fringing reefs and deeper shelf waters of the park. Feeds predominantly on seagrass and algae. No nesting recorded on the LHIG.
Lord Howe Island Gecko *Christinus guentheri*	V	Recorded land reptile	Endemic to LHI and Norfolk Island. Once abundant on the main island until the mid-1930s, after which it declined dramatically, most likely due to predation by rats. Now rare on Lord Howe Island, more common on Blackburn and Roach Islands. Possibly present on other large offshore islets. This species feeds on beetles, spiders, moths, ants and other insects amongst the leaf litter.
Leatherback Turtle *Dermochelys coriacea*	E	Recorded Vagrant/irregular visitor; Marine Reptile	Has been sighted very occasionally in waters around the LHIG and is likely to migrate periodically through the park's waters; it has a carnivorous diet consisting of jellyfish and other soft-bodied invertebrates. No nesting recorded on the LHIG.
Hawksbill Turtle *Eretmochelys imbricata*	V	Recorded Vagrant/irregular visitor; Marine Reptile	Occasionally recorded in waters around the LHIG and is also observed relatively regularly in the lagoon. It feeds primarily on sponges but also consumes seagrasses, algae, soft corals and shellfish. No nesting recorded on the LHIG.
Flatback Turtle *Natator depressus*	V	Recorded Vagrant/irregular visitor; Marine Reptile	Rarely recorded in waters around the LHIG. No nesting recorded on the LHIG.
Lord Howe Island Skink *Oligosoma lichenigera*	V	Recorded land reptile	Rich metallic bronze or olive above with numerous small brown longitudinal flecks or streaks, to about 80mm in length. Endemic to the Lord Howe Island Group and Norfolk Island. Rare on Lord Howe Island, more common on offshore islets – Blackburn Island, Roach Island and Ball's Pyramid, possibly other large offshore Islets. They feed on beetles, spiders, moths, ants and other insects amongst the leaf litter.
Plants			
Calystegia affinis	CE	Recorded	A delicate thin-stemmed twiner with white to pale pinky-purple flowers. Rare and very localised and restricted in its range. This species is endemic to Lord Howe Island and Norfolk Island. On Lord Howe Island it is known from eight locations; one on a slope at Old Settlement, the others at various locations in the southern mountains. Seed and seedlings potentially browsed by rodents.
Phillip Island Wheat Grass	CE	Recorded	A tufted perennial grass, 30–100 cm tall, with a low, spreading habit, known from the Norfolk Island group and LHI. On LHI the subspecies (about 50 individuals) is record

Elymus multiflorus subsp. kingianus			from only 2 locations (in close proximity) occurring between exposed basalt-derived cliffs near the water's edge, with littoral rainforest upslope (Auld *et al.* 2011). Seeds presumed to be predated by rodents.
Geniostoma huttonii	E	Recorded	A rare scrambling shrub to 1m high. Mainly found on the remote ridges and sheltered habitats in the southern mountains. On Mt Lidgbird it occurs on the south east corner at about 500m altitude. On Mount Gower it occurs on the cliff which leads into Little Pocket and above the Get Up Place.
Little Mountain Palm , Moorei Palm *Lepidorrhachis mooreana*	CE	Recorded	A stout, dwarf palm with a trunk to 2m high endemic to LHI. Confined to higher elevations in the southern mountains, mainly above 750m altitude. Rats are known to predate heavily on the developing seeds, and also chew the stems of leaf fronds.
Rock Shield Fern *Polystichum moorei*	E	Recorded	A fern with distribution limited to the southern mountains, favouring sheltered cliff faces and overhangs. Also known from low elevation near Kings Beach and mouth of Erskine Creek.
Xylosma parvifolia	E	Recorded	Shrub to 2 m high. Restricted to the remote ridges in the southern mountains. Seed and seedlings potentially browsed by rodents.

4.3 Listed Migratory Species

A Protected Matters Search undertaken on 21/12/15 and combined with Island fauna records identified 68 bird species, nine mammal species, five turtle species and four shark and ray species listed as Migratory Species under the EPBC Act, occurring or with the potential to occur in the project area. These are described in the table below.

Table 13 EPBC Listed Migratory Species Occurring or With the Potential to Occur on the LHIG

Species	Type of Presence	Distribution, Abundance and Diet relevant to the LHI REP*
Bar-tailed Godwit *Limosa lapponica*	Regular visitor	The bar-tailed godwit's diet consists of crustaceans, molluscs, worms, insects and some plant material. They arrive on LHI from September (Hutton 1991). The bar-tailed 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.
Black-browed Albatross *Thalassarche melanophris*	Vagrant (pelagic)	Only three records of occurrence in the LHIG, and all were at sea (McAllan *et al.* 2004). This species feeds on fish and squid.
Black-naped Tern *Sterna sumatrana*	Vagrant	Only one bird has been recorded on the LHIG (in April 1989) (McAllan *et al.* 2004).
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).
Brown Booby *Sula leucogaster*	Vagrant (pelagic)	Only four birds seen in the vicinity of the LHIG in the period 1971 to 2003 (McAllan *et al.* 2004. Eats fish.
Buff-breasted Sandpiper *Tryngites subruficollis*	Vagrant	Only one record of this species seen on LHI (circa 1980) (McAllan *et al.* 2004).
Buller's Albatross *Thalassarche bulleri*	Rare visitor (pelagic)	Low numbers occasionally recorded at sea during winter around island but not recorded on land (Hutton pers comms, 2016). Feeds mainly on squid, supplemented by fish and krill
Campbell Albatross *Thalassarche impavida*	Rare visitor (pelagic)	Low numbers occasionally recorded at sea during winter around island but not recorded on land (Hutton pers comms, 2016). Feeds on krill and fish, with some cephalopods, salps and jellyfish.
Caspian Tern *Hydroprogne 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). Mostly feed at sea on a diet consisting of fish. Some insects (taken in pastures) are consumed.

Chatham Albatross *Thalassarche eremita*	Vagrant/irregular visitor (pelagic)	Known to forage over deep water in the area on probably eats fish and cephalopods.
Common Greenshank *Tringa nebularia*	Vagrant/irregular visitor	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.
Common Noddy *Anous stolidus*	Regular visitor; breeds LHIG	Although present mainly from September to May, Common Noddies have been seen on the LHIG in all months (NSWBA cited in McAllan *et al.* 2004). They leave their nest early in the morning to surface-skim the sea for fish and small crustaceans (Hutton 1991). They return late in the day. Egg laying commences in October.
Common Sandpiper *Tringa hypoleucos*	Vagrant/irregular visitor	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.
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).
Curlew Sandpiper *Calidris ferruginea*	Vagrant/irregular visitor	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.
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 (approximately 6) are seen on LHI between February and July (Hutton 1991).
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. The Eastern Curlew is carnivorous, mainly eating crustaceans (including crabs, shrimps and prawns), small molluscs, as well as some insects
Flesh-footed Shearwater *Ardenna carneipes*	Regular visitor; breeds LHIG	This deep-sea fish-eater arrives at LHI in August and departs in May (McAllan *et al.* 2004).
Fork-tailed Swift *Apus pacificus*	Vagrant	An insectivorous bird only recorded once on LHI (in November 1971) (McAllan *et al.* 2004).
Glossy Ibis	Vagrant	Food is mostly aquatic invertebrates and insects, some fish, rice seed. Only one record for LHI.

Plegadis falcinellus		
Great Knot *Calidris tenuirostris*	Vagrant	Only one bird recorded on the LHIG, and that was in November, 2002.
Greater Sand Plover *Charadrius leschenaultii*	Vagrant	The three records for this species, spanning 1914 to 2002, are confined to Spring and Summer.
Grey Plover *Pluvialis squatarola*	Vagrant	Low numbers of birds recorded (two from November 1959 and one from January 1971).
Grey-tailed Tattler *Tringa brevipes*	Regular visitor	Grey-tailed 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 (> 37) were reported in the months November to April.
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).
Lesser Frigatebird *Fregata ariel*	Vagrant (pelagic)	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 frigatebird had been blown to the area. Diet consists of fish.
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.
Little Curlew *Umenius minutus*	Irregular visitor	Only seven records of this species on LHI; and these are for the months from November to March.
Little Tern *Sternula albifrons*	Vagrant	The five individuals recorded on LHI from 1967 to 2003 were seen in the period October to March (McAllan *et al.* 2004). Their diet consists of mainly fish (but also crustaceans, insects and molluscs) collected by diving into the sea or gleaning from its surface.
Pomarine Jaeger *Stercorarius pomarinus*	Vagrant	Only two birds recorded for the LHIG; one in April 1975, the other in March 2002.
Marsh Sandpiper *Tringa stagnatilis*	Vagrant	Only four birds seen on LHI between 1977 and 1998 (McAllan *et al.* 2004).

Masked Booby *Sula dactylatra tasmani*	Resident; breeds LHIG	On LHI year round. Breeds from June to February with most egg-laying occurring in December. LHI is the most southerly breeding colony of boobies in the world (McAllan *et al.* 2004). This sub-species breed only on the Lord Howe, Norfolk and Kermadec island groups (McAllan *et al.* 2004). The birds feed at sea.
Northern Giant Petrel *Macronectes halli*	Rare visitor (pelagic)	Low numbers occasionally recorded at sea during winter around island but not recorded on land, (Hutton pers comms, 2016). The Northern Giant-Petrel eats seal, whale, and penguin carrion, and seal placentae. It also eats substantial quantities of krill and other crustaceans, octopus, squid and fish. It will kill and eat immature albatross and a variety of other seabirds, which are either consumed as carrion or captured at sea.
Northern Royal Albatross *Diomedea epomophora sanfordi*	Rare visitor (pelagic)	Low numbers occasionally recorded at sea during winter around island but not recorded on land (Hutton pers comms, 2016). Feeds primarily on cephalopods, fish, crustaceans and salps.
Oriental Cuckoo *Cuculus saturatus*	Vagrant	Recorded on LHI in December 1913 and between February and May 1915.
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).
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).
Pacific Golden Plover *Pluvialis fulva*	Regular visitor	They arrive on LHI in September and leave in April, although some, less than 10, over-winter. They feed on insects, molluscs, crustaceans and some plant material (Hutton 1991).
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. They are a summer migrant so will be on eggs in Siberia.
Providence Petrel *Pterodroma solandri*	Regular visitor; breeds LHIG	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).
Rainbow Bee-eater	Vagrant	One bird seen in August 1990.

Merops ornatus		
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).
Red-footed Booby *Sula sula*	Vagrant	Only one individual has been recorded on the LHIG (in February 1974) (McAllan *et al.* 2004).
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).
Red-tailed Tropicbird *Phaethon rubricauda*	Regular visitor; breeds LHIG	Summer-breeder; with about 500 to 1000 pairs being active. Only a few birds are present during the winter months (McAllan *et al.* 2004).
Ruddy Turnstone *Arenaria interpres*	Regular visitor	Begin to arrive on LHI in September and most have left by April. A small number remain (10-20) to overwinter (Hutton 1991). They eat crustaceans, molluscs and worms sheltering under organic debris such as seaweed (Hutton 1991). Main foraging habitat is exposed sea grass beds. Ruddy Turnstones will also scavenge opportunistically.
Sharp-tailed Sandpiper *Calidris acuminata*	Regular visitor	Records suggest that low numbers of Sharp-tailed Sandpipers (one to four individuals) are likely to be present on LHI over Spring and Summer (McAllan *et al.* 2004).
Short-tailed Shearwater *Ardenna 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. Feeds at sea on a diet of fish and squid.
Shy Albatross complex Shy Albatross *Thalassarche cauta cauta* Salvin's Albatross *Thalassarche cauta salvini*	Rare visitor (pelagic)	Low numbers occasionally recorded at sea during winter (subspecies unknown) around island but not recorded on land (Hutton pers comms, 2016). Diet includes fish, squid, crustaceans and tunicates.

White-capped Albatross *Thalassarche cauta steadi*		
Sooty Shearwater *Ardenna 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.
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 near Balls Pyramid between 1978-1980 (McAllan *et al.* 2004). The Southern Giant-Petrel is an opportunist scavenger and predator. In summer at least, it will scavenge primarily penguin carcasses, although it will also feed on seal and whale carrion. It catches and kills live birds. It is also recorded consuming octopus, squids, krill other crustaceans, kelp, fish, jellyfish, and rabbit.
Southern Royal Albatross *Diomedea epomophora (sensu stricto)*	Rare visitor (pelagic)	Low numbers occasionally recorded at sea during winter around island but not recorded on land (Hutton pers comms, 2016). Feeds primarily on squid and fish.
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.
Wandering Albatross complex: Wandering Albatross *Diomedea exulans* (sensu lato) Amsterdam Albatross *Diomedea amsterdamensis* Antipodean Albatross *Diomedea antipodensis* Tristan Albatross *Diomedea dabbenena*	Vagrant	Only five records of occurrence in the LHIG, species unknown. 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.
Wandering Tattler	Regular visitor	Records indicate that this bird may be present on LHI only over late Summer and Autumn.

Tringa incana		
Wedge-tailed Shearwater *Ardenna pacifica*	Regular visitor; breeds LHIG	Small numbers arrive at breeding sites on LHI in late August, but the bulk of the population (10,000-100,000 pairs) only arrives in mid to late September. Adults depart April, chicks leave in May. Feeds at sea in deep water. Birds return to the island and their burrows on or after dusk.
Westland Petrel *Procellaria westlandica*	Vagrant	Only one at-sea record for this species for the LHIG.
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.
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.
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). Diet consists of fish caught offshore.
White-throated Needletail *Hirundapus caudacutus*	Irregular visitor	An insectivorous bird that may be present between September and April.
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.
Wilson's Storm- petrel *Oceanites oceanicus*	Vagrant	Only one record; a bird seen near Balls Pyramid in March 2002 (McAllan *et al.* 2004).
Antarctic Minke Whale *Balaenoptera bonaerensis*	Rare visitor	May transit waters around the LHIG
Brysdes Whale *Balaenoptera edeni*	Rare visitor	May transit waters around the LHIG
Blue Whale *Balaenoptera musculus*	Rare visitor	May transit waters around the LHIG
Pygmy right whale	Rare visitor	May transit waters around the LHIG

Caperea margniata		
Great White Shark *Carcharodon carcharias*	Recorded with the LHI Marine Park	Occasionally recorded in waters around the LHIG
Loggerhead Turtle *Caretta caretta*	Recorded Vagrant/irregular visitor; Marine Reptile	Occasionally recorded in waters around the LHIG as a visitor in the park during trans-Pacific migrations. Loggerheads are carnivorous, eating shellfish, crabs, sea urchins and jellyfish. No nesting recorded on the LHIG.
Green Turtle *Chelonia mydas*	Recorded Vagrant/irregular visitor; Marine Reptile	In the LHIG, Green turtles regularly occur from the sheltered habitats of the lagoon through to the offshore fringing reefs and deeper shelf waters of the park. Feeds predominantly on seagrass and algae. No nesting recorded on the LHIG.
Leatherback Turtle *Dermochelys coriacea*	Recorded Vagrant/irregular visitor; Marine Reptile	Has been sighted very occasionally in waters around the LHIG and is likely to migrate periodically through the park's waters; it has a carnivorous diet consisting of jellyfish and other soft-bodied invertebrates. No nesting recorded on the LHIG.
Hawksbill Turtle *Eretmochelys imbricata*	Recorded Vagrant/irregular visitor; Marine Reptile	Occasionally recorded in waters around the LHIG and is also observed in the lagoon. It feeds primarily on sponges but also consumes seagrasses, algae, soft corals and shellfish. No nesting recorded on the LHIG.
Southern Right Whale *Eubalaena australis*	Rare visitor	May transit waters around the LHIG
Dusky Dolphin *Lagenorhynchus obscurus*	Rare visitor	May transit waters around the LHIG
Mackerel Shark *Lamna Nasus*	Rare visitor	Occasionally recorded in waters around the LHIG
Reef Manta Ray *Manta alfredi*	Rare visitor	Occasionally recorded in waters around the LHIG
Giant Manta ray *Manta birostris*	Rare visitor	Occasionally recorded in waters around the LHIG
Humpback Whale *Megaptera novaeangliae*	Recorded Vagrant/irregular visitor; Marine Mammal	Occasionally recorded in waters around the LHIG

Flatback Turtle *Natator depressus*	Recorded Vagrant/irregular visitor; Marine Reptile	Rarely recorded in waters around the LHIG. No nesting recorded on the LHIG.
Killer Whale *Orcinus Orca*	Rare visitor	May transit waters around the LHIG
Sperm Whale *Physeter macrocephalus*	Recorded Vagrant/irregular visitor; Marine Mammal	Occasionally recorded in waters around the LHIG

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

4.4 Commonwealth Marine Area

4.4.1 Description

Ocean waters from the high water mark to three nautical miles offshore from Lord Howe Island (including the Admiralty Islands and Balls Pyramid) form part of the state of NSW and are protected under the approximately 47,000 hectare NSW Lord Howe Island Marine Park, declared in 1999 (see Figure 26).

The Australian Economic Exclusion Zone and Territorial Sea commence three nautical miles from shore of the LHIG, extending 200 nautical miles. The recently declared 110,000km^2 Lord Howe Commonwealth Marine Reserve (replacing the former 3,000 km^2 Lord Howe Island Marine Park (Commonwealth Waters)) also commences three nautical miles from the high water mark of the LHIG (see Figure 26). Transitional management arrangements were in place however no operational changes were yet in effect.

The waters of Lord Howe Island are renowned for their clarity, relatively high coral and algae cover. The island supports the southernmost barrier coral reef and associated lagoon in the world, differing considerably from more northerly warm water reefs. It also provides a rare example of the transition between coral and algal reefs due to movement of tropical and temperate water around the Island (known as the Tasman Front). This front forms where the eastward flow of the warm East Australian Current meets the waters of the southern temperate Tasman Current (Environment Australia, 2002).

The fringing coral reef and associated sheltered lagoon, open coast, near shore rocky reefs, sandy beaches, mid-shelf reefs, intertidal reefs, seagrass beds, mangroves, unconsolidated shelf habitats, rugged seamount shelves and slopes, pelagic waters shallow inshore lagoons, and the steep drop offs to deep ocean create a diverse topography that maximises exposure to ocean currents from all directions and thus the potential for high biodiversity (Environment Australia, 2002). Tropical species tend to dominate in terms of total species counts, although temperate animals and plants dominate in terms of abundance and biomass (Marine Parks Authority 2010b). A number of EPBC listed species are recorded within Lord Howe Island waters. These are discussed in previous sections of this referral.

Examples of World Heritage values of the Lord Howe Island Group specific to the marine environment (Environment Australia, 2002) include:

- the unusual combination of tropical and temperate taxa of marine flora and fauna, including many species at their distributional limits, reflecting the extreme latitude of the coral reef ecosystems which comprise the southernmost true coral reef in the world;
- the diversity of marine benthic algae species, including at over 300 species of which 12 per cent are endemic
- the diversity of marine fish species, including 447 species of which 400 are inshore species and 15 are endemic; and
- the diversity of marine invertebrate species, including more than 83 species of corals and 65 species of echinoderms of which 70 per cent are tropical, 24 per cent are temperate and 6 per cent are endemic (Environment Australia, 2002)

Limited information is available on the productivity and ecological importance of the flora, fauna or communities of the deeper shelf waters other than to note that they are clearly unique (Environment Australia, 2002).

The seamount areas appear to be isolated marine systems and that low species overlap between different seamounts in the region leads to highly localised species distributions that are exceptional for the deep sea. (Environment Australia, 2002)

It is difficult to distinguish the values of the NSW Lord Howe Island Marine Park from the Lord Howe Commonwealth Marine Reserve so a summary of value is presented below.

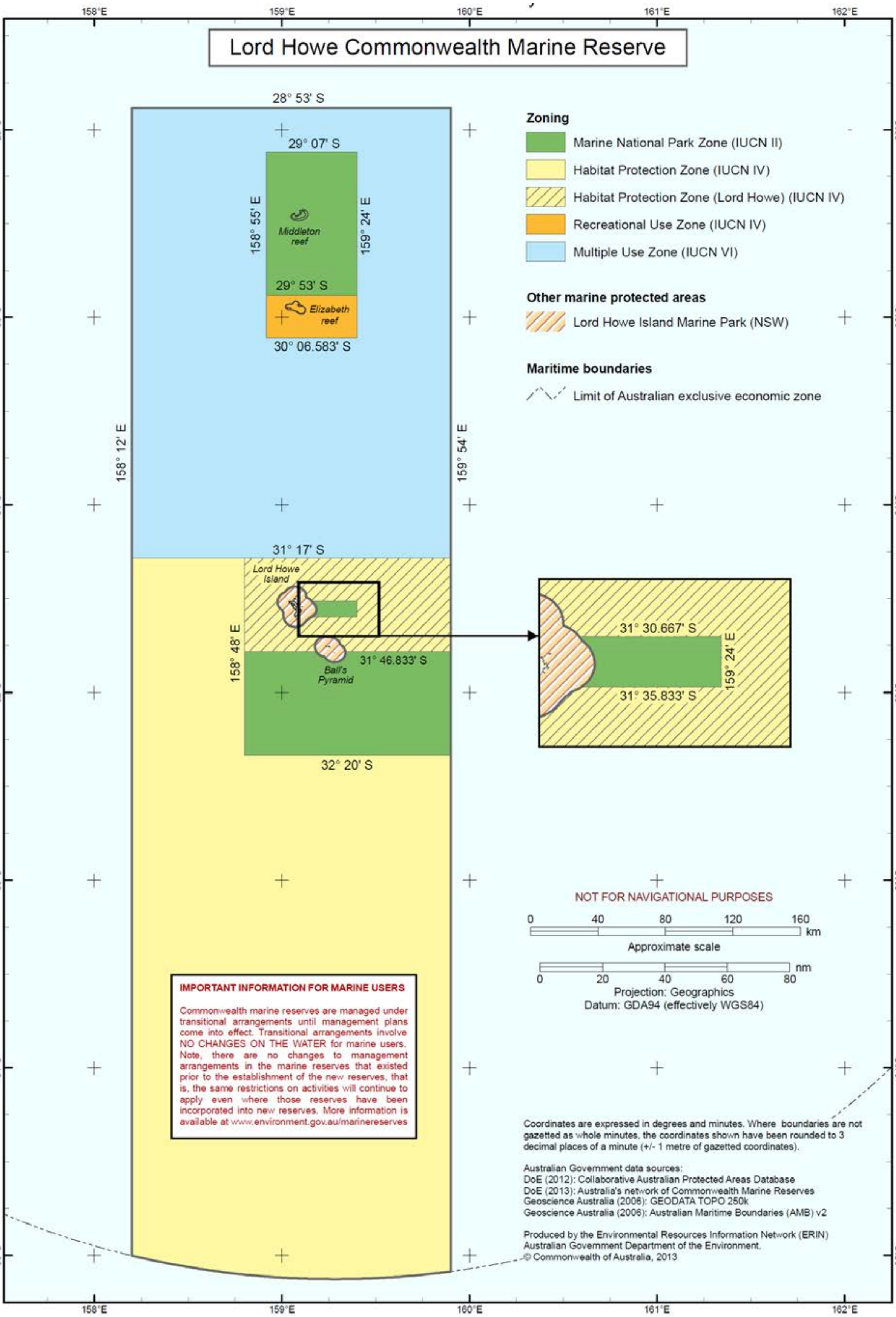


Figure 26 Commonwealth Marine Reserve Boundary

Fish

Lord Howe Island supports a diverse fish fauna, with 447 species and 107 families recorded the Island. There are 47 species of wrasse, 25 of damselfish, 23 gobies and 22 coralfish. Butterfly cod, parrot fish, painted morwong and the doubleheader are commonly found in the lagoon (Environment Australia, 2002). The deep-water pelagics known through fishing activities include marlin (blue and striped), sharks (Galapagos, whalers, some tigers, whites and makos), sailfish, dolphin fish, yellowfin tuna, wahoo, trevally, bonito, yellow-tail kingfish and spangled emperor.

Corals, Invertebrates and Echinoderms

Coral and echinoderm species found at Lord Howe Island include common and widespread tropical forms which also occur on the Great Barrier Reef, as well as tropical species at their southern limits of distribution and subtropical species which are rare or absent from the Great Barrier Reef.

There are at least 83 species from 33 genera in 11 families; this represents relatively high diversity considering the Islands' latitude and isolation from other major coral communities. More than 65 species of echinoderms, made up of 70 per cent tropical species, 24 per cent temperate species and 6 per cent endemic species, have also been recorded (Environment Australia, 2002).

Mobile invertebrates are highly diverse, with more than 1,500 species of molluscs (snails and shellfish) likely to occur in the park, in addition to at least 110 species of echinoderms (Hoggett and Rowe 1988), and 70 species of crustaceans (Marine Parks Authority 2010b).

Whilst there is limited information available on deep-water invertebrates offshore from the Lord Howe Island group, it is believed that the shelves had a high conservation value due to their relatively pristine state compared to other Australian shelves and the high endemicity of the Island's fauna (Environment Australia, 2002).

Algae

Algae form one of the most striking features of the marine habitat within the Lord Howe Island area. For its size, the Island is one of the richest localities for green macroalgae. Lord Howe Island is also particularly important because it sits at the extreme latitudinal limit of many green algal species and genera. It holds the world's highest latitude populations of many species. There are 174 species of red algae, 68 species of brown algae and 76 species of green algae, which include at least 47 (15%) endemic species. The close proximity of temperate macroalgal and tropical coral community species is considered to be unique globally (Marine Parks Authority 2010b).

Marine Mammals

The bottlenose dolphin *Tursiops truncates* is common in Lord Howe Island waters. Migratory dolphins, such as the spinner dolphin, the dusky dolphin and pan tropical spotted dolphin, may pass through. The marine park is in the migratory pathways of species such as the humpback whale *Megaptera novaeangliae*. Other whale species recorded around Lord Howe Island include the sperm whale *Physeter macrocephalus*, pilot whales *Globicephala* sp. and the dense-beaked whale *Mesoplodon densirostris* (Marine Parks Authority 2010b).

Reptiles

Marine reptiles in the park consist of turtles and sea snakes. At least four species of turtle (green, hawksbill, leatherback and logger head have been recorded (Marine Parks Authority 2010). There are no recent records of turtles nesting on the islands of the park. 11 species of sea snake including the yellow-bellied sea snake have been recorded (Marine Parks Authority 2010b).

Birds

Sea birds are described above in sections 3.1 d) and e).

Cultural Heritage

The marine environment has contributed significantly to the cultural heritage value of the LHIG through the first reported sighting European sighting and subsequent claiming as a British possession in 1788, to visiting ships of the First, Second and Third Fleets to whaling, early settlement, trading and provisioning, scientific expedition, and the kentia palm and tourism industries. In addition it is believed that several ships have been lost in the Lord Howe area, including six believed to have been lost in the vicinity of Lord Howe Island however no shipwrecks have been located. Lost ships include the Wolf, wrecked in 1837, the Zeno, wrecked in 1895, Maelgyn, lost in 1907, and the Laura, wrecked in 1913. Another important part of the island's history is the era of the flying boat service, planes that were used for transport to the island from Sydney. Aircraft wreckage of some of these planes is known to be submerged in the deeper waters of the island.

The marine environment continues to be of primary importance to LHI residents and the local economy through recreation, food security and tourism and trade. The local fishing charter operators sell their catch to restaurants and visitors on the island.

Key tourism activities in the NSW and Commonwealth Marine Parks include beach and reef walking, swimming, snorkelling, scuba diving, fish feeding, surfing, underwater photography, windsurfing, sea-kayaking, fishing, sightseeing cruises and eco tours, and other water sports and beach activities

4.5 World Heritage and Natural Heritage Values

4.5.1 World Heritage

The LHIG was inscribed on the World Heritage List in 1982. The LHIG World Heritage property boundary is shown in Figure 27. The Statement of Outstanding Universal Value (UNESCO, 2016) is presented below.

"*Brief synthesis*

The Lord Howe Island Group is an outstanding example of oceanic islands of volcanic origin containing a unique biota of plants and animals, as well as the world's most southerly true coral reef. It is an area of spectacular and scenic landscapes encapsulated within a small land area, and provides important breeding grounds for colonies of seabirds as well as significant natural habitat for the conservation of threatened species. Iconic species include endemics such as the flightless Lord Howe Woodhen (Hypotaenidia sylvestris), once regarded as one of the rarest birds in the world, and the Lord Howe Island Phasmid (Dryococelus australis), the world's largest stick insect that was feared extinct until its rediscovery on Balls Pyramid.

About 75% of the terrestrial part of the property is managed as a Permanent Park Preserve, consisting of the northern and southern mountains of Lord Howe Island itself, plus the Admiralty Islands, Mutton Bird Islands, Balls Pyramid and surrounding islets. The property is located in the Tasman Sea, approximately 570 kilometres east of Port Macquarie. The entire property including the marine area and associated coral reefs covers 146,300 hectares, with the terrestrial area covering approximately 1,540 hectares.

Criterion (vii): The Lord Howe Island Group is grandiose in its topographic relief and has an exceptional diversity of spectacular and scenic landscapes within a small area, including sheer mountain slopes, a broad arc of hills enclosing the lagoon and Balls Pyramid rising abruptly from the ocean. It is considered to be an outstanding example of an island system developed from submarine volcanic activity and demonstrates the nearly complete stage in the destruction of a large shield volcano. Having the most southerly coral reef in the world, it demonstrates a rare example of a zone of transition between algal and coral reefs. Many species are at their ecological limits, endemism is high, and unique assemblages of temperate and tropical forms cohabit.

The islands support extensive colonies of nesting seabirds, making them significant over a wide oceanic region. They are the only major breeding locality for the Providence Petrel (Pterodroma solandri), and contain one of the world's largest breeding concentrations of Red-tailed Tropicbird (Phaethon rubricauda).

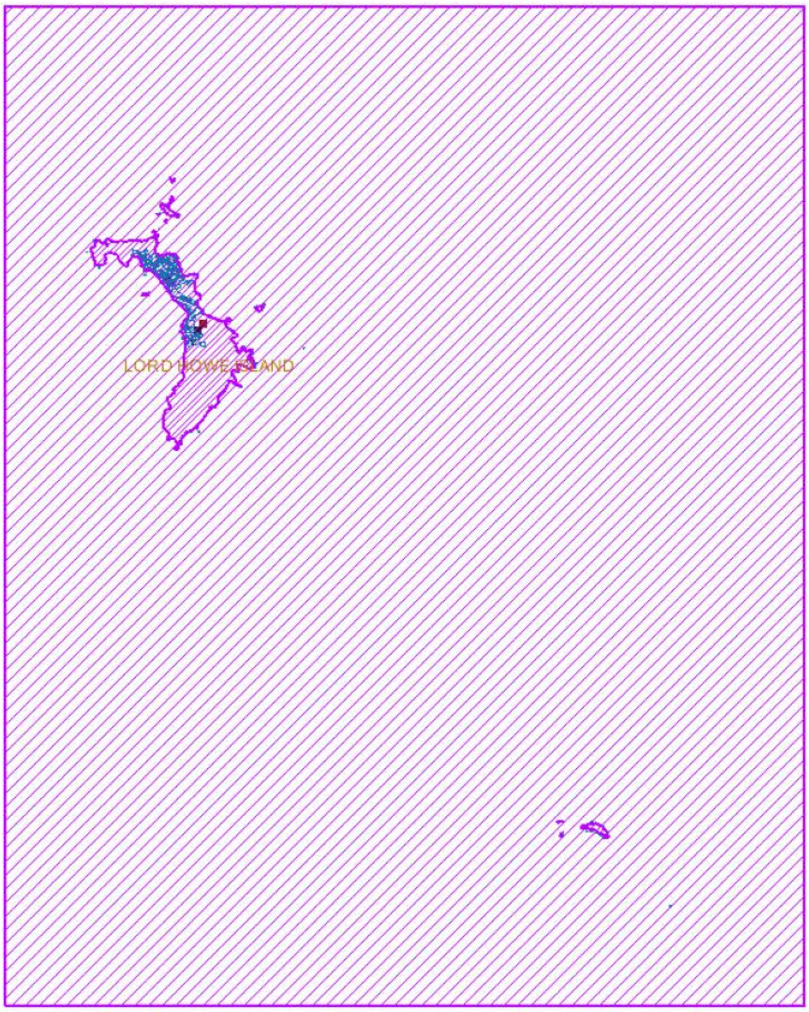
Criterion (x): The Lord Howe Island Group is an outstanding example of the development of a characteristic insular biota that has adapted to the island environment through speciation. A significant number of endemic species or subspecies of plants and animals have evolved in a very limited area. The diversity of landscapes and biota and the high number of threatened and endemic species make these islands an outstanding example of independent evolutionary processes.

Lord Howe Island supports a number of endangered endemic species or subspecies of plants and animals, for example the Lord Howe Woodhen, which at time of inscription was considered one of the world's rarest birds. While sadly a number of endemic species disappeared with the arrival of people and their accompanying species, the Lord Howe Island Phasmid, the largest stick insect in the world, still exists on Balls Pyramid. The islands are an outstanding example of an oceanic island group with a diverse range of ecosystems and species that have been subject to human influences for a relatively limited period.

Integrity

The boundary of the property includes all areas that are essential for maintaining the ecosystems and beauty of the property. It includes all of the above water remains of the ancient shield volcano and surrounding reefs and a substantial proportion of the Lord Howe Island and Balls Pyramid seamounts. The island component of the property is largely Permanent Park Preserve (PPP) and the surrounding waters are Marine Parks. The land area not included in the PPP is managed to ensure that the property's values are maintained. The inscribed property would be strengthened by the inclusion of the entire Commonwealth Marine Park.

At time of inscription concern was raised with respect to a proposal to construct four telecommunications masts without thorough assessment by way of an Environmental Impact Statement. These were then built, although today no longer exist. Other potential threats to the integrity of the property include development pressures, introduced plants and animals and visitor / tourism pressures. Since inscription, a programme improving the conservation status of the Lord Howe Woodhen, and the successful eradication of feral pigs, cats and almost eradication of goats has contributed significantly to the enhancement of World Heritage values beyond their status at listing."



Place Details

Scale 1:300000

Place Name:	Lord Howe Island Group
Place ID:	105694
Heritage List:	National Heritage List
Class:	Natural
Status:	Listed place
Street Name:	
Suburb or Town:	Lord Howe Island
State	NSW
Postcode:	2898

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Australian Government
Department of the Environment and Water Resources

Figure 27 World Heritage Property Boundary

4.5.2 National Heritage

LHIG group is a National Heritage Place, listed on 21 May 2007 in recognition of its natural heritage significance in that it met four of the possible nine criteria as listed in the Commonwealth of Australia Gazette No. S 99, 21 May 2007, namely:

a) the place has outstanding heritage value to the nation because of the place's importance in the course, or

b) pattern, of Australia's natural or cultural history;

c) the place has outstanding heritage value to the nation because of the place's possession of uncommon,

d) rare or endangered aspects of Australia's natural or cultural history;

e) the place has outstanding heritage value to the nation because of the place's potential to yield

f) information that will contribute to an understanding of Australia's natural or cultural history;

g) the place has outstanding heritage value to the nation because of the place's importance in exhibiting particular aesthetic characteristics valued by a community or cultural group.

The Summary Statement of Significance and Official Values (Department of the Environment, 2016) are shown below.

"Summary Statement of Significance

The Lord Howe Island Group was inscribed on the World Heritage List for its outstanding natural universal values: as an example of superlative natural phenomena; and containing important and significant habitats for in situ conservation of biological diversity.

Located 700 kilometres north-east of Sydney and covering an area of 146 300 hectares, the Lord Howe Island Group comprises Lord Howe Island, Admiralty Islands, Mutton Bird Islands, Ball's Pyramid, and associated coral reefs and marine environments.

Nearly seven million years ago geologic movement of the Lord Howe Rise (an underwater plateau) gave birth to a large shield volcano on its western edge. Over time the sea eroded 90 per cent of the original volcano, leaving the islands that today comprise the Lord Howe Island Group.

Lord Howe Island has a spectacular landscape with the volcanic mountains of Mount Gower (875 m) and Mount Lidgbird (777 m) towering above the sea. The central low-lying area provides a marked contrast to the adjacent mountains and northern hills.

There are 241 different species of native plants, of which 105 are endemic to Lord Howe Island. Most of the island is dominated by rainforests and palm forest. Grasslands occur on the more exposed areas of Lord Howe Island and on the offshore islands. Most of the main island and all of the offshore islands are included in the Lord Howe Island Permanent Park Preserve.

The islands support extensive colonies of nesting seabirds and at least 168 bird species have been recorded either living at, or visiting, the islands. A number of these are rare or endangered.

The endangered woodhen is one of the world's rarest bird species. During this century the population of woodhens experienced a significant decline in numbers as a result of hunting by humans, habitat loss and disturbance by feral animals. Over the last few years a successful captive breeding program and other conservation measures have increased the numbers of these small flightless birds to around 220.

The islands are one of two known breeding areas for the providence petrel, a species that is also found nesting on Phillip Island, near Norfolk Island. They also contain probably the largest breeding concentration in the world of the red-tailed tropicbird, and the most southerly breeding colony of the masked booby.

The waters surrounding Lord Howe Island provide an unusual mixture of temperate and tropical organisms. The reef is the southernmost coral reef in the world and provides a rare example of the transition between coral and algal reefs. A marine national park was declared by the State of New South Wales in 1999 to increase protection of the marine environment.

Europeans apparently discovered Lord Howe Island when the island was sighted in 1788 from the British colonial naval vessel HMS Supply, en route from Sydney to the penal colony on Norfolk Island. The first landing was made two months later on the return voyage to Sydney.

By the 1830s there was a small permanent settlement in the lowland area of the main island. The settlers made a living by hunting and fishing, and by growing vegetables, fruit and meat for trade with passing ships.

Pigs and goats, which were introduced to Lord Howe Island for food, later went wild and caused extensive vegetation and habitat changes, threatening populations of native species. Rats arrived on the island in 1918 from a wrecked ship, and have since been responsible for the extinction of five bird species. Over the last decade there have been intensive efforts to control these feral animals and the wild pigs have been successfully eradicated.

Lord Howe Island and its associated islands are under the care, control and management of the LHIB. When carrying out its functions, the LHIB is required to have particular regard to the World Heritage status of the area and to conserve those values for which the area was listed as a World Heritage property.

Official Values

Criterion A Events, Processes-

The place has outstanding heritage value to the nation because of the place's importance in the course, or pattern, of Australia's natural or cultural history;

This place is taken to meet this National Heritage criterion in accordance with subitem 1A(3) of Schedule 3 of the Environment and Heritage Legislation Amendment Act (No. 1) 2003, as the World Heritage Committee has determined that this place meets World Heritage criterion (x).

Criterion B Rarity

The place has outstanding heritage value to the nation because of the place's possession of uncommon, rare or endangered aspects of Australia's natural or cultural history;

This place is taken to meet this National Heritage criterion in accordance with subitem 1A(3) of Schedule 3 of the Environment and Heritage Legislation Amendment Act (No. 1) 2003, as the World Heritage Committee has determined that this place meets World Heritage criterion (x).

Criterion C Research

The place has outstanding heritage value to the nation because of the place's potential to yield information that will contribute to an understanding of Australia's natural or cultural history;

This place is taken to meet this National Heritage criterion in accordance with subitem 1A (3) of Schedule 3 of the Environment and Heritage Legislation Amendment Act (No. 1) 2003, as the World Heritage Committee has determined that this place meets World Heritage criterion (x).

Criterion E Aesthetic characteristics

The place has outstanding heritage value to the nation because of the place's importance in exhibiting particular aesthetic characteristics valued by a community or cultural group.

This place is taken to meet this National Heritage criterion in accordance with subitem 1A (3) of Schedule 3 of the Environment and Heritage Legislation Amendment Act (No. 1) 2003, as the World Heritage Committee has determined that this place meets World Heritage criterion (vii)."

5 Relevant Impacts

5.1 Potential Impacts of the Project

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

Potential impacts likely to arise from the REP are well understood based on impacts (or lack of impacts) that have been documented in the global literature on similar eradications. Therefore it is considered unlikely that unknown, unexpected or irreversible impacts will occur.

The potential likelihood, consequences, duration and extent of these impacts are described in detail in the section below. Potential socio-economic impacts are described in Section 10.

5.2 Assessment of Potential Impacts

5.2.1 Pollution

Fate of the Bait and Toxin in the Environment

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

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

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

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

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

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

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

Fate in the Air

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

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

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

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

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

Fate in Soil

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

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

A condition index for assessing bait breakdown has been developed (Craddock, 2004). The index uses a 1-6 scale, based on the following conditions and illustrated in Figure 28:

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

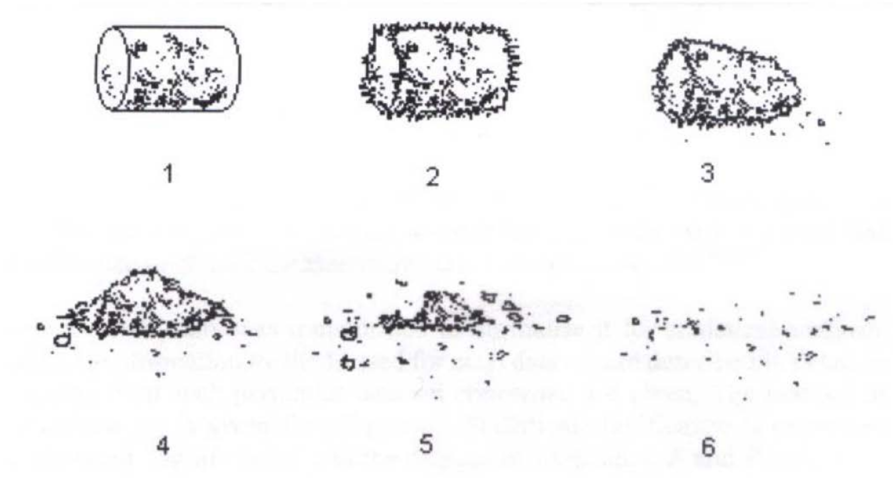

Figure 28 Illustration of typical bait condition (reproduced from Craddock, 2004)

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

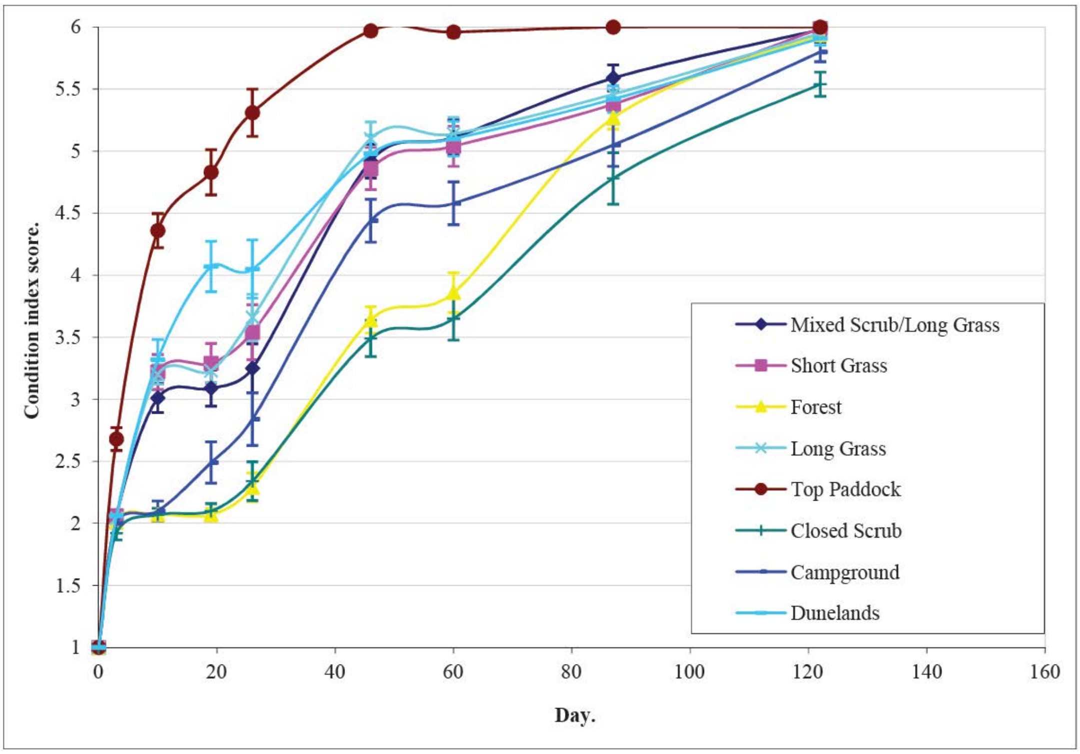

Figure 29 Bait Breakdown times of 10mm pellets (sourced from Craddock 2004)

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

Results of similar breakdown studies of Pestoff 20R in the environment on other temperate islands in 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 takes longer to break down. Environmental factors such as temperature, rainfall, leaf litter, and presence or types of micro-organisms will determine breakdown times.

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

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

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

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

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

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

No residues of Brodifacoum were detected in soil samples taken from Lady Alice Island before, and then 2, 12, 34 and 210 days after an aerial poisoning operation using Talon □20P cereal pell
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 pel
islands in October 1992.

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

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

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

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

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

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

Fate in Fresh Water

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

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

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

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

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

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

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

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

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

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

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

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

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

Fate in the Marine Environment

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

Howald *et al.* (2005) investigated how much bait entered the water when applied aerially to steep cliffs. The bait was applied with a spreader bucket and deflector arm at the rate of 15 kg/ha. SCUBA divers were used to count bait pellets on the sea floor and to observe the behaviour of marine organisms that encountered the baits. Boat- and island-based observers reported that no bait was directly spread into the ocean but a small amount of bait was seen to enter the water as a result of bouncing off the cliff faces (ibid). The divers counted a mean of 72 baits (range: 69-75) over 500 metres, at a 1-4 m depth on the ocean floor. No fish or other animals were observed feeding on the baits. This would equate to less than 0.5% of baits out of the approximate 15,000 baits applied over that area. On Gough Island, Cuthbert *et al.* (2014), found that compared with adjacent flat areas, the vegetated cliff areas of the island retained an average 66-76% of pellets.

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

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

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

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

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

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

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

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

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

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

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

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

Fate in Plants

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

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

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

5.2.2 Bioaccumulation

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

Bioaccumulation in Terrestrial Invertebrates

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

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

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

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

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

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

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

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

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

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

Bioaccumulation in Terrestrial Vertebrates

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

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

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

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

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

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

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

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

Bio-accumulation in fish/aquatic organisms

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

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

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

Following aerial application of baits on Shakespeare Open Sanctuary north of Auckland a large marine monitoring programme was undertaken, collecting 206 samples of 33 marine taxa from 4 sites before and after baiting. Among these samples were 2 blue cod, 1 parore (*Girella tricuspidata*), 1 spotty, 1 triple fin (*Forsterygion varium*), 1 moki (*Latridopsis ciliaris*), and 1 snapper (*Chrysophrys auratus*) taken 1 or 8 days after bait application. No detectable residues were found in any of the fish samples (MDL 0.001ppm). Samples were also collected for Pacific oysters (*n*=7), crayfish (*Jasus edwardsii*) (*n*=2), cushion star (*Asterina spp.*) (*n*=2), shrimps (*n*=1), kina (*n*=2), cockles (*Austrovenus stutchburyi*) (n=2), whelks, crab and sea cucumber (*Stichopus spp*). One of the post bait application samples catseye (*Turbo smaragdus*) had detectable residues (0.006ppm). Interestingly one sample of catseye and one oyster sample taken before any bait was laid had low levels of Brodifacoum (0.009ppm and 0.002ppm respectively). However on re-testing the catseye sample remained below and the oyster sample equal to - the limit of detection (0.001ppm) (Maitland 2012).

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

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

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

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

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

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

Nine of ten black spot sergeant fish (*Abudefduf sordidus*) collected live following aerial bait application of Bell Labs 25w bait on Palmyra Atoll were found to contain residues ranging from 0.05 to 0.315 ppm (whole fish). Two applications of bait (80 kg/ha and 75 kg/ha) were applied about 10 days apart. Fish samples were collected shortly after the second application. A number of mullet (*Liza vaigiensis* and *Moolgarda engeli*) and a single puffer fish were found dead after this application and were found to contain residues ranging from 0.058 to 1.16 ppm. Interestingly, over half the residue results from the dead mullet samples were within the range of residues found in the live sergeant fish (Pitt *et al.* 2012). All hermit crab samples collected soon after baiting contained residues with levels ranging from 0.134 to 1.58 ppm less than 5 days after baiting. By the 3rd sampling period (22-25 days post first bait application) one of 5 samples had no detectable residues, and by the 4^{th} sampling period (6 weeks after the last baiting) only one sample had detectable residues (MLD<0.018). Aquatic fiddler crabs were also collected during this study and showed similar results (Pitt *et al.* 2015)

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

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

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

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

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

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

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

5.2.3 Potential Impact to Threatened Birds

Potential impacts to EPBC listed threatened birds from the proposed LHI REP include:

- Primary poisoning from consumption of bait pellets
- Secondary poisoning from consumption of poisoned rodents, fish or invertebrates
- Disturbance as a result of helicopter activities
- Collisions with the helicopter
- Impacts as a result of handling and captive management during the captive management program (LHIC and LHW only)

Risks to non-target bird species during an eradication programme are a function of the species present on the island group and their behaviour, susceptibility of those species present to the poison, composition and delivery method of the bait and the probability of exposure to the poison either directly or indirectly. The REP poses a significant risk to the LHPC (secondary poisoning) and the LHW (primary and secondary poisoning). These risks and mitigation are discussed in detail below. The remaining Threatened birds have been categorised based on their likelihood of occurrence and abundance on LHI at the time of the proposed REP and potential impacts are discussed. Likelihood of occurrence and impacts are summarised in Table 15.

Land Birds

During 2007, a study using non-toxic baits (similar to those cereal pellets to be used in the proposed eradication operation) was conducted on LHI to examine bait uptake by non-target species (DECC, 2007a) (in Appendix D – LHI Trials Package). These baits contained a fluorescent dye that glowed under ultraviolet light. The Woodhen produced fluorescing faecal samples, indicating that they had consumed bait and was observed feeding directly on baits. Although currawongs did not consume baits they are vulnerable to secondary poisoning from feeding on dead or dying rodents that have taken baits. The study is included in this report as part of Appendix D – LHI Trials Package.

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. This is discussed in more detail below.

During the trial conducted on LHI, some ants, slugs, cockroaches and snails (not Placostylus) were observed feeding on baits (DECC, 2007a). For each of these groups only a small proportion of individuals had consumed bait; 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.

Potential impact to Lord Howe Island Currawong *Strepera graculina crissalis*

The proposed rodent eradication poses a significant threat to Lord Howe Pied Currawong (LHPC). LHPC were not found to consume non-toxic baits during a trial conducted in 2007 (Appendix D – LHI Trials Package), thus they are highly unlikely to eat the baits deployed in the REP but there is a risk that some individuals will succumb to secondary Brodifacoum poisoning by eating poisoned rodents even though most poisoned rodents will die underground. Fenn *at el (*1987) found that during the rat poisoning on English farms that the "majority" of rats died underground, while Harrison *et al.* (1988) estimated that only 4% of rats died above ground during baiting programs. Although approximately 90% of those rodents poisoned are likely to die in dens underground or amongst dense vegetative cover (Taylor 1993, Howald 1999, Buckelew 2007), it is possible that a number of free-ranging LHPC will consume baited rodents during the eradication, thereby placing some of the current population at risk. To mitigate this impact, as many individuals of the population as possible (approximately 50-60%) from across the island (to maintain genetic diversity) will be captured immediately prior to the baiting, and will remain in captivity until baits and rodent carcasses have disintegrated, which is expected to take 100 days after final baiting. After this time the risk of secondary poisoning for currawongs is likely to be negligible (as by then poisoned rodents will no longer be a potential food source). Once breakdown of bait and carcasses has been confirmed, captured birds will be released regardless of whether the eradication was a success or not.

A mortality rate for free-ranging Currawongs cannot be predicted with any certainty but it is expected to be low and thus not have a significant impact on the population. Studies of the diet of LHC have shown that rodents make up only a small proportion of the food taken by LHPC: of 441 identified items of food provided to nestlings only 11 (2.5%) of those items were rodents (Carlile and Priddel 2006). Moreover, 50% of breeding pairs (2 of 4 nests that were closely observed) provided no rodents to their chicks. Further evidence that it is unlikely that a large number of LHPC will succumb to secondary poisoning is provided by the LHIB's practice of collecting dead or moribund birds that are suspected to be suffering from Brodifacoum poisoning as a result of eating rodents that have been poisoned from baits used in the current control programme. Subsequent testing of those birds for Brodifacoum residues have shown that since 2009, no LHPC have been observed or collected with suspected Brodifacoum poisoning, This is in contrast to the 14 individuals of other species processed, 11 (two Masked owls, eight LHW, and one Buff-banded rail) of which tested positive for Brodifacoum residues. Therefore, while 40-50% of LHPC will not be taken into captivity it is unlikely that a significant proportion of these birds will die from eating poisoned rodents.

The stability displayed in the present population size and the presence of non-breeding LHPC during the breeding season (a result of a lack of availability of unoccupied breeding territories), suggests that LHI is currently at carrying capacity for LHPC. If so, the potential death of a proportion of the free-ranging LHPC population from poisoning due to the proposed REP does not, in itself, threaten the long-term viability of the population. It is expected that losses due to poisoning will be compensated by increased breeding success of the survivors, including those released from captivity. The removal of rodents may also lead to an increase in the carrying capacity of LHI and/or a rise in breeding success as there will be substantially more food available for LHPC (e.g., forest fruits, seeds, invertebrates, reptiles and small birds).

In the unlikely event a large number of free-ranging individuals die from secondary poisoning, the genetic diversity in the LHPC population could be reduced. No genetic studies of LHPC have been undertaken, so current levels of genetic diversity or whether any genetic population structure exists, are not known. However, the remoteness of LHI from the mainland source populations suggest that the LHPC population is likely to have been founded by a small number of individuals and thus may already have low levels of genetic diversity (e. g. Bollmer *et al*. 2011). Thus it is difficult to predict the genetic consequences of losing some of the free-ranging individuals from the population. Nonetheless, to mitigate the potential impact of a loss in genetic variation a relatively large number of individuals will be taken into captivity (100 to 120 individuals or 50-60% of the population) and LHPC will be caught from across their island range. This strategy should ensure that a large proportion (>95%) of the current genetic variation is included in the captive population (Weeks *et al.* 2011). An integral component of the captive management of LHPC is the capture of free-ranging LHPC. Carlile and Priddel (2007) noted that LHPC can be caught in reasonable numbers in the period from June to October but are more difficult to catch outside this period. To ensure that LHPC can be caught outside of this optimal period, a number of feeding stations will be established across the island in winter-spring 2016. In 2013 a trial captive management and release of LHPC and LHW was managed by Taronga Zoo staff (Taronga Conservation Society Australia, 2014) with the assistance of OEH Science Manager. The LHPC for the trial were sourced from a single location where a local resident had been regularly feeding the birds. At this single location, not only were the 10 pairs caught and removed for three months of the trial, but a subsequent 55 individuals were caught at the site prior to their release. The feeding station provided an ideal location for capture and monitoring of individuals within a section of the island. The 2007 report by Carlile and Priddel had relied on broad-scale locations for trapping where a maximum of 10 birds could be caught at a single site over an eight–day period. Using the feed station in 2013, 50 birds were caught in a seven–day period (Australian Bird and Bat Banding Scheme data). The feeding table attracts good numbers of visiting birds outside the 'optimum period' determined by Carlile and Priddel (2007) and presents a far superior opportunity for capture of LHPC than previously available. The established stations will provide a reliable source of food for LHPC and will become focal points for captures. Already established stations indicate that LHPC readily use the stations and it is expected that this strategy will enable the necessary number of LHPC to be caught during the time available prior to commencement of rodent baiting.

Holding LHPC in captivity from approximately June until October may disrupt the birds' breeding season for one year. However, it is unlikely that all birds left in the wild will be poisoned by the operation and thus disruption would not impact the entire population, and given that currawongs can live for more than 20 years (David Drayman ABBBS pers com) such disruption is not expected to result in a significant long-term impact to the population.

The captive facility will be located on LHI and will be managed by a highly experienced team of aviculturists most likely from Taronga Zoo. The LHIB is unaware of any previous attempts to hold or breed LHI currawong away from LHI. To ensure all husbandry protocols are correct, a trial involving 10 LHPC was conducted in 2013 (Taronga Conservation Society Australia, 2014) with all birds successfully released. One critical lesson learnt from this trial was how currawongs reacted to being confined with or near other currawongs during the breeding season. Further detail on the proposed captive management is provided in Section 2.237. The trial report is included in Appendix E – Captive Management Package**.** Surveys will be performed post-eradication to monitor the outcomes of the mitigation strategy (for details see Section 6.5).

In summary, in the absence of mitigation, a significant impact to LHPC is likely to occur from the LHI REP. With the proposed mitigation in place, it is considered possible that the REP will still have a significant impact on LHPC through the temporary disruption of a breeding cycle, although it is unlikely that a long-term population decrease will occur. Any potential impacts will be temporary. This temporary potential impact, will be substantially offset by the improvement in biodiversity if impacts of rodents are removed as a result of the REP. No other offsets are proposed.

In the event that rodents are detected after the eradication attempt and contingency measures are considered, potential impacts to the captive managed population will be reassessed.

Potential impact to Lord Howe Woodhen *Hypotaenidia sylvestris*

This species is at risk of both primary and secondary poisoning. Woodhen have been recorded eating non-toxic Pestoff bait pellets (DECC, 2007a). They are also known to eat rodents that have been poisoned during the ground baiting that currently takes place around the Settlement and will also consume poisoned birds.

The protection of this species requires that it be taken into captivity during the eradication. Approximately 80 - 85% of the population will be captured prior to the baiting and will remain in captivity for the duration of the operation; that is, until the baits (and rodent carcasses) have disintegrated and pose no further risk approximately 100 days (Craddock, 2004). After this time the risk of secondary poisoning for woodhens is likely to be negligible (as by then poisoned rodents will no longer be a potential food source). Once breakdown of bait and carcasses has been confirmed, captured birds will be released regardless of whether the eradication was a success or not.

It is expected that individuals that are not captured may succumb to primary or secondary poisoning, however a mortality rate cannot be accurately predicted. Studies of similar species in New Zealand (Weka and Kiwi) have found a wide range in mortality rates to the species from similar eradications. Weka mortality rates as high as 80-90% was observed during a rodent eradiation on Ulva Island (Eason *et al.* 2002) whilst on Taukihepa Island a deliberate attempt to eradicate introduced weka following a rodent eradication was abandoned due to a higher than expected survival of weka post poisoning (P. McClelland pers comm.). Little Spotted kiwi were monitored through the Kapiti Island rat eradication using 50 banded birds, 10 of which also had radio-transmitters (Robertson and Colbourne 2001). Two of the 10 birds with radio-transmitters died (a mortality rate of 20%) within a month of the poison drops. Six months after the eradication, 46 of the banded birds were still alive. Robertson and Colbourne (2001) estimated that in the worst-case, poison induced mortality was 8%. Two brown kiwi were found dead following aerially applied Pestoff 20R on Motuarohia Island as part of Project Island Song in 2009. One was confirmed to have Brodifacoum residues and the other was too decomposed to test. Anecdotal reports of kiwi calls after the operation did not indicate a change in population (Vestena and Walker 2010). At Rarewarewa and Riponui, Northland, none of 55 radio collared brown kiwi died from Brodifacoum poisoning after eradication (Robertson *et al.* 1999).

The captive population will include both adults and juveniles, and will be collected from across LHI to ensure that the deepest practical gene pool is maintained. It should be noted however that the gene pool experienced a severe bottle neck with the reduction in numbers prior to the captive breeding program in the 1980s. Birds originating from the remotest parts of LHI (e.g., the summit of Mt Gower) will be transported to, and back from, the holding facility by helicopter to minimise transport time and its associated stress on the birds. The captive facility will be located on LHI and will be managed by a highly experienced team of aviculturists most likely from Taronga Zoo. Woodhen have previously been successfully held in captivity (Gillespie, 1993) so information is already at-hand for captive management. A trial involving 22 birds was conducted in 2013 to ensure all husbandry protocols are correct (Taronga Conservation Society Australia, 2014). No aggression was noted during the 2013 trial with many birds per aviary. The trial report is included in Appendix E – Captive Management Package. As part of the recovery program and captive breeding program on LHI in the late 1980s, there is anecdotal evidence that two woodhens (a male and a female) were removed to Taronga Zoo on the mainland in

1989. The birds were observed mating but were not bred. The female died in 1990 after 11 months in captivity, with post mortem revealing that she died as a result of being egg bound. The male died in 1994 after more than 4 years in captivity. Results of the post mortem examination indicated that the male died of trauma. There was no indication of what had caused the trauma (Fry, G, pers comms, 2013). A captive colony could be established on the Australian mainland, subject to finding a zoo that is interested. Discussions with Taronga Zoo have indicated that they do not have available space or interest in establishing a LHW population. Discussions are continuing with other zoos. These actions, namely the establishment of on-site and off-island captive facilities, are in accordance with recommendations made in the "Recovery Plan for the Lord Howe Woodhen *Gallirallus sylvestris*" (NPWS 2002) which calls for the development of a plan for the establishment of an on-island captive-breeding facility in the event of a substantial reduction in woodhen numbers; and the establishment of captive populations at sites other than LHI as insurance against a catastrophe affecting the wild population. Further detail on the proposed captive management is provided in Section 2.2.

Woodhens are to be held in captivity during most of the duration of one breeding season. Although the release of the birds is dependent on how long it takes the baits and carcasses to breakdown, it is likely that the woodhen will be released by December, a hundred or so days after the second aerial bait-drop. If so, then the birds will have up to two months of the current breeding season to lay eggs (Gillespie 1993). Body conditioning through diet manipulation, such as the provision of woodgrubs in the weeks leading up to release, may also be able to improve reproduction immediately post release (Gillespie, 1993). Woodhens have also been bred very successfully in captivity on LHI (in pair cages) and may therefore breed in captivity. The full or partial loss of one breeding season is unlikely to have a significant effect on the population particularly given the lifespan can be in excess of 15 years. Similarly, the death of many of those woodhen that are not taken into captivity is also unlikely to result in long-term harm to the overall population. Presently, about 60% of juveniles die in their first year (Harden and Robertshaw 1989) and this is more than likely a result of a lack of high-quality habitat (NPWS 2002) for them to occupy. The death of the adult birds that are not taken into captivity will provide vacant territories for many, otherwise doomed, juveniles that fledge in the years immediately following the rodent eradication.

Previous post-release monitoring of captive LHW shows that the captive breeding programme is likely to be successful. An integral component of the conservation recovery programme for the LHW was an *in situ* captive breeding program established in 1980 (Miller and Mullette 1985). Between 1981 and 1985, 82 captive-reared LHW were released, along with the wild LHW taken into captivity, across six sites in the lowlands and slopes of the southern mountains (Miller and Mullette 1985). Depending on the release site, between 0% and 75% of released LHW were subsequently re-sighted (Harden *et al.* unpubl. data). The site where no released LHW were resighted was Little Slope, which was difficult to access and therefore poorly monitored. However, the number of LHW on Little Slope, where no wild LHW occurred, almost doubled within six years of the release of captive-bred birds (Miller and Mullette 1985; Harden 1999).This indicates survival and/or breeding success of released captive-bred LHW at Little Slope was high. Of the 20 LHW held in captivity in 2013 as part of a trial to establish captive husbandry protocols for the LHI REP (Taronga Zoo Conservation Society 2014), 25% were observed post-release in 2014 and/or 2015.

In the absence of mitigation, a significant impact to woodhens is likely to occur from the LHI REP. However with the mitigation proposed in place, it is considered unlikely that either long term population decrease or major disruption to a breeding cycle will occur. Impacts are likely to be temporary. It is therefore considered unlikely that the REP will have a significant impact on woodhens. In the event that rodents are detected after the eradication attempt and contingency measures are considered, potential impacts to the captive managed population will be reassessed.

The eradication of rodents is likely to result in an increase in terrestrial invertebrates which will likely lead to population increases for woodhen. The density of LHI Wood-feeding Cockroach on Blackburn Island (Carlile and Priddel 2013) suggests that following reintroduction of this species to the main island will present a significant increase in food availability for woodhen.

Regularly occurring threatened non-seabird species

The following listed Threatened non-seabird species occurs as a regular migrant on LHI (as per Table 12):

- Far Eastern Curlew *Numenius madagascariensis*

Table 14 summarises data on occurrence and abundance of the Eastern Curlew collected during the COG surveys in 2013 and 2014. The species consistently occurred at low abundance and had highly localised distributions on LHI.

Table 14 Occurrence and abundance of threatened regular shorebird species on LHI recorded in COG surveys.

The percentage of survey sites (n=96) where the species was present, the percentage of surveys (n=300 in 2013, 384 in 2014) that detected the species, and the maximum count within a 50m radius of the survey point summed across survey sites are shown for each species.

Species	Survey sites (%)	Surveys (%)	Max. count

	2013/2014	2013/2014	2013/2014
Far Eastern Curlew	0.0 / 1.0	0.0 / 0.3	0 / 0

These data suggest the abundance of the Eastern Curlew will be very low in winter 2017, even after taking into consideration the COG survey sites represented only a small proportion of the land area within the lowlands. The expected low abundance is also supported by published records and observations of LHI Board and OEH ecologists and island naturalists (J. Shick and I. Hutton pers. comm.).

The small sizes of the populations of the Eastern Curlew on LHI are insignificant at a state, national and international scale. Therefore, the proposed REP is unlikely to impact an ecologically significant proportion of the population of these species.

Irregular or vagrant threatened non-seabird species

The following four listed Threatened non-seabird species occur as irregular migrants or vagrants on (as per Table 12):

- Australasian Bittern Botaurus poiciloptilus
- Curlew Sandpiper Calidris ferruginea
- Australian Painted Snipe Rostratula australis
- Swift Parrot Lathamus discolor

Only the Curlew Sandpiper, with nine records has been recorded more than five times on LHI. None of the four irregular or vagrant species have been recorded breeding on the LHIG and the small number of individuals of each species that have been recorded indicate the LHI population is insignificant at a state, national and international scale.

It is therefore highly unlikely any of the four listed Threatened non-seabird species will be present during the proposed baiting operations in winter 2017. The impact of the proposed rodent eradication programme is assessed to be non-existent for these four species.

Seabirds

Nineteen listed Threatened seabird taxa occur on LHI or in the waters surrounding the island group (as per Table 15). These are divided below into, species that regularly occur at sea surrounding LHI, and vagrant species recorded at sea around LHI.

Regularly occurring pelagic seabirds

The white-bellied storm-petrel breeds on the outer islands of the LHIG. The Kermadec petrel breeds on Balls Pyramid. The remaining seven regularly occurring listed Threatened seabird taxa are regularly, but sometimes infrequently, observed at sea surrounding the LHIG (as per Table 15 EPBC Referral 2016-7703). None of these remaining seven species have been recorded on land within the LHIG.

- Buller's Albatross *Thalassarche bulleri*
- Campbell Albatross *Thalassarche melanophris impavida*
- Kermadec Petrel *Pterodroma neglecta*
- Northern Giant Petrel *Macronectes halli*
- Northern Royal Albatross *Diomedea sanfordi*
- Salvin‘s Albatross *Thalassarche cauta salvini*
- Shy Albatross *Thalassarche cauta cauta* (formerly *Thalassarche cauta sensu stricto*)
- Southern Royal Albatross *Diomedea epomophora epomophora*
- White-bellied Storm-petrel

The white-bellied storm-petrel breeds on outer islands of the Lord Howe Group. White-bellied storm-petrels forage in deep water and only come on land at night from September to May. This species is unlikely to be present during the baiting operation and thus is unlikely to come into contact with bait. No impact on this species is expected. Kermadec petrel breeds on Balls Pyramid, (which will not be baited) from November to May and may be present around Mt Gower in summer. This species also forages in deep water and is unlikely to come into contact with bait. The remaining seven regularly occurring pelagic seabird taxa also typically forage in deeper water or are observed on migration, as such they are very rarely observed in the relatively shallow waters within two kilometres of LHI, the Admiralty Islands and surrounding islets (J. Shick pers. comm.). Consequently, regularly occurring pelagic seabird taxa are highly unlikely to come into contact with Brodifacoum baits or come within 2km of helicopters during the baiting operation and for the duration baits are accessible within the environment. The impact of the proposed rodent eradication programme is therefore assessed to be non-existent or negligible for these nine species.

Vagrant pelagic seabirds

Ten listed Threatened seabird species have been recorded on seven or fewer occasions in the LHIG since ornithological records commenced in the early 1900s, but do not breed in the LHIG.

- Black-browed Albatross *Diomedea melanophris*
- Fairy Prion *Pachyptila turtur*
- Gould's Petrel *Pterodroma leucoptera*
- Southern Giant Petrel *Macronectes giganteus*
- Wandering Albatross complex (comprised of *Diomedea exulans*, *D. amsterdamensis*, *D. antipodensis antipodensis, D. a. gibsoni* and *D. dabbenena*; treated here as a single taxon since available records do not distinguish among these morphologically similar and previously conspecific taxa)

Most vagrant seabird taxa were recorded only at sea. Of the records where dates were given, all occurred in spring, summer or autumn. Beachcast specimens of Fairy Prions have been found in winter. It is highly unlikely any of these vagrant seabird taxa will be present during the proposed baiting operations in winter 2017. If any are present, they are highly unlikely to occur in shallower water within 2km from LHI, the Admiralty Islands and surrounding islets. The impact of the proposed rodent eradication programme is therefore assessed to be non-existent or negligible for listed vagrant seabirds.

Table 15 Significant Impacts to EPBC Listed Threatened Birds

Species	EPBC Act Status	Significant Impact from the LHI REP
Australasian Bittern *Botaurus poiciloptilus*	E	No impact at local, regional, state, national or international scale. Species unlikely to be present.
Black-browed Albatross *Thalassarche melanophris*	V	No impact at local, regional, state, national or international scale. Species unlikely to be present and unlikely to have exposure to bait.
Bullers Albatross *Thalassarche bulleri*	V	No impact at local, regional, state, national or international scale. Species unlikely to be present and unlikely to have exposure to bait.
Campbell Albatross *Thalassarche melanophris impavida*	V	No impact at local, regional, state, national or international scale. Species unlikely to be present and unlikely to have exposure to bait.
Chatham Albatross *Thalassarche eremita*	E	No impact at local, regional, state, national or international scale. Known to forage in the area but unlikely to have exposure to bait.
Curlew Sandpiper *Calidris ferruginea*	CE	No impact at local, regional, state, national or international scale. May be small number present but unlikely to have significant exposure to bait.
Eastern Curlew *Numenius madagascariensis*	CE	No impact at local, regional, state, national or international scale. Species unlikely to be present.
Fairy Prion *Pachyptila turtur Subantarctica*	V	No impact at local, regional, state, national or international scale. Species unlikely to be present and unlikely to have exposure to bait.
Gould’s Petrel *Pterodroma leucoptera*	E	No impact at local, regional, state, national or international scale. Species unlikely to be present and unlikely to have exposure to bait.
Kermadec Petrel *Pterodroma neglecta*	V	No impact at local, regional, state, national or international scale. Species unlikely to be present and unlikely to have exposure to bait.
Lord Howe Island Currawong *Strepera graculina crissalis*	V	Yes. This subspecies is endemic to LHI so any impact would be at local, regional, state, national and international scales. With the proposed mitigation in place, it is considered possible that the REP will still have a significant impact on currawongs through disruption of a breeding cycle. See

		further detail above. This temporary potential impact will be substantially offset by the improvement in biodiversity if impacts of rodents are removed as a result of the REP. No other offsets are proposed.
Lord Howe Woodhen *Hypotaenidia sylvestris*	V	No impact at local, regional, state, national or international scale. With the proposed mitigation in place, it is considered unlikely that the REP will have a significant impact on woodhens. See further detail above.
Northern Giant Petrel *Macronectes halli*	V	No impact at local, regional, state, national or international scale. Species unlikely to be present and unlikely to have exposure to bait.
Northern Royal Albatross *Diomedea sanfordi*	E	No impact at local, regional, state, national or international scale. Species unlikely to be present and unlikely to have exposure to bait.
Painted Snipe *Rostratula benghalensis*	E	No impact at local, regional, state, national or international scale. Species unlikely to be present.
Salvin's Albatross *Thalassarche cauta salvini*	V	No impact at local, regional, state, national or international scale. Species unlikely to be present and unlikely to have exposure to bait.
Shy Albatross *Thalassarche cauta cauta*	V	No impact at local, regional, state, national or international scale. Species unlikely to be present and unlikely to have exposure to bait.
Southern Giant Petrel *Macronectes giganteus*	E	No impact at local, regional, state, national or international scale. Species unlikely to be present and unlikely to have exposure to bait.
Southern Royal Albatross *Diomedea epomophora*	V	No impact at local, regional, state, national or international scale. Species unlikely to be present and unlikely to have exposure to bait.
Swift Parrot *Lathamus discolor*	E	No impact at local, regional, state, national or international scale. Species unlikely to be present and unlikely to have exposure to bait.
Wandering or Snowy Albatross *Diomedea exulans (sensu lato)* Amsterdam Albatross *Diomedea amsterdamensis*	V E	No impact at local, regional, state, national or international scale. Species unlikely to be present and unlikely to have exposure to bait.

Antipodean Albatross *Diomedea antipodensis* Tristan Albatross *Diomedea dabbenena* Gibson's Albatross *Diomedea antipodensis gibsoni*	E E V	
White-bellied Storm-petrel *Fregetta grallaria*	V	No impact at local, regional, state, national or international scale. Species unlikely to be present and unlikely to have exposure to bait.
White-capped Albatross *Thalassarche cauta steadi*	V	No impact at local, regional, state, national or international scale. Species unlikely to be present and unlikely to have exposure to bait.

5.2.4 Potential Impacts to Threatened Marine Species

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

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

Black Cod and Great White Sharks are unlikely to have sufficient exposure to the bait to have a significant impact at a population level.

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

It is very unlikely that Green Turtles *Chelonia mydas* could be exposed to rodenticides by consuming baits directly or prey items that have ingested rodenticides. Adult Green Turtles feed exclusively on various species of seagrass and seaweed. Plants have not been documented to take up and store anticoagulants; therefore no effect on adult Green Turtles is expected to occur from ingestion of rodenticide in their food.

Juvenile Green Turtles and the other four species of turtle (Flatback Turtle *Natator depressus*, Hawksbill Turtle *Eretmochelys imbricata*, Leatherback Turtle *Dermochelys coriacea* and Loggerhead Turtle *Caretta caretta*) that may be encountered in the marine park are carnivorous, and will eat soft corals, shellfish, crabs, sea urchins and jellyfish. However, it is unlikely that these turtles will encounter marine invertebrates that may have been contaminated with Brodifacoum as a result of aerial baiting the LHIG with Pestoff® 20R. Evidence against the existence of a significant dietary exposure pathway for invertebrates is outlined in section 5.2.2. No turtle nesting occurs on the LHIG.

In summary, the proposed baiting of LHI does not pose a threat to threatened marine life (Cetaceans, turtles, fish or sharks) because:

- The use of specialised equipment on the bait hopper will ensure minimal bait entry to the water. The amount of bait that may bounce off the cliffs to fall into the sea will be minimal (Howald *et al.* 2005; Samaniego-Herrera *et al.* 2009);
- The breakdown of baits that do land in the sea will be rapid (Empson and Miskelly 1999), therefore the opportunity for fish to take baits will be limited;
- Fish have shown a lack of interest in baits (Samaniego-Herrera *et al.* 2009, U.S. Fish and Wildlife Service and Hawai'i Department of Land and Natural Resources 2008), so it is unlikely that many fish will take baits;
- The possible death of those few fish that find and eat enough baits to prove fatal does not pose a threat at the population level;
- Baiting other islands using similar methods, although sometimes using significantly more bait, has not resulted in adverse effects on the marine environment as a whole.
- Potential impacts are likely to be very localised and temporary in nature.

Further details regarding potential impacts to the marine environment are provided in Section 3.1 f).

Table 16 Significant Impacts to EPBC Listed Threatened Marine Animals

Threatened Marine Animals	EPBC Act Status	Significant Impact from the LHI REP
Black rock Cod *Epinephelus daemelii*	V	No. Unlikely to have sufficient exposure to bait.
Great White Shark *Carcharodon carcharias*	V	No. Species unlikely to be present or present in small numbers. Unlikely to have sufficient exposure to bait.
Blue Whale *Balaenoptera musculus*	E	No. Species unlikely to be present or present in small numbers. Unlikely to have sufficient exposure to bait.

Southern Right Whale *Eubalaena australis*	E	No. Species unlikely to be present or present in small numbers. Unlikely to have sufficient exposure to bait.
Humpback Whale *Megaptera novaeangliae*	V	No. Species unlikely to be present or present in small numbers. Unlikely to have sufficient exposure to bait.
Sperm Whale *Physeter macrocephalus*	V	No. Species unlikely to be present or present in small numbers. Unlikely to have sufficient exposure to bait.
Loggerhead Turtle *Caretta caretta*	E	No. Species unlikely to be present or present in small numbers. Unlikely to have sufficient exposure to bait.
Green Turtle *Chelonia mydas*	V	No. Unlikely to have sufficient exposure to bait.
Leatherback Turtle *Dermochelys coriacea*	E	No. Species unlikely to be present or present in small numbers. Unlikely to have sufficient exposure to bait.
Hawksbill Turtle *Eretmochelys imbricata*	V	No. Species unlikely to be present or present in small numbers. Unlikely to have sufficient exposure to bait.
Flatback Turtle *Natator depressus*	V	No. Species unlikely to be present or present in small numbers. Unlikely to have sufficient exposure to bait.

5.2.5 Potential Impacts to Threatened Invertebrates

The only REP associated activity with the potential to impact on EPBC listed terrestrial invertebrates is through direct consumption of bait (primary poisoning).

Consumption of Brodifacoum is not expected to have significant effects on invertebrates as they have different blood clotting systems to mammals and birds. Introduced slugs and snails used as analogues for native snail species in experiments suggest NZ terrestrial molluscs are not susceptible to Brodifacoum poisoning (Broome *et al.*2016). Whilst most studies of molluscs indicate a lack of impact of Brodifacoum (Booth *et al.* 2003; Bowie and Ross 2006), a study conducted in Mauritius reported mortality in two snail species after reports of snails consuming toxic baits (Gerlach and Florens 2000). Trials done in NZ so far have failed to show any effect on invertebrates feeding on Brodifacoum baits (Booth *et al.* 2001; Booth *et al.* 2003; Craddock 2003; Bowie and Ross 2006).

Booth *et al.* (2003) carried out a laboratory evaluation of the toxicity of Brodifacoum to native snails, using introduced common garden snails as a model. In one experiment, common garden snails were exposed to soil contaminated with Brodifacoum at 0.02 to 2 mg ai/kg. In a second experiment, snails were exposed to contaminated soil (100 to 1000 mg ai/kg) and Talon® 20P pellets. No snail mortality was observed in either experiment. The authors concluded that primary poisoning of native *Powelliphanta* snails from cereal pellets containing Brodifacoum was unlikely.

Bowie and Ross (2006) allowed introduced slugs (*Deroceras* spp.) held in captivity, to feed freely for 40 days on Talon 50WB® wax baits containing 0.05 mg/kg Brodifacoum. No mortality was observed.

Gerlach and Florens (2000) reported 100% mortality of two Seychelles Islands snails (*Pachnodus silhouettanus* and *Achatina fulica*) after they consumed Brodifacoum baits. Lethal doses varied with snail size, with 15-20mm *P. silhouettanus* being killed by a dose of 0.01 to 0.2 mg/snail within 72 hours. This is equivalent to a *P. silhouettanus* eating between 0.5 and 10 g of 0.02 g/kg Brodifacoum bait. *A. fulica* were killed by a dose of 0.04 mg/kg in 72 hours (Booth *et al.* 2003). This is equivalent to an *A. fulica* eating approximately 0.2 g of 0.02 g/kg Brodifacoum bait. Both species are ground-dwellers and ecologically similar to the larger, ground-dwelling species on LHI, such as *P. bivaricosus*, *G. sophiae* and *G. s. magnifica*.

Gerlach and Florens (2000) also reported observing *Pachystyla bicolor* eating baits and finding significant numbers of recently dead snails following a Brodifacoum operation to control rats in Mauritius.

In another experiment by Brooke *et al.* (2011) native snails were collected from the litter layer on Henderson Island in the Pitcairn group and held on the island in plastic boxes to which broken pieces of Pestoff 20R cereal pellets containing 20mg/kg Brodifacoum were added. A control group of snails in boxes were kept in similar conditions with no exposure to Brodifacoum. Each of seven species (Orobophana spp and Achatinellids spp) was tested this way for 10 days. After 10 days exposure a total of 3 snails from the treatment groups were found dead from a total of 57. In the control boxes a total of 4 snails were found dead from a total of 53 held. None of the dead snails were found to contain Brodifacoum residues.

During 2007, a study using non-toxic baits (similar to those cereal pellets to be used in the proposed eradication operation) was conducted on LHI to examine bait uptake by non-target species (DECC, 2007a) (in Appendix D – LHI Trials Package). These baits contained a fluorescent dye that glowed under ultraviolet light. During the trial conducted on LHI, some ants, slugs, cockroaches and snails (not Placostylus) were observed feeding on baits (DECC, 2007a). For each of these groups only a small proportion of individuals had consumed bait.

Research was conducted in 2009 to assess the vulnerability of the endangered LH Placostylus to Brodifacoum baits (Wilkinson and Hutton, 2013) (in Appendix D – LHI Trials Package). When given a choice between their natural diet and bait pellets, Placostylus will feed preferentially on their natural diet, ignoring bait. When all other feed was denied to them, they fed exclusively on Brodifacoum baits, but no mortality occurred. These findings demonstrate that there is negligible risk posed to *Placostylus bivaricosus* by the proposed eradication operation as the probability of a significant proportion of the *Placostylus bivaricosus* population consuming and dying from toxic baits in the wild is extremely unlikely. This is supported by an Australian Museum assessment in 2016 (Kohler *et al.*, 2016). Full report attached in Appendix N – Land Snail Survey 2016.

The assessment also considered the probability of the other four listed land snails coming contact with the broadcasted baits (at a density of 1 per 2 m^2) based on their ecology and behaviour.

Three of the critically endangered land snails, minute to small leaf litter-dwellers with small activity ranges (*Mystivagor mastersi*, *Peudocharopa ledgbirdi*, *P. whiteleggei*) were considered at moderate risk of exposure to bait placed (i.e. some but not all individuals may get in contact with baits). Susceptibility to brodifacoum was unknown.

The fourth species *Gudeconcha sophiae magnifica*, a large ground-dwelling species with large activity ranges was considered to be at high risk of exposure to bait. This taxon belongs to the same family and is ecologically similar to *Pachystyla bicolor* from Mauritius, a species shown to be susceptible to brodifacoum.

The study recommended experimental testing be conducted to examine the susceptibility of the common subspecies *G. sophiae sophiae* to Brodifacoum as surrogates for the critically endangered subspecies *magnifica*. It also recommended that, where possible, insurance populations of listed or brodifacoum-susceptible species are kept in captivity over the duration of the baiting program but noted this is probably not a realistic option for the very rare and hard to find species *M. mastersi*, *P. ledgbirdi*, and *P. whiteleggei* and may also prove challenging for the rare taxon *G. sophiae magnifica* (Kohler *et al.*, 2016). Therefore it is considered that the extreme rarity of these species precludes any testing of their susceptibility to Brodifacoum, or capturing the species to safeguard them in captivity.

The one endangered: *Placostylus bivaricosus* and four critically endangered species of land snails on LHI: Masters' charopid land snail, Mount Lidgbird charopid land snail, Whitelegge's land snail and *Gudeoconcha sophiae magnifica* are highly threatened by rat predation and it is likely that if rats are not removed these species will become extinct; some may already be extinct. (Kohler *et al.*, 2016). Whilst it is possible that some individuals of these species may be at risk of poisoning, this possibility must be weighed up against the threats associated with not removing rodents including almost certainty that predation by rats will result in the extinction of these species, in particular the critically endangered species living at high altitudes, where they are currently largely unprotected from rodent predation due to the inaccessibility of the area. Therefore a significant impact to these species is not expected from the REP when compared to not proceeding with the eradication. Proceeding with eradication of rats is listed as a priority action in the Commonwealth Conservation Advices for these species.

In summary, significant impacts to threatened invertebrate species is considered unlikely.

Table 17 Significant Impacts to EPBC Listed Threatened Invertebrates

Terrestrial Invertebrates	EPBC Act Status	Significant Impact from the LHI REP
Magnificent Helicarionid Land Snail *Gudeoconcha sophiae magnifica*	CE	No.
Masters' Charopid Land Snail *Mystivagor mastersi*	CE	No
Lord Howe Flax Snail, Lord Howe *Placostylus bivaricosus*	E	No
Mount Lidgbird Charopid Land Snail *Pseudocharopa ledgbirdi*	CE	No

Whitelegge's Land Snail *Pseudocharopa whiteleggei*	CE	No

Other Invertebrates

While there are no other EPBC listed threatened invertebrates on the LHIG, a large number of terrestrial invertebrate species exist there and many of these species are found nowhere else in the world (DECC 2007). Therefore an assessment of the likely impact on non-listed invertebrates is provided.

More than 1,600 species of invertebrates have been recorded in the LHIG, 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).

As mentioned above, Brodifacoum cannot affect invertebrates in the same way as it does vertebrates because invertebrates have different blood-clotting systems compared to that of vertebrates (Shirer 1992). However Walker *et al.* (2001) reported that Brodifacoum does bind to carboxylase enzymes, and that such enzymes are present in molluscs and arthropods therefore there is the potential for a Brodifacoum-related effect on these taxa. A summary of research findings is outlined below.

Terrestrial Invertebrates

Arthropods

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

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

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

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

Annelids (earthworms)

Lord Howe Island has 21 species of native earthworms, including the Lord Howe Island Earthworm *Pericryptodrilus nanus,* which is listed as endangered under the NSW TSC Act. There is no specific data available about the interaction of the local earthworms with Brodifacoum. However, studies of the effect of Brodifacoum on the pasture worm (*Aporrectodea calignosa*) indicate that extremely high concentrations of Brodifacoum are required to kill worms (Booth *et al.* 2003). The concentration of Brodifacoum in soil required to cause mortality in pasture earthworms (500 to 1000 micrograms of poison per gram of soil) is more than 1000 times higher than the likely levels of Brodifacoum that would be found in soil directly below a bait pellet at the application rate proposed for LHIG. To put it another way, all the Brodifacoum present in 25 to 50 kg of bait would need to be distributed through 1 kg of soil for that soil to be toxic to earthworms (Broome *et al.* 2016). "Worms have shown no evidence of vulnerability to Brodifacoum poisoning" Broome *et al.* (2016).

Aquatic invertebrates

Only a few aquatic invertebrates have been tested for their reaction to Brodifacoum (see table below). 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. For example, for Brodifacoum in water, the LC_{50} (96 hours) for Bluegill Sunfish is 0.165mg of Brodifacoum/litre of water, and for Rainbow Trout it is 0.051mg/L. For Daphnia, an aquatic crustacean, the LC_{50} (48h) is 0.34 mg/L.

Table 18 Acute Oral Toxicity (LC50 mg/kg) of Brodifacoum for Aquatic Invertebrates (Source Broome *Et Al.* 2016).

Aquatic Invertebrates	**Range: 0.34 - >10.0 mg/L (i.e. parts per million)**	
Daphnia (*Daphnia magna*) 1st instar	1.0 (24 hour LC50)	Eason and Wickstrom (2001)
	0.34 (48 hour LC50)	Eason and 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 and Moon (2011)

There is a scarcity of information on the effect of Brodifacoum on aquatic invertebrates; however, risks to aquatic fauna on LHIG can be assessed based on the impacts on waterways resulting from other baiting programmes.

Brodifacoum concentration of water sampled within 20 cm of bait pellets conducted 24 hours after the aerial application of Brodifacoum (20 ppm) on the Ipipiri Islands indicated negligible contamination. One sample returned a Brodifacoum concentration of 0.083 ppm while no residue was detected in the remaining three samples (Vestena and Walker 2010). However, there was some Brodifacoum residue in sediment samples taken near these pellets; seven of 18 such sediment samples contained measureable residues up to two months after baiting. This is in line with the known characteristics of Brodifacoum in that it is poorly soluble (hence low or nil concentration in water near baits) and that it will tightly bind to organic matter such as stream sediment (Eason and Wickstrom 2001).

Within 24 hours of Pestoff 20 baits being dispersed during the Hauturu rat eradication, water was sampled from eight points directly downstream from pellets in the streambed; Brodifacoum was not detected in any of the samples (Griffiths 2004).

Pestoff 20 was dispersed onto Maungatautari in two applications of 15 kg/ha and 8 kg/ha in 2004. A total of 217 water samples were taken from four streams flowing out from the area treated. Time to sampling was, in hours, 1, 2, 3, 6, 9, 12, 24, 48, and 72 post baiting. Sampling at two weeks and three months was also undertaken. No Brodifacoum was detected (Fisher *et al.* 2011).

Seven-hundred kilograms of Pestoff 20 was spilt into a freshwater lake in Fiordland. No Brodifacoum was detected in the 27 samples of lake water collected over the subsequent month (Fisher *et al.* 2012).

No residues of Brodifacoum were found from streams on Lady Alice Island at two, 12 and 34 days after the application of cereal bait applied at the rate of 15 kg/ha (Ogilvie *et al.* 1997).

Brodifacoum residue has been found in water samples (two from ten) taken after cereal pellets were dispersed onto Rat Island, Alaska but there is a chance that these samples were cross contaminated because the people taking the water samples were the same as those hand broadcasting bait (Buckelew *et al.* 2009).

The lack of water contamination shown in all but one of the above examples and the relatively high tolerance to Brodifacoum shown by invertebrates in general suggest that aquatic invertebrates will not be put at risk by the proposed rodent eradication.

5.2.6 Potential Impacts to Threatened Terrestrial Reptiles

There are two species of native terrestrial reptile on LHI, the LHI Skink *Oligosoma lichenigera* and the LHI Gecko *Christinus guentheri*. Both species occur on the offshore islets around LHI. Although once widespread across the main island (DECC 2007), the skink now seems to be confined to sedge-grass habitat (Bray personal communication, Wheeler and Madani 2015), the dense structure of which may protect the skink from predators such as rodents. Predation by introduced rodents is regarded as the major threat to these species (DECC 2007).

REP activities with the potential to impact on EPBC listed terrestrial reptiles include distribution of the bait through primary poisoning (direct consumption) and secondary poisoning (consumption of poisoned invertebrates). Each species is considered to be at low risk of poisoning, and both are likely to substantially increase in abundance following the removal of rodents (Towns and Daugherty 1994, Hoare *et al.* 2006).

There is little published information on the interactions between reptiles and Brodifacoum worldwide (Hoare and Hare 2006). There has only been one reported incident of widespread death amongst reptiles following eradication operations that have used Brodifacoum baits (Merton 1987). In general, reptiles do not appear to be interested in cereal pellets (Merton 1987) but, after cereal-based pellets were dispersed onto Round Island, Mauritius, Telfair's Skinks *Leiolopisma telfairi* were seen eating rain-softened Talon pellets containing Brodifacoum at 20 parts per million (Merton 1987). A number of larger (80–100 g) skinks were later found dead (ibid). Ten skinks were autopsied but only one showed evidence of internal bleeding. The low proportion of deaths that could be attributable to haemorrhaging plus the observation that it was only larger skinks found dead, and for death to be associated with warm days, led Merton (1987) to conclude that Brodifacoum interfered with this reptile's ability to thermoregulate. Despite these deaths the number of reptiles, including Telfair's Skink, on Round Island has markedly increased since the baiting was undertaken (North *et al.* 1994).

Gunther's Gecko *Phelsuma guentheri,* although present during the same baiting programme as Telfair's Skink, showed a lack of interest in pellets (Merton 1987). Reluctance to eat bait was also shown by the skink *Oligosoma maccanni* (which is a close relative of the LHI Skink). When lizards in the laboratory were offered cereal-based pellets as their sole source of food, only a relatively small amount of bait was consumed (Freeman *et al.* 1996). However, two species of New Zealand geckos have been observed consuming Brodifacoum baits (Christmas 1995; Hoare and Hare 2006); therefore it is possible that the Lord Howe Gecko may eat Pestoff® 20R pellets. A number of skinks and geckos have been recorded eating Brodifacoum baits but without apparent harm. Wright's Skink (Mabuya wrightii) commonly took Brodifacoum baits from bait stations on Fregate Island but no mortality was observed (Thorsen *et al.* 1999). Fisher and Campbell (2012) noted that at least 25% of the population of Lava Lizards (Microlophus duncanensis) would sample bait on Pinzon Island but considered that there was no population level effect. Most (i.e., 60-80%) of bait stations at Tauwharanui showed regular visitation by Oligosoma smithii between February and April 2007 but no dead skinks were ever found, and out of 802 captures in pit traps, no live-trapped skinks showed signs of poisoning (Wedding 2010 Aerial application of Brodifacoum baits was undertaken on Palmyra Atoll and followed up with sampling 28 geckoes (Mourning Gecko Lepidodactylus lugubris and the Common House Gecko Hemidactylus frenatus) for Brodifacoum residues; it was found in 14 of them (Pitt *et al.* 2012).

The two LHI species are considered at risk of ingesting Brodifacoum if they feed on invertebrates that have themselves fed on Brodifacoum-laced baits. However the risk of secondary poisoning for these species is low because:

- Baiting will take place in winter when reptiles may be relatively inactive. Unpublished reports by Rebecca Bray (Monash University) to the LHIB indicate that both species of reptile are active in autumn, and that, for the skink, this level of activity is less than half that which occurs in summer; pitfall trapping in November/December 2010 and February 2011 caught 244 and 266 skinks respectively while the same trapping effort in April/May 2010 resulted in 117 captures. No comparable surveys were conducted in winter. However, in keeping with the precautionary principle, it is accepted that a number of reptiles will be active during the baiting period.

- the proportion of invertebrates that will have fed on Brodifacoum baits will be small so even if they are foraging at this time then most of the potential prey that they will encounter will not be poisoned (on Red Mercury Island for example, no Brodifacoum residue was found in 99% of the sample of invertebrates collected after the aerial application of Brodifacoum baits (Morgan *et al.* 1996);

Although there is potential for the two threatened reptiles to ingest Brodifacoum, the world-wide trend for reptiles on islands that have been baited with Brodifacoum to eradicate introduced mammals such as rodents, is to greatly increase in number (Towns 1991, 1994; North *et al.* 1994).

Two months after the application of Brodifacoum baits on Stanley Island, lizard pitfall capture rates were 29% higher than the previous best (Towns *et al.* 1993). The population of the Spotted Skink Oligosoma lineoocellatum on Nukuwaiata Island increased by 67% over the two years following aerial baiting with Brodifacoum (Brown 1997). There was no change in the abundance of the population of the gecko *Tarentola bischoffi* immediately after baiting with Pestoff 20 was undertaken on Selvagem Grande Island; but there was a significant population increase after three years (Olivera *et al.* 2010). The number of skinks on Korapuki Island in New Zealand increased 30 fold within 5 years of rats being removed (Towns 1994).

Another potential source of ingesting Brodifacoum for reptiles is through their consumption of invertebrates that have fed on baits (that is, through secondary poisoning). However, most invertebrates are unlikely to contain Brodifacoum; published values for the proportion of invertebrates containing Brodifacoum residue after baiting range from 1% (Morgan *et al.* 1996) through to 4% (aerial baiting) and 44% (baiting using bait stations) (Broome *et al.* 2016) on to 51% (Booth *et al.* 2001).

Because the available world-wide evidence indicates that skinks and geckos either do not eat baits, or if they do, with the exception of Telfair's Skink, they do so with impunity, then both species are not in danger of primary poisoning leading to haemorrhaging. The positive response of geckos and skinks after baiting referred to above also indicates that secondary poisoning is not a threat. This is evidenced on LHI, where the main population of the LHI skink occur at North Bay, which is currently extensively baited for rodents. If consuming Brodifacoum from any source risks compromising the ability of the two reptiles to thermoregulate as may have been the case with Telfair's Skink (Merton 1987) then such a possibility is mitigated by conducting the rodent eradication in winter.

Table 19 Significant Impacts to EPBC Listed Threatened Terrestrial Reptiles

Terrestrial Reptiles	EPBC Act Status	Significant Impact from the LHI REP
Lord Howe Island Gecko *Christinus guentheri*	V	No
Lord Howe Island Skink *Oligosoma lichenigera*	V	No

5.2.7 Potential Impacts to Threatened Terrestrial Plants

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

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

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

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

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

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

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

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

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

Table 20 Significant Impacts to EPBC Listed Threatened Plants

Plants	EPBC Act Status	Significant Impact from the LHI REP
Lord Howe Island Morning Glory *Calystegia affinis*	CE	No
Phillip Island Wheat Grass *Elymus multiflorus subsp. kingianus*	CE	No
Geniostoma huttonii	E	No
Little Mountain Palm , Moorei Palm *Lepidorrhachis mooreana*	CE	No
Rock Shield Fern *Polystichum moorei*	E	No
Xylosma parvifolia	E	No

5.2.8 Potential Impact to Listed Migratory Bird Species

Potential impacts to EPBC-listed Migratory birds from the proposed LHI REP include:

- Primary poisoning from consumption of bait pellets
- Secondary poisoning from consumption of poisoned rodents or other animals
- Disturbance as a result of helicopter activities
- Collisions with the helicopter

Risks to non-target bird species during an eradication program are a function of the species present on LHIG at the time of baiting and during the period when baits will remain accessible within the environment (<100 days), their behaviour, and the likelihood of exposure to Brodifacoum either directly or indirectly. A thorough assessment of the likelihood of a significant impact to listed Migratory species is presented below.

The 64 bird taxa listed as Migratory Species under the EPBC Act and identified to occur or potentially occur on the LHIG in Table 13 are grouped into three categories and discussed separately below: regular non-seabird migrants, irregular or vagrant non-seabird migrants, and seabirds.