Mouse eradication using aerial baiting Current agreed best practice used in New Zealand

Version 1.0

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SUMMARY

Eradication is not control 'intensified'. It must remove the last individual which means taking individual behaviour into account from the very beginning, and the level of resourcing is 'whatever it takes'. The New Zealand Department of Conservation Island Eradication Advisory Group advises wildlife managers planning to eradicate mice using the technique of aerial broadcast of rodenticide baits. This knowledge represents the current agreed best practice available at the time of publication and provides a benchmark of mouse eradication practice for temperate island ecosystems. These best practice guidelines are valuable for eradications outside New Zealand but require adaptation to suit other legal, political, social, and environmental situations. The advice presented has been gleaned from some of the largest and most challenging projects worldwide and there is a good track record of success with this method. The continuous improvement of our best practice allows new information to be readily incorporated and promulgated. The flexibility to allow case by case modifications to be considered during project planning to meet emerging issues has been a particular strength of the system.

INTRODUCTION

Eradication of invasive species populations differs greatly from control of those same species and requires a shift in thinking about the approach. Population control sustains a harvest of pests to reduce numbers and therefore impacts. The level of harvest balances acceptable impacts of remaining pests and efficiency in the costs of harvest. Eradication is not control 'intensified'. It must remove the last individual which means taking individual behaviour into account from the very beginning, and the level of resourcing is 'whatever it takes'. Every step in the design and implementation of an eradication project must strive to minimise the risk of failure with robust and meticulous planning (Cromarty et al, 2002). To under-achieve eradication, even though this may be still a high level of control, means failure. The approach must be to over-achieve it.

The social context and engagement with relevant communities of interest is sometimes overlooked by biologists with a strong focus on biodiversity goals. Specialist skills and advice in this area can often make a big difference to the feasibility and sustainability of outcomes (Morrison et al 2011). Effective consultation and communication with stakeholders is often a critically important aspect of an eradication project, especially for aerial baiting which can be unfamiliar and disconcerting to some people (Fitzgerald et al 2000). The guidelines presented here do not comprehensively address community engagement processes but some advice is provided.

Aerial baiting is carried out on New Zealand (NZ) islands using helicopters fitted with navigational guidance systems which carry purpose built bait application buckets on their cargo hooks (figure 1). These buckets use a motor driven spinning disc to 'throw' bait in a wide circle below the helicopter. The forward motion of the helicopter along pre-determined parallel flight lines generated by the navigation computer produces an even spread of rodent baits up to 50m either side of each flight line.

Figure 1. A helicopter with baiting bucket applying rodenticide baits to Macquarie Island in 2011.

This paper collates advice provided by the NZ Department of Conservation (DOC) Island Eradication Advisory Group (IEAG) to support wildlife managers planning to eradicate mice using the technique of aerial broadcast of rodenticide baits. House mouse (*Mus musculus*) is the only mouse species introduced to New Zealand. Invasive rat species are also targeted with similar methods, but are outside the scope of this paper because they are covered elsewhere (Broome et al 2017), and due to some differences in technique. Where both rats and mice occur on an island, the eradication design needs to take this into account. Generally speaking, following this guideline should be sufficient to eradicate both rats and mice- all other things being equal.

The IEAG is a small group of DOC staff who represent the best island pest eradication experience available within DOC. Set up in 1997 to capture existing knowledge and expertise and provide technical advice to DOC projects, the role has diversified to include evaluation of best practice, building capability within DOC, advice on national priorities and international networking, including advice to projects outside NZ to maintain DOC's knowledge base (Broome et al 2011). The advice and practices described here are agreed by members of the IEAG as the most appropriate for mouse eradications taking place on NZ islands. However many aspects have application elsewhere, especially in temperate climates with latitudes similar to NZ (29 to 52 degrees South).

We use the term 'current agreed best practice' because best practice is a fluid concept which needs frequent updating to remain 'current' with the latest available information. It is 'agreed' by a network group of expert practitioners, in this case the IEAG, because not every aspect of the advice given is proven as fact by robust science, rather it falls into the category of expert opinion. Agreement among experts in the absence of robust science is sometimes challenging but this interaction to forge agreement does fill the gap in advising 'what to do' in situations where assumptions and judgement is called for (Martin et al 2012).

Following current agreed best practice does not guarantee success but it does help minimise the risk of failure. All pest eradication projects have unique ecological circumstances, political climates and abiotic constraints (e.g. terrain or weather) which necessitate some variations to the advice stated. In these circumstances, we urge project managers to seek further expert advice on the best way forward for their particular circumstances. We do not intend DOC's current agreed best practice to be used as a 'code of practice' available to regulatory agencies to enforce compliance. However, deviations from best practice should state their rationale in operational plans and fully consider any consequent risks to the project.

Within DOC, we regard current agreed best practice documents as 'live' and open to constant updating and improvement as new technologies, understanding or issues arise in this field. The IEAG discuss suggestions for change and produce a new version of the agreed best practice. This is version 1.0, available on the Department's website. The IEAG maintain other eradication best practice documents for rat eradication using other techniques (e.g., ground based broadcast and bait station delivery of rodenticide) and for other pest species (e.g., rabbits) as internal documents. A best practice document closely following this version but with important differences in eradication design to target rats is also available (Broome et al 2017).

Figure 2. Pacific Invasives Initiative eradication resource kit project process diagram. This diagram is borrowed with permission from the Pacific Invasives Initiative (PII) http://www.pacificinvasivesinitiative.org It shows the typical stages in the life cycle of an eradication project and how stakeholder engagement, monitoring and evaluation, and biosecurity are ongoing activities relevant to every stage. A wealth of useful guidance, document templates and examples are available in this resource kit.

DEPARTMENT OF CONSERVATION CURRENT AGREED BEST PRACTICE – AERIAL BAITING

Where possible the current agreed best practice is stated for each subject and followed in *italics* with further explanation. We use **Bolding** to allow the reader to readily find topics of interest and numbering to facilitate discussion on particular points.

FEASIBILITY STUDY

1. Complete a peer reviewed **feasibility study** before finally committing to an eradication project[1]. This study should fully evaluate the social and biological context, and identify all issues to overcome to deliver and sustain the stated goals and predicted outcomes with the maximum chances of success (Broome et al 2005). *A good feasibility study will clearly articulate the goals of the project and the rationale behind them. It will provide a sound basis for investors to evaluate the costs, risks, benefits and scope of a project. This information is directly relevant to the project design phase.*

2. Identify all possible **stakeholders** during the feasibility study and determine the level of interest, support, opposition and social issues to resolve during consultation (Ogden and Gilbert 2011). Consultation with key stakeholders during the feasibility study stage, before any decision to take the project forward has clear advantages (Griffiths et al 2012).

3. **Reassess feasibility** if at any time critical factors change or new issues emerge before project implementation. *For example a change in stakeholder support may render the project untenable or the necessary ongoing biosecurity unsustainable* (Wilkinson and Priddel 2011, Oppel et al 2010).

4. Identify all **biosecurity** risks for the project at the feasibility study stage. This includes the risks of quarantine failure, sabotage and target animals reinvading through swimming to the island. The distance mice can swim to reinvade islands may vary from site to site and is largely unknown in any more than a general sense (Russell 2007). Multiple factors may influence the probability of mice successfully swimming to an island (e.g. water temperature, current, coastal cliffs, predators in water and on land, prevalence of floating debris) (Russell 2007; Russell et al 2008a). Mice are not thought of as strong swimmers due to their size and their ability to stowaway in cargo is well known. Hence unequivocally separating invasion events into stowaway or swimming is problematic. Mice have been seen up to 600m from shore in NZ lakes.

5. Take representative **DNA samples** from each population of target species on the island and from likely/possible source locations on the mainland or neighbouring islands. (Russell et al 2010; Russell et al 2009, Fewster et al 2011). *Results can estimate gene flow to the island which will support a decision on whether an eradication is the best course of action or if other options should be investigated (e.g. sustained control). While the cost of DNA analyses can sometimes be significant, it is far lower than the financial and social costs (e.g. loss of public support) of having mice quickly reinvade an island. DNA comparisons can determine if rodents collected on the island after the eradication reinvaded or were part of the original gene pool, i.e. the eradication failed.*

6. Identify all necessary **trials and research** required to eliminate knowledge gaps in the biological and logistical aspects of the project. Some of these information needs may be driven by what stakeholders want to know. *Knowing about these requirements during the feasibility stage allows time and money to be built into the project design and informs the decision to invest further in the project.*

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[1] For unpublished examples of eradication project documents see PII Resource kit for eradication of rats and cats http://rce.pacificinvasivesinitiative.org/ or contact the authors.

7. Where natural **alternative food** is abundantly available to rodents all year round, even if only at specific sites on the island, undertake bait acceptance trials during the feasibility study to determine whether all mice will eat the bait. These trials need to, as much as possible, replicate the anticipated conditions encountered during the implementation phase and be of sufficient scale to minimise edge effects (e.g. unmarked animals which have moved into the trial area).

PROJECT DESIGN

8. A **project plan** will greatly enhance the transparent management of an eradication project. This document will take account of the issues and complexities raised in the feasibility study and clearly outline the roles, actions and timeline to achieve project goals[2]. Unambiguous project governance, clarity in decision making and opportunities for technical input are all indicators of a good project plan. *Eradication failures can be technical, logistical or a result of poor project management. A good project plan helps to manage the project well. Project success requires more than just good biological and logistical planning* (Morrison et al 2011).

9. When **costing** projects take care to cost all aspects adequately and allow for contingencies. *Money shortages affect morale and lead to cutting corners which raise operational risks. If this leads to failure, it will be more expensive in the long term.*

10. The **choice of technique** will depend on local circumstances and should be investigated through a feasibility study prior to operational planning. The most common method in New Zealand to eradicate rodents has been the aerial application of rodent baits containing the second generation anticoagulant toxin brodifacoum, the focus of this best practice. If aerial application is not feasible then investigate hand broadcasting brodifacoum baits. If this is not feasible then consider applying brodifacoum baits in bait stations. *A hand broadcasting operation usually requires more people involved and takes longer to implement, thereby increasing the chances of mistakes. It may require track cutting with the associated cost and environmental damage. Applying bait in stations increases the length of the project implementation phase and introduces another variable, the bait station. The latter is particularly relevant when targeting more than one rodent species because inter- and intra-specific competition may result in some animals avoiding the stations. Spacing stations closely enough to intercept all mouse territories can also be logistically problematic.*

11. Consider **non-target species** present on the island that may consume or spoil bait (e.g. ungulates, rabbits). Options to manage this include controlling them prior to rodenticide application or applying extra bait to compensate. *The presence of other mammals increase the risk of operational failure because they can sometimes eat large quantities of bait leaving the potential for some mice to remain unexposed to a lethal dose of the toxin.*

12. Give thorough consideration to the potential for **non-target effects on native species present**. Undertake a peer reviewed Assessment of Environmental Effects and build any necessary mitigation measures into project planning from the outset[3]. Unintended outcomes or 'surprise effects' can result from removing invasive rodents from the island ecosystem (Courchamp et al 2011). A well-considered Assessment of Environmental Effects must identify all potential environmental costs, risks and benefits and allow the project management team to make transparent decisions on what mitigation is appropriate. *An eradication project must have benefits which outweigh the costs and risks that remain*

[2] For further information on project planning see http://rce.pacificinvasivesinitiative.org/project/3_Project_Design.html

[3] For unpublished examples of eradication project documents see PII Resource kit for eradication of rats and cats http://rce.pacificinvasivesinitiative.org or contact the authors.

after mitigation. Perceptions of non-target impacts can be an important reason for stakeholder opposition to a project.

13. Clearly define the **area to be treated**. The treatment area must include all dry land accessible to the target species including neighbouring islands, islets and rocks, as well as those in inland water (e.g. lakes) etc. *Baiting all potential mouse habitat is critical.* Treat rock stacks above high water around an island even if mouse presence seems unlikely. Treat islands on inland water (lakes) in the same way. *This will eliminate the possibility of mice surviving nearby to reinvade the island.* Minimise the number and size of exclusion zones for aerial coverage of bait. *Alternative baiting techniques to cover these areas usually carry a higher risk of failure than aerial. Exclusion zones add complexity to the aerial application and increase the risk of bait gaps between techniques.* Ensure island size is correct, if any doubt exists either physically measure the island size early in the planning phase or use the largest known figure as a worst case scenario. *Past projects have found discrepancies which could lead to a shortage of bait available to complete a larger than expected island (Pierce et al 2010, Torr and Brown 2012).*

14. In **summary**, the fundamental requirement is to ensure sufficient bait is distributed to every mouse territory on the island to provide a lethal dose of high quality toxic bait to every individual mouse. This requires good management of bait quality, good timing, and comprehensive coverage of the island with adequate quantities of bait which will remain available to mice for several days.

PLANNING

15. Well prior to the eradication operation, establish island **biosecurity** procedures to prevent the reinvasion of the target species or invasion of other pest species, particularly those which would have a higher chance of successful establishment in the absence of the target species (Russell et al 2014). Allow enough time to implement and test any required improvements before the eradication begins. *The risk of future invasions of introduced species needs management from the outset to protect the investment made in carrying out the eradication operation. The eradication itself represents a potential biosecurity risk when landing significant amounts of cargo.*

16. Where an **external permission** is required, apply for a period of several years. *This allows flexibility to undertake the operation in subsequent years, if other factors cause project delays.* Establish a good working relationship with the permitting authority early in the process to facilitate the transfer of information and avoid misunderstandings. Permission applications should attempt to keep conditions as general as possible to allow flexibility in how they are complied with as planning progresses. For example, stipulate an overall average bait sowing rate which is the total amount of bait transported to the island (including contingency bait) divided by the total area of the island. If the detail of the bait spreading pattern and calculations have not been finalised before the permission application is made then choose a worst-case scenario for the application. *This will allow re-baiting of parts of the island (e.g. to fill gaps) without risk of breaching conditions on rate of application.* Once the permission has been received, go through the conditions in detail to check they can be complied with. Seek amendments where necessary. Cross-check planning documents to ensure the conditions are covered by delegated tasks where necessary. *We suggest annotating a copy of the permission indicating where each condition is covered. This information will be used in the readiness check (see point 32).*

17. Winter to early spring is the **preferred season** in NZ to apply the bait. *We base this timing on past successes and it tends to coincide with times of natural food scarcity, lower numbers of mice and low breeding. It can also coincide with times of low non-target activity.* Actual target dates for application will involve a trade-off between these and other factors relating to the island's environmental, social

and logistical constraints. However biological constraints associated with the target species should take precedence over project management or financial difficulties. If necessary be prepared to postpone the project into the following year rather than increase the risk of not completing the implementation during the optimal time (Springer 2014).

18. Where practical, eliminate or reduce as many other **potential sources of mouse food** as possible before baiting (e.g. store all food scraps from the field teams inside sealed rodent proof containers, seal all emptied food containers and tins inside sealed rodent proof containers, etc). Where possible, bury or dispose at sea any wildlife found dead. *This will minimize the risk of mice utilizing alternative foods in preference to the toxic baits.*

19. For all **toxic baits**, evaluate carefully the available evidence supporting:

- The 100% acceptance to target species
- Knowledge of the risks to non-target species
- Other environmental effects
- Storage and handling properties
- Performance when used in mechanical bait spreading buckets

In New Zealand, the most-widely used bait for rodent eradication projects which meets the above criteria is Pestoff Rodent Bait 20R™ (Animal Control Products www.pestoff.co.nz) containing 20ppm brodifacoum. Ten millimetre diameter (2gm) baits are currently most often used.

20. Check the **legal conditions** of registration of the bait product. The intended use must be in compliance with label instructions available on the product label. If the bait is Pestoff Rodent Bait 20R™ comply with the 'Limitations on Use' requirements on the product label. For DOC projects where the eradication:

- Covers land on NZ islands where stock return to graze in future or
- On the NZ mainland behind a pest proof fence.
- The project must comply with the approved code of practice (Animal Control Products 2006).

21. Aim to apply bait in **two separate applications at least 14 days apart**. *This may counter an unforeseen deluge washing out the first drop and may allow young mice in the nest at the time of the first drop exposure to fresh bait in the second drop if breeding is underway.* Once again the final interval between applications will become a trade-off between weather and logistical constraints which require expert judgement by members of the project team with current situational awareness. **Apply 8 kg/ha for both applications**. Use higher sowing rates when other species are present which will take bait (*see point 11 above*). *These sowing rates have worked previously on single species mouse eradications in New Zealand. Lower rates may be possible but remain untested and the IEAG consider lower flow rates, through bait sowing buckets of current design, at risk of causing temporary stoppages in bait flow potentially leading to gaps in coverage which will not show in GPS data.*

22. Apply the **bait** in parallel **flight lines** guided by GPS and spaced to 50% of the effective swath width produced by the sowing bucket. When setting up the GPS flight lines the sowing bucket swath width should be conservatively set to a distance where bait has shown (in calibration trials) to be consistently sown. *This is often less than the maximum distance the bucket can throw baits, and will reduce the risk of leaving insufficient bait or gaps in coverage.* Set the bucket bait flow rate for both the

first and the second bait applications at half the required rate (e.g. at 4kg/ha with swath overlaps by 50% resulting in a total application rate of 8kg/ha on the ground).

23. In the **first and second applications** apply additional **bait around** the island's **coastline** (to the water's edge) in addition to the parallel flight lines. The distance coastal sowing should be extended inland will depend on the terrain, 70m is usually sufficient. *Coastal baiting further reduces the risk of gaps in bait coverage caused by one or more of several problems during bait application along parallel flight lines:*

- *delays in bait flow through the sowing bucket starting a line*
- *shutting off bait flow too early at the end of a line;*
- *bucket swinging as a result of helicopter turning causing the bait trajectory to change ,*

Coastal baiting also provides extra bait in littoral zones which may be favoured feeding grounds for mice. Very steep areas (i.e. slopes exceeding 50 degrees) should receive an additional application of bait in each application. On many islands steep slopes are only found on the coastline where additional coastal swathes will suffice but where steep slopes are found inland they must be mapped and extra bait applied. *This will ensure adequate bait is applied to steep terrain which has a larger actual area than the 2D plan area calculated from maps and to counter uneven bait distribution from bait falling down-slope.*

24. In the **first and second applications** ensure **other** 'special' **areas** are **treated**, by specifically targeted actions. Bait should be applied in, around and where practical under all buildings (all portions, including cellars, attics, etc), in large caves, on offshore rock stacks that are still exposed at high tides, on islets within inland lakes, steep cliffs etc. Create a comprehensive list of every site requiring special treatment beforehand, and 'tick them off' when baiting of each has occurred. Baiting in buildings should be done by placing a known number of baits in a shallow dish (e.g. paper plate) which will allow regular checks to be carried out and any missing or damaged bait to be replaced. It is prudent to continue building baiting long after the aerial application of bait elsewhere. Islands with permanent human habitation should continue for six months or longer. Bait application around buildings is best done by aerial application. *This keeps the operation less complex by avoiding exclusions zones around buildings* However other constraints may require hand broadcasting or bait stations (Wilkinson and Priddel 2011).

25. Either eliminate **areas of dense vegetation** (e.g., rank grass) or provide extra bait to these areas. *Such areas can provide excellent mouse habitat leading to locally high numbers of mice* (Goldwater et al 2012).

26. Flight lines for the **second application** should not be identical to those used for the first. A change in the heading (bearing) of parallel flight lines, a change in the initial starting point for bait laying, and/or a change in blocks assigned to each pilot (where multiple helicopters are used) are all ways to reduce the risk of gaps in bait coverage (*which are not apparent in GPS data*) from the second application replicating gaps produced in the first application; and *further reducing the risk of gaps in bait coverage overall.*

27. When ordering **bait**, allow at least 10% **contingency** for unforeseen events (e.g. spillage, loss of some bait, larger treatment area than expected, additional treatment of areas i.e. coastline). If the island size is not definitively established, or it is less than 50ha, or has a complex shape, then allow a greater contingency. *Island size is sometimes reported incorrectly. Small islands or those with complex coastlines will likely need more bait to fix mistakes than the 10% calculation allows for.* Build in

allowances for places where extra bait may be required such as dense vegetation cover (see point 25 above). Get bait quantity calculations peer reviewed. *Running out of bait before the entire island is covered will result in failure.* Consider the disposal of excess bait during planning (i.e. unused contingency bait). Where possible plan to use it on the island to enhance areas of highest risk.

28. **Install and test equipment** for all navigational guidance before the operation to ensure they function and integrate correctly when using multiple aircraft. This should include the ability to download and upload flight lines between a computer and the helicopter GPS unit whenever required in the field. *Minor issues of electronic compatibility can, at best cost valuable time during implementation and, at worst lead to errors in recording coverage or prevent flight lines being inspected for complete coverage. The lead pilot must not only bait the island comprehensively, s/he must have the evidence to prove it* (See also point 30 below).

29. Log **island boundaries** (coastline) into the GPS before sowing begins with the project manager in the helicopter directing the pilot. *This will ensure the boundary is logged exactly where the project manager wants it and give a check on the total island area at the outset of the sowing.* Do this well ahead of time and combine it with testing GPS and radio signal coverage, and finalising loading site requirements. *The accuracy required when logging boundaries cannot be achieved while sowing bait.*

30. Have **back-up equipment** including aircraft, loading, sowing and GPS on site or available at short notice. *Having alternatives for all critical machinery will reduce the risk of breakdowns preventing the operation being completed in the chosen weather window. Breakdowns take valuable daylight time to fix compared with swapping to back up equipment on site and ready to go.* Ensure computer equipment, including back-up equipment, for viewing/printing GPS flight data is available on site and compatible with the aerial contractor's equipment. *It is important to carefully view flight line data at a scale suitable to identify possible gaps in coverage and fill these gaps on the same day of each application. The LCD screen available to the pilot on some GPS systems is not adequate for this task.*

31. **Plan for extra capacity** to complete the bait sowing in as short a time as possible. This will allow a contingency of 'spare time' to fix any problems arising. *Even small problems can use up valuable daylight hours during an operation.* Wherever possible, aim to cover the entire island in a single day. *Completing bait coverage in a single day poses least risk of failure due to rodents moving from un-baited areas into areas where bait has degraded or disappeared. It also reduces the risk of weather changing to affect the last bait to be applied.* For very large islands which cannot be treated in a single day the risk of rodent movement between treated/untreated areas needs to be addressed in the planning and decisions taken on a case by case basis during operations.

32. Have operational **planning peer reviewed** throughout development, *to ensure the eradication design matches the terrain and ecology of the island and you have thought the details of the logistics through completely.* Involving peer reviewers early in the process allows better exchange of information, better final plans and better buy in by all involved in the planning. Giving peer reviewers an opportunity to familiarise themselves with the island through a field visit and background information will help them to identify pertinent comments. Invite peer reviewers or other experts to check the state of readiness for the project team to proceed to implementation. Do this in time to allow any changes or improvements identified to be implemented. *This gives an independent audit of the state of planning, training and logistical organisation of the project to ensure you can deliver on the implementation as it is described in the (peer reviewed and subsequently revised) operational plan.*

33. Choice of **aircraft** will depend on:

- Availability and pilot familiarity - *the primary concern is to select the best pilots with the best equipment.*
- Loading options - *very large capacity buckets require a mechanical loading system, whereas smaller buckets can also be loaded by hand*
- Haul distance from the loading site to the treatment area - *long hauls are more cost effective with bigger loads and fewer trips; aircraft size makes little difference when actually sowing bait*
- Landing options - *larger aircraft need larger sites and more fuel*

34. Choice of **pilot(s)** is crucial to the success of the operation and there is no substitute for experience. Consider:

    - Experience with aerial baiting and eradication projects in particular
    - Experience with the selected aircraft
    - Experience with the selected navigational guidance system
    - Experience with other aspects of the project requiring specialist flying skills (e.g., operating off ships, marine rescue).
    - Personality – willingness to take direction but give considered feedback and ability to work as part of a team
    - Availability at short notice throughout the entire operational period to undertake the project.

    Confirm the lead pilot early in the planning so s/he can contribute to the project planning as part of the project team. Consider opportunities to involve and up skill other pilots. *The skill required to apply bait to the required standard for eradication projects using this equipment comes only with the experience of many hours using the equipment in the air. The skill should be viewed as highly specialised and additional to the (already demanding) skill of flying a helicopter.*

35. **Bait spreading buckets** should produce a consistent swath pattern and constant rate of spread whether full or near empty. Check this by calibrating the bucket prior to the operation. Calibrate all bait buckets, including spares and any deflector modifications prior to the operation. Use a bait bucket specifically designed for distributing cereal pellets *to minimise bait breakage during sowing. A spinner designed for spreading fertiliser may increase the number of broken baits. All buckets, even those of identical design and manufacture, behave differently and need to be checked.* Sowing buckets should have a proven reliable system for pilot to start and stop bait sowing (e.g. bucket on/off switch is interfaced with the GPS system). *This will minimise the risk of bait gaps undetectable in the GPS printout and risk of sowing bait outside the treatment area.*

36. Use **GPS navigational guidance** to ensure uniform, total coverage of the area. When using multiple aircraft ensure compatibility of guidance systems to allow integration of flight line data. Produce bait coverage maps on the day of the operation in time to identify and fill gaps. GPS navigational guidance systems can be differentially corrected (DGPS) or not (GPS). DGPS receives another radio signal giving corrections to the aircraft position indicated by the GPS satellites. This can increase accuracy of the position to less than 1 metre. GPS positions without differential correction are subject to a number of signal errors which, in a worst-case scenario (i.e. where every error is at theoretical maximum and in the same direction) can reach about 15 metres. In practice this rarely happens and may only be momentary during a flight line unless there is a malfunction. IEAG consider DGPS

desirable but not strictly necessary for rodent eradication operations using best practice design elements identified here (i.e. proven pilot and equipment with wide swath sowing buckets; 50% overlap in flight lines and more than a single application) which compensate for anomalies in bait coverage caused by GPS error. Make the final decision following discussions between the lead pilot and the project manager.

37. **Use freshly manufactured bait** where possible. Do not store for longer than recommended by the manufacturer (12 months for Pestoff Rodent Bait 20R). *This ensures high bait palatability, which has a direct influence on success. Old baits have been used successfully, but may be less palatable than natural food available to the target species at the time of application.*

IMPLEMENTATION

38. Check the condition of bait (e.g. hardness, intactness, moisture) by opening some of the bags of bait (before accepting delivery). Take quality control **bait samples** at the factory and during the operation. Store samples for later testing if required or immediately if there is any doubt. *This may allow bait quality and toxin loading issues to be discounted if the operation is later found to have failed.*

39. **Handle bait with care** to avoid crushing or contamination. Where bait is packaged in paper-walled sacks, avoid or minimize repeated handling of individual bags during transportation where possible. Never throw bags of bait. Do not stack more than 8 bags high. Avoid stacking pallets of bait on top of others to save space. Separate bait from fuel or other chemicals during shipping and storage to avoid contamination from spills or fumes. Do not use contaminated bait. *Presenting bait to all rodents in the best condition possible will maximise palatability and avoid problems with sowing equipment*

40. Undertake regular inspection of **bait** when in **storage** and take measures to minimise damage, especially from water leaks, condensation or attack by rodents or insects i.e. by placing traps around bait and spraying the storage area with pyrethrum sprays. Bait storage on the island would ideally use an existing building, however tents, plywood/plastic/ waxed cardboard boxes, or steel shipping containers have all been used successfully. *Bait must be kept dry and free from contamination or damage whilst in storage to ensure good condition and high palatability when applied.*

41. A weather forecast of at least 72 hours (3 nights) without significant rain (ie more than 10mm) is best for bait application. *This should give all mice time to encounter and eat a lethal dose of bait.* A **decision to go ahead with the baiting** involves trade-offs which require expert input at the time. Use an experienced professional weather forecaster to provide a forecast specifically for the treatment area. The project manager must make the final decision to go ahead after considering the weather forecast information and the views of the lead pilot and other members of the project team. Flying operations needs all the key people to agree it's safe to begin, but any one person in the team can stop the project if they consider it unsafe to continue. The pilot always retains the authority to stop operations if s/he considers flying conditions to be unsafe. *If the weather is too windy when applying bait, the risk of gaps in coverage increases due to bait drifting downwind and/or aircraft being pushed off course. Gusty wind is least desirable as its influence on bait and aircraft is variable and unpredictable. If the weather is too wet after bait application, the target animals may not eat the bait before it is destroyed. If the bait becomes wet before it is applied it can cause problems with the sowing bucket.*

42. Put in place a '**decision support team**' whose role is to provide advice and support to the project manager on the day of the application (i.e. help identify issues, provide advice and act as a sounding board for project manager), when s/he is making decisions. Membership is confined to those present

on the day of the application because they will understand the local situation. Members may include lead pilot, deputy project manager and eradication advisor.

43. When the bait **bucket empties during sowing** there is potential for gaps if the refilled bucket does not resume sowing in the right place. Instruct pilots to be conservative in overlapping the resumption of a bait application flight line with the point where sowing had previously stopped. *This avoids a gap in bait coverage which could not be detected in GPS printouts.*

44. Monitor bait usage throughout the bait application. *Sowing rates can vary due to flying conditions or mechanical problems with the bucket.* A careful **check of bait sowing rates** can be maintained with most GPS systems in 2 ways:

    - by having the pilot radio in the number of hectares shown on screen as completed with each bucket load. The target number of hectares will be the size of the load multiplied by the sowing rate.

    - A spreadsheet can maintain a running total for each aircraft, of the amount of bait loaded into the bucket and the area within the treatment boundary covered by that quantity of bait as it comes to hand from downloaded data.

    The smaller the island the closer the rate needs to be monitored as there is less opportunity to make changes. *Finishing the bait before the island is covered will lead to failure.*

45. View **flight line data** early to establish everything is set up and working. Schedule subsequent downloads at each refuelling to identify and fill gaps in coverage before the end of the day. *Completing bait coverage in a single day poses least risk of failure due to mice moving from un-baited areas into areas where bait has degraded or disappeared.* Download and review data carefully near the beginning of the operation. Things to check:

    - the equipment works and the data can be viewed as expected;

    - the application rate is as expected;

    - the average work rate (productivity) of the helicopters is in line with predictions and if not the actual rate is extrapolated out to recalculate the total flying time (and fuel) required to finish the job;

    Flight line data will need ongoing scrutiny to identify potential gaps in coverage for later re-sowing. Filling gaps in bait coverage is important but should be at the end of each day and not take precedence over completion of the block. Keep a level of contingency bait in reserve for the final loads and to give all the flight line data thorough scrutiny before distributing the last of the bait. View flight line data at a realistic scale to identify gaps easily. Use a laptop with mapping software. *Printouts of small scale or viewing GPS screens in the aircraft are inadequate to eliminate the possibility of gaps being overlooked.*

46. Re-sow all but the smallest **gap in bait coverage** indicated in the navigational guidance data even if it appears to be covered by the 50% overlap. The size of the gap tolerable is related to the anticipated movement of the target species over the period bait is likely to be available. Gaps larger than 10m are usually filled by extra applications when targeting mice. *The GPS printout will show where the helicopter went but not necessarily where the bait landed on the ground, so gap filling needs to be conservative.*

47. Complete **the first application** over the entire island at the prescribed **rate** or higher, even if this means using some bait originally planned for the second application. If required, make adjustments to the rate for the second application. *The first application is important to get right because weather or other circumstances may prevent a second application.*

48. The project manager should decide what **rock stacks** above mean high water require bait application when flying the boundaries with the pilot, if s/he has not already decided this. The project manager can also decide whether an observer with aerial eradication experience is required to fly with the pilot during bait application on rock stacks. *Where to lay the bait is the project manager's decision, not the pilot's.* Map or list all relevant rock stacks and cross them off as they are baited for each application. *Some islands can be challenging to differentiate between rocks as part of the coastline and those to treat separately.*

49. On **large islands** with several days operation interspersed by weather delays the project manager and decision support team should consider the need to reapply bait over a previous work to counter potential mouse movement. Some of the factors to consider when making this decision:
    - length of delay
    - shape of the baited and unbaited areas
    - proximity to natural barriers
    - condition of bait already laid
    - overall progress and time constraints on the project
    - any bait supply constraints
    - weather forecast
    - species present

MONITORING AND EVALUATION

50. **Monitor** for the presence of **mice** after an eradication as part of normal biosecurity surveillance. However extra effort can be deployed to decrease the uncertainty around rodent survival if necessary. As a rule of thumb island managers in New Zealand normally wait at least two rodent breeding seasons before undertaking extra monitoring effort. *This gives time for any remaining mice to breed up to a level where they are likely to be detected.*

51. The variables to be considered when **declaring an eradication successful**:

    - how long with no detections? *Longer timeframes in theory allow surviving pests to build up to detectable numbers so the productivity and timing of pest breeding has to be considered.*

    - how hard have you looked? *This should incorporate a judgement on the quality of detection effort as well as the quantity (Russell at al 2008b; Samaniego-Herrera et al 2013).*

    - the species involved- both target and non-target. Includes vulnerable species present in low numbers or previously present that may self-introduce if eradication is successful; species proposed to be translocated; and the species supposed to be eradicated (some are easier to detect than others). *Highly vulnerable native species might actually be good detection devices, e.g. the natural return of vulnerable seabirds on some islands with no sign of predation can be a good indication that the predators have gone.*

    - the effectiveness of biosecurity *If this is not up to standard then the successful eradication might only be temporary anyway.*

- the urgency for confirmation i.e. what management action requires this information and how urgent is it? *If you have a critical species that needs urgent reintroduction to the island or if confirmation allows you to wind down or defer some other project, then confirmation is more urgent. If it's just to know the eradication was successful with no urgent management action (recognising that for eradication planning elsewhere the confidence of transferring lessons from a confirmed eradication is preferable) what's the rush?*

- the consequences of wrongly declaring success. *If the translocation proposal is to release a relatively robust or common species, then the consequences of being wrong about the eradication outcome are not that serious and perhaps you could afford to take a greater risk.*

- the cost. *Extremely remote islands can be very costly to visit so monitoring visits may be more cost effective if combined with other reasons for making the journey.*

  To get the same confidence level that nil sign is confirmation of eradication do more effort early, less effort later. Too early and huge effort will still give little confidence, very late and minimal effort will give good confidence provided eradication failure can be distinguished from biosecurity failure through DNA samples (*See point 5 above*). Make these judgements on the facts available at the time (i.e. what has actually been done/ is the situation) rather than planned work.

52. Use a **range of indicators** to detect the presence of mice following eradication.

- Deploy a range of detection devices in the most likely places, it doesn't have to be a transect or grid, just try to sample different habitats and choose places most likely to have the target species.

- Look for mouse sign wherever you go but especially around burrowing seabirds, sandy beaches or soft mud. Beware of sign that pre-dates the eradication which may be still present. *Faeces can often last for years in sheltered sites.*

- Consider some night searches if you have a likely area to look safely.

- A trained rodent detection dog is a useful and relatively sensitive tool (Gsell et al. 2010).

- If using kill traps result in captures of non-target species, leave the carcass secured in the trap for a few days to see if it gets scavenged by a mouse.

All work should be recorded on GPS and mapped to show the amount of island coverage achieved. Any tangible sign or indication of rat presence should be photographed and if possible retrieved as a labelled sample for expert opinions on identification and DNA analysis.

53. **Detection devices** include snap traps, live capture traps, wax tags, chew cards, inked footprint tracking tunnels, dressed timber stakes soaked in peanut oil, candles, lard, chocolate, wax block rodenticide baits secured in bait stations, wooden boxes providing shelter and wood shavings as nesting material (rodent motels), trail cameras.

CONCLUSION

The global eradication database has records for 36 mouse eradications in NZ since 1984 where mice were a deliberate target species (Broome et al in prep). Of these 28 were successful (78%), 7 failed and for one (Antipodes) the result is yet to be determined. Twelve projects broadly followed the eradication design provided in these guidelines. All (apart from Antipodes still to be determined) were successful. A total of over 8,000 ha of NZ islands have had mice removed, including those where mice were not a declared target such as Enderby (710 ha).

The continued development of best practice for rodent eradications and its oversight by the IEAG gives both managers and funders the confidence to take on and succeed with increasingly larger and more complex projects. Many targeted more than one species of rodent and some made 'world first' attempts at challenges such as multiple pest species (e.g. Rangitoto/ Motutapu Islands; Griffiths et al 2013), large size (e.g. Macquarie Island; Springer 2014) or biosecurity (e.g. Project Island Song; http://www.doc.govt.nz/conservation/restoration-projects/project-island-song).

There is therefore a good track record for this method in NZ. Of course projects can be successful without the benefit of best practice (Appendix 1). However the advice presented in this paper has been gleaned from some of the largest and most challenging projects worldwide (Howald et al 2007; Simberloff et al 2014; Towns and Broome 2003).

The continuous improvement of our best practice allows new information to be readily incorporated and promulgated. The flexibility to allow case by case modifications to be considered during project planning to meet emerging issues has been a particular strength of the system. We encourage project managers to follow best practice as closely as possible but to openly discuss with technical experts, any aspect which does not fit their circumstances, and to document their rationale for any deviations.

This paper has focussed on technical and project management advice for mouse eradication projects in temperate conditions. Continuity of lessons and knowledge between projects in NZ has been largely maintained over the last 30 years through a mixture of professional relationships, reporting and reviewing of projects and coordination through the Department of Conservation (Veitch and Bell 1990; Thomas and Taylor 2002; Cromarty et al 2002; Towns and Broome 2003; Clout and Russell 2006; Broome 2009; Broome et al 2011, Russell & Broome 2016).

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REFERENCES

Animal Control Products 2006. Aerial and hand broadcast application of Pestoff Rodent Bait 20R™ for the intended eradication of rodents from specified areas of New Zealand. Code of Practice prepared for NZ Food Safety Authority Wellington. http://www.pestoff.co.nz/pdf/Code%20of%20Practice%2020R.pdf (Accessed March 2014).

Broome, K.G.; Golding, C.; Brown, K.P.; Corson P.; Bell, P.; 2017: Rat eradication using aerial baiting: Current agreed best practice used in New Zealand (Version 3.1). New Zealand Department of Conservation internal document DOC-29396, Wellington, New Zealand.

Broome, K.G., Brown, K.P., Brown, D., Murphy, E., Golding, C., Corson, P., and Cox, A. ., (in prep). House mice on islands: Management and lessons from New Zealand.

Broome, K., Cromarty, P., Cox, A., Griffiths, R., McClelland, P., Golding, C. 2011. The Island Eradication Advisory Group (IEAG) – a model of effective technical support for eradication project planning and management. Poster abstract in Veitch, C.R., Clout, M.N., and Towns, D.R. (eds). Island invasives: eradication and management. Proceedings of the international conference on island invasives. Gland Switzerland: IUCN and Auckland, New Zealand: p 524.

Broome, K. 2009: Beyond Kapiti- A decade of invasive rodent eradications from New Zealand islands. *Biodiversity* Vol 10 No. 2 & 3 14-24. http://www.tandfonline.com/doi/abs/10.1080/14888386.2009.9712840

Broome, K.G., Cromarty, P., Cox. A. 2005. Rat eradications – how to get it right without a recipe. Proceedings of the 13th Australasian Vertebrate Pest Conference, Te Papa Wellington, New Zealand, 2-6 May 2005: 152 – 157. http://www.feral.org.au/rat-eradications-how-to-get-it-right-without-a-recipe/

Clout, M. N.; Russell, J. C. (2006) The eradication of mammals from New Zealand islands. In: Koike, F.; Clout, M. N.; Kawamichi, M.; De Poorter, M.; Iwatsuki, K. (eds) Assessment and Control of Biological Invasion Risks. IUCN, Gland, Switzerland and Cambridge, U.K., and Shoukadoh Book Sellers, Kyoto, Japan, pp. 127-141

Courchamp, F., Caut, S., Bonnaud, E., Bourgeois, K., Angulo, E., Watari, Y. 2011. Eradication of alien invasive species: surprise effects and conservation successes. In Veitch, C.R., Clout, M.N., and Towns, D.R. (eds). Island invasives: eradication and management. Proceedings of the international conference on island invasives. Gland Switzerland: IUCN and Auckland, New Zealand: Pp 285-289.

Cromarty, P.L., Broome, K.G., Cox, A., Empson, R.A., Hutchinson,W.M., & McFadden, I. 2002; Eradication planning for invasive alien animal species on islands – the approach developed by the NZ Department of Conservation. In Veitch & Clout , Turning the Tide: the eradication of invasive species. IUCN SSC Invasive Species Specialist Group. Pages 85-91.
http://www.issg.org/database/species/reference_files/TURTID/Cromarty.pdf

Fewster, R.M., Miller, S.D., Ritchie, J. 2011. DNA profiling- a management tool for rat eradication. In Veitch, C.R., Clout, M.N., and Towns, D.R. (eds). Island invasives: eradication and management. Proceedings of the international conference on island invasives. Gland Switzerland: IUCN and Auckland, New Zealand: 426-431.

Fitzgerald, G., Wilkinson, R., Saunders, L., 2000. Public perceptions and issues in possum control. In Montague, T.L. (ed). The brushtail possum. Biology,impact and management of an introduced marsupial. Manaaki Whenua Press, Lincoln NZ:187-197.

Goldwater N., Perry, GLW, Clout, MN 2012. Responses of house mice to the removal of mammalian predators and competitors. Austral Ecology 37: 971 - 979.

Griffiths, R., Buchanan, F., Broome, K.G., Butland, B., 2012. Rangitoto and Motutapu- a starting point for future vertebrate pest eradications on inhabited islands. Proceedings of the 25th Vertebrate Pest Conference, Monterey, California.

Griffiths, R., Broome, K., Brown, P., Buchanan, F. 2013. Multispecies invasive mammal eradication on Rangitoto and Motutapu Islands, Hauraki Gulf New Zealand. Department of Conservation internal report DOCDM-898404.

Gsell, A.;Innes, J. G.; de Monchy, P.; Brunton, D. 2010: The success of using trained dogs to locate sparse rodents in pest-free sanctuaries. *Wildlife Research* 37 (1): 39-46. http://www.publish.csiro.au/paper/WR09117.htm (Accessed March 2014).

Holmes, N.D., Pott, M., Alifano, A., Will, D., Griffiths, R., Russell, J.C. 2014 (in prep). Why have tropical rat eradications failed more often? Analyses of factors associated with success and failure in rat eradications. Biological Conservation special issue. Tropical island conservation: rat eradication for species recovery.

Howald, G.C., J. Donlan, J.P. Galvan, J.C. Russell, J. Parkes, A. Samaniego, Y. Wang, C.R. Veitch, P. Genovesi, M. Pascal, A. Saunders, and B. Tershey. 2007. Invasive rodent eradication on islands. *Conservation Biology*, Vol. 21 (5): 1258 – 1268.

McClelland, P.J., 2011. Campbell Island – pushing the boundaries of rat eradications. In Veitch, C.R., Clout, M.N., and Towns, D.R. (eds). Island invasives: eradication and management. Proceedings of the international conference on island invasives. Gland Switzerland: IUCN and Auckland, New Zealand: 204-207.

Martin, T.G., Burgman, M.A., Fidler, F., Kuhnert, P.M., Low-Choy, S., McBride, M., Mengersen, K. 2012. Eliciting expert knowledge in conservation science. Conservation Biology 26 (1) 29-38. DOI: 10.1111/j.1523-1739.2011.01806.x

Morrison, S.A., Faulkner, K.R., Vermeer, L.A., Lozier,L., Shaw, M.R. 2011. The essential non-science of eradication programmes: creating conditions for success. In Veitch, C.R., Clout, M.N., and Towns, D.R. (eds). Island invasives: eradication and management. Proceedings of the international conference on island invasives. Gland Switzerland: IUCN and Auckland, New Zealand: 461-466.

Ogden, J., and Gilbert J., 2011. Running the gauntlet: advocating rat and feral cat eradication on an inhabited island – Great Barrier Island, New Zealand. In Veitch, C.R., Clout, M.N., and Towns, D.R. (eds). Island invasives: eradication and management. Proceedings of the international conference on island invasives. Gland Switzerland: IUCN and Auckland, New Zealand: 467-471.

Oppel, S., Beavan, B.M., Bolton, M., Vickery, J., Bodey, T.W. 2010. Eradication of invasive mammals on islands inhabited by humans and domestic animals. Conservation Biology 25 (2) 232-240. DOI: 10.1111/j.1523-1739.2010.01601.x

Pierce, R., Anterea, N., Coulston, G., Gardiner, C., Shilton, L., Taabu, K., Wragg, G. 2010. Atoll restoration in the Phoenix islands Kiribati: Survey results in November December 2009. EcoOceania Pty Ltd and Pacific Expeditions Ltd report for Government of Kiribati, Critical Ecosystem Partnership Fund, NZ Department of Conservation, NZAID and Pacific Invasives Initiative. http://phoenixislands.org/pdf/pipa2009final1pdf.pdf (accessed March 2014).

Russell, J. C. 2007. Invasion ecology and genetics of Norway rats on New Zealand islands. PhD thesis. University of Auckland School of Biological Sciences. Section 6.2.4 pp140-145.

Russell, J. C.; Towns, D.R. and Clout, M. N. 2008a. Review of rat invasion biology. Implications for island biosecurity. Science for Conservation 286. Department of Conservation, Wellington New Zealand. http://www.doc.govt.nz/upload/documents/science-and-technical/sfc286entire.pdf

Russell, J.C., Beavan, B.M., MacKay, J.W.B., Towns, D.R., Clout, M.N. 2008b. Testing island biosecurity systems for invasive rats. Wildlife Research 35. 215-221.

Russell, J.C., Mackay, J.W.B., Abdelkrim, J. 2009. Insular pest control within a metapopulation context. Biological Conservation 142: 1404-1410. doi:10.1016/j.biocon.2009.01.032

Russell, J.C., Miller, S.D., Harper, G.A., MacInnes, H.E., Wylie, M.J., Fewster, R.M. 2010. Survivors or reinvaders? Using genetic assignment to identify invasive pests following eradication. Biological Invasions 12 1747-1757. DOI 10.1007/s10530-009-9586-1

Russell, J.C., Sataruddin, N. S.; Heard, A. D. 2014 Over-invasion by functionally equivalent invasive species. Ecology Vol 95 (8). 2268-2276. http://dx.doi.org/10.1890/13-1672.1

Russell, J.C. and Broome, K.G. 2016. Fifty years of rodent eradications in New Zealand: another decade of advances. NZ Journal of Ecology Vol 40 (2) 197-204.

Samaniego-Herrera, A., Anderson, D.P., Parkes, J.P., Aguirre-Munoz, A. 2013. Rapid assessment of rat eradication after aerial baiting. Journal of Applied Ecology 50 (6). 1415-1421. DOI: 10.1111/1365-2664.12147.

Springer, K. 2014. Island Arks state of the islands report case study. Pest eradication on Macquarie Island. http://islandarks.com.au/state-of-the-islands-report-case-study-pest-eradication-on-macquarie-island

Thomas, B.W. and Taylor, R.H. 2002. A history of ground –based rodent eradication techniques developed in New Zealand, 1959-1993. In Veitch & Clout , Turning the Tide: the eradication of invasive species. IUCN SSC Invasive Species Specialist Group: 301-310.

Torr, N. and Brown D. Henderson Island restoration project post operational report. Unpublished report for the Royal Society for the Protection of Birds UK.

Towns, D.R. and K.G. Broome. 2003. From small Maria to massive Campbell: forty years of rat eradications from New Zealand islands. *NZ Journal of Zoology* Vol. 30: 377-398.
http://www.royalsociety.org.nz/Site/publish/Journals/nzjz/2003/031.aspx

Veitch, C.R. and Bell, B.D. 1990. Eradication of introduced animals from the islands of New Zealand. In Towns, D.R., Daugherty, C.H., Atkinson, I.A.E., (eds). Ecological restoration of New Zealand islands. Department of Conservation Wellington.

Wilkinson, I.S., and Priddel, D., 2011. Rodent eradication on Lord Howe Island: challenges posed by people, livestock, and threatened endemics. In Veitch, C.R., Clout, M.N., and Towns, D.R. (eds). Island invasives: eradication and management. Proceedings of the international conference on island invasives. Gland Switzerland: IUCN and Auckland, New Zealand: 508-514.

Appendix 1 Mouse eradication projects on NZ islands 1984-2017 (where mice were a declared target).

Year	Island	Mice only or multiple target species	Area	Result (mice)	NZ Best Practice
1984	Whenuakura	Multi species	2	Successful	No
1989	Mana	Mice only	217	Successful	No
1989	Allports	Mice only	16	Successful	No
1989	Ramiriki	Mice only	22	Successful	No
1989	Motutapu (Marlborough)	Mice only	2	Successful	No
1992	Moturemu	Multi species	5	Successful	No
1994	Motutapere	Multi species	46	Successful	No
1995	Browns	Multi species	60	Successful	No
1996	Papakohatu (Crusoe)	Multi species	<1	Successful	No
1996	Mou Waho	Mice only	140	Successful	No
1996	Mokoia	Mice only	135	Failed	No
1996	Matakohe	Mice only	37	Failed	No
1997	Motuihe	Multi species	179	Successful	No
1997	Matakohe	Mice only	37	Failed	No
1998	Matakohe	Mice only	37	Failed	No
2001	Matakohe	Mice only	37	Failed	No
2001	Mokoia	Mice only	135	Successful	No
2004	Patiti	Multi species	13	Failed	No
2005	Blumine	Multi species	377	Successful	No
2005	Pickersgill	Multi species	96	Successful	No
2005	Ohinau	Multi species	46	Successful	No
2007	Pomona	Multi species	262	Successful	Yes
2007	Rona	Mice only	60	Successful	Yes
2007	Adele	Mice only	88	Successful	Yes
2007	Fisherman	Mice only	4	Successful	Yes
2007	Tonga	Mice only	8	Successful	Yes
2008	Coal	Mice only	1163	Successful	Yes
2008	Te Hapua (Saddle)	Mice only	6	Successful	No
2009	Quail	Multi species	85	Failed	No
2009	Motutapu	Multi species	1509	Successful	Yes
2009	Rangitoto	Multi species	2311	Successful	Yes
2010	Te Hapua (Saddle)	Mice only	6	Successful	No
2010	Indian	Multi species	167	Successful	Yes
2013	Rotoroa	Mice only	82	Successful	Yes
2014	Maud	Mice only	309	Successful	Yes
2016	Antipodes	Mice only	2012	Not yet known	Yes

Projects were considered to have followed NZ Best Practice if the following criteria were met:

1. A written operational plan
2. GPS guided aerial bait spread
3. At least two applications
4. Each application at least 8kg/ha
5. Each application used 50% overlap in swath