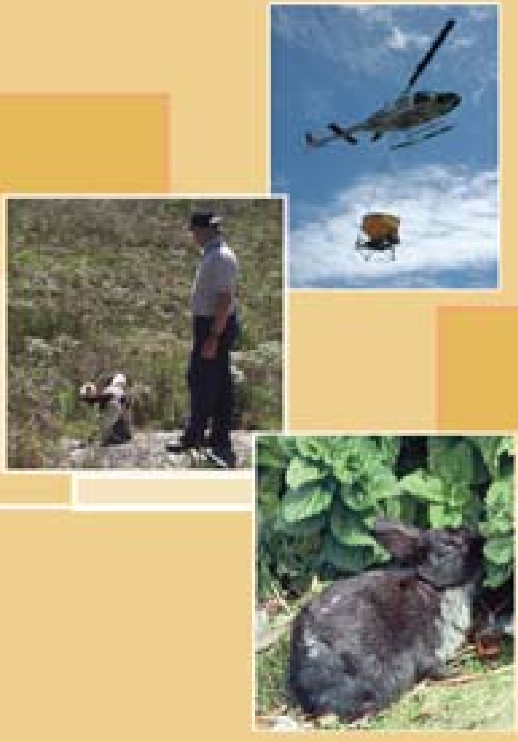

Workshop proceedings: Improving the efficiency of rabbit eradications on islands

4-5 February 2010, Christchurch, New Zealand

Elaine Murphy, Michelle Crowell and Wendy Henderson

Invasive Animals Cooperative Research Centre

"Together, create and apply solutions"

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Pavilions Hotel, Christchurch, New Zealand

Hosted by the Invasive Animals Cooperative Research Centre

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Workshop Proceedings: Improving the efficiency of rabbit eradications on islands
Report prepared for the Detection and Prevention Program's Project: 9.D.11 Rabbit Workshop: Improving the efficiency of rabbit eradications on islands.

Published by: Invasive Animals Cooperative Research Centre.
Postal address: University of Canberra, ACT 2600.
Office Location: University of Canberra, Kirinari Street, Bruce ACT 2617.
Telephone: (02) 6201 2887
Facsimile: (02) 6201 2532
Email: contact@invasiveanimals.com
Internet: http://www.invasiveanimals.com

ISBN 978-1-921777-04-2
Web ISBN 978-1-921777-06-6

Cover images (top to bottom): aerial poisoning on Stanley Island (J Greenwood), sniffer dogs on Broughton Island (D Priddel), French blue rabbit on Enderby Island (C Robertson), rabbit damage on Macquarie Island (K Springer).

This document should be cited as: Murphy E, Crowell M and Henderson W (2010). *Workshop Proceedings: Improving the Efficiency of Rabbit Eradications on Islands.* 4–5 February 2010, Christchurch. Invasive Animals Cooperative Research Centre, Canberra, Australia.

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Summary

Rabbits (*Oryctolagus cuniculus*) have been nominated as among '100 of the world's worst' invaders (Global Invasive Species Database 2009), in recognition of their extensive damage to biodiversity and difficulty to eradicate. The Invasive Animals Cooperative Research Centre hosted an international workshop in February 2010 to share and progress knowledge and experience of rabbit eradications, particularly on islands. This report summarises the invited papers, main discussions and recommendations of the expert workshop. It also includes a stand-alone appendix on 'Current agreed best practice on rabbit eradication on islands'.

The workshop was held in Christchurch, New Zealand and included 23 professionals from New Zealand (Department of Conservation, Landcare Research, Otago Regional Council, Wildlife Management International Ltd, Environment Canterbury and several independent contractors), Australia (New South Wales Department of Environment, Climate Change and Water; Tasmanian Department of Primary Industries, Parks, Water and Environment; and Tasmania Parks and Wildlife Service), United Kingdom (Forest Research), Mexico (Conservacion de Islas) and the United States (Island Conservation). Invited papers described rabbit eradication programs on islands off Australia, Hawaii, Ireland, Mexico, New Zealand, Portugal and the United Kingdom. The preparation and operational plan for the rabbit and rodent eradication on Macquarie Island was also discussed.

The attendees agreed that best initial population knockdowns are achieved with poison programs. Operational technical standards must be kept to the highest level to ensure the best chance of eradication, including:

- bait type and quality — including preference and acceptance trials, consideration of location limitations, storage and handling
- feed rates — tailored to population; acceptance trials help determine best rates
- toxin choice and loading — acute or chronic poisoning, considering non-target susceptibility and poison shyness
- method of application — considering location, topography and logistics.

Poisoning is generally followed by a suite of secondary control measures to locate and dispatch rabbit survivors. These methods traditionally include the use of sniffer dogs, shooters and various traps. Habitat type (eg dense vegetation), climate extremes and the need for multispecies control can complicate eradication success. Possible

solutions to these issues were discussed, in the context of operations on the mainland, and subantarctic, temperate and tropical islands. A number of hypothetical scenarios were also discussed, where aerial poisoning was not completely effective on a large or small island. It was agreed that a control option should not be discounted until it has been fully evaluated for the conditions involved: a 'one size fits all' approach cannot be taken for rabbit eradication.

The group suggested innovative methods that could be trialled in future, such as fibre optics and remote cameras, rabbit lures (eg pheromones), hair tubes, sticky traps and Judas rabbits. The use of rabbit haemorrhagic virus, aerial shooting, directional netting/traps, water points in arid environments and mineral pegs in nutrient-deficient environments were also discussed.

Research priorities discussed by the group centred on developing techniques to be able to detect and kill rabbits at low densities, particularly post-poison operations. A better understanding of the biology and behaviour of surviving rabbits was considered most important. Research was recommended into bait stations for rabbits, kill traps or snares (preferably multiple-kill with automatic reset functions), new baits and lures, including pheromones. New methods of toxin delivery that do not require bait should also be researched (eg a 'Tarbaby' approach as from the *Tales of Brer Rabbit*). Search/detection models for validating the effectiveness of detecting survivors in the field are also needed. In the longer term, research should be conducted into rabbit genome sequencing to identify any potential weaknesses that could be exploited.

Enderby Island rabbit (image: Jeff Flavell)

1. Introduction

Rabbits (*Oryctolagus cuniculus*) have been nominated as among '100 of the world's worst invasive alien species' (Global Invasive Species Database). They cause severe damage to the environment, contributing to the decline of threatened flora and fauna by overgrazing and destroying habitat. As prey, they support populations of introduced predators that also prey on native species.

In Australia, competition and land degradation by feral rabbits are listed as a key threatening process under the *Environment Protection and Biodiversity Conservation Act 1999* and pose a threat to a large number of native species (DEWHA 2008). Rabbits are widely distributed across the Australian mainland, Tasmania and many offshore islands. Rabbits, along with foxes and cats, are considered to be Australia's most serious vertebrate pests — rabbits are present on 14 of the top 100 priority high-conservation-status offshore islands and their eradication is recommended (DEWHA 2008, Ecosure 2009, Appendix 2).

Worldwide, rabbits have been introduced to over 800 islands with devastating impacts. There have been at least 48 attempts to eradicate them, with about a five percent failure rate (Keitt et al 2011), but even on small islands eradicating them is very difficult and often requires a combination of techniques (Courchamp et al 2003, Flux and Fullager 1992).

The aim of this workshop on improving the efficiency of rabbit eradications on islands was to bring a group of international rabbit experts together to:

- pool knowledge
- discuss what has worked and what has not
- agree on priority research that would help with future eradications.

Workshop attendees are listed in Table 1. The agenda is summarised in Appendix 1. The workshop was particularly timely in view of the planned eradication of rabbits (and rodents) on Macquarie Island starting in the winter of 2010.

Table 1. Workshop attendees

Name	Affiliation
Chema Barredo	Conservacion de Islas, Mexico
Elizabeth Bell	Wildlife Management International Ltd, New Zealand
Neil Bolton	Department of Conservation, Twizel, New Zealand
Keith Broome	Department of Conservation, Hamilton, New Zealand
Derek Brown	Independent contractor, Nelson, New Zealand
Karl Campbell	Island Conservation, United States
Brian Cooke	Invasive Animals Cooperative Research Centre, University of Canberra, Australia
Michelle Crowell	Department of Conservation, Christchurch, New Zealand
Patrick Dawson	Independent contractor, Wanaka, New Zealand
Brent Glentworth	Environment Canterbury, Timaru, New Zealand
Richard Griffiths	Department of Conservation, Auckland, New Zealand
Elaine Murphy	Department of Conservation, Christchurch, New Zealand
Tonny Ortiz	Conservacion de Islas, Mexico
John Parkes	Landcare Research, Lincoln, New Zealand
Peter Preston	Otago Regional Council, New Zealand
David Priddel	Department of Environment, Climate Change and Water, New South Wales, Australia
Don Robson	Otago Regional Services, New Zealand
Sue Robinson	Department of Primary Industries, Parks and Water Tasmania, Australia
Keith Springer	Parks and Wildlife Service, Tasmania, Australia
Fraser Sutherland	Independent contractor, Wanaka, New Zealand
Nick Torr	Independent contractor, Te Anau, New Zealand
Roger Trout	Forest Research, Alice Holt Farnham Surrey, United Kingdom
Geoff Woodhouse	Parks and Wildlife Service, Tasmania, Australia

2. Invited papers

2.1 Eradication of rabbits from three offshore islands in New South Wales, Australia

David Priddel, Department of Environment, Climate Change and Water, NSW, Australia

This talk focussed on Cabbage Tree Island, Montague Island and Broughton Island in New South Wales. All three islands are relatively small and heavily vegetated. Eradication programs to rid these islands of rabbits were successful and are discussed below.

Cabbage Tree Island 1997

This island is 30 hectares in size and European rabbits were the only mammal pest present. Prior to eradication, rabbits were severely degrading the rainforest understory and this degradation was in turn impacting on nesting seabirds.

Rabbits were eradicated using three methods sequentially: reintroduction of myxomatosis, introduction of rabbit haemorrhagic disease virus (RHDV), and aerial delivery of brodifacoum cereal bait.

Myxomatosis was already present on the island, but thousands of European and Spanish rabbit fleas were released to increase the disease's effectiveness in the months preceding a natural outbreak during May–July 1997. This release resulted in the rabbit population being reduced from about 250 to 100 rabbits.


Cabbage Tree Island (images: Nicholas Carlile)

RHDV was released in August 1997, soon after the myxoma epizootic had finished, using seven inoculated rabbits. RHDV reduced the population from about 100 to 45 rabbits.

Palatability trials were done prior to aerial baiting. Initial trials had found rabbits favoured cereal pellets over (in decreasing palatability) apples, carrots, oats, chaff and molasses and endive. Aerial baiting was undertaken in September 1997 using a helicopter. A single drop of 11.5 kilograms per hectare of Talon 20P brodifacoum cereal bait with five-metre wide swath was used, with flight lines approximately 50 metres apart. There were recognised gaps in coverage, but rabbit home ranges were known to cover several hectares and they moved hundreds of metres daily. Rabbits died 5-13 days after the baiting program.

The effectiveness of RHDV and poison baiting were assessed by attaching radio transmitters to 70 rabbits. These rabbits were all dead by mid-September 1997.

222 monitoring stations were set up to detect any surviving rabbits. Each monitoring station was a 250 millimetre length of 100 millimetre diameter plastic drainage pipe. A whole apple on a metal spike was placed inside the pipe. Apples were chosen as they remained edible for several weeks and rabbit tooth marks could be readily identified. Monitoring was undertaken for six months after the eradication operation to detect any surviving rabbits. No rabbits were found during this period. Since then, there has been a huge regeneration of rainforest understorey.

Question:
BG: How were rabbit fleas on Cabbage Tree introduced?

DP: Fleas infected with myxoma virus were provided by CSIRO. This was a standard service to support the use of myxomatosis by the agriculture industry, but ceased following the introduction of RHDV. The fleas were spread on captured rabbits as well as being placed directly in warrens.

Montague Island 2007

This island is 82 hectares in size, and rabbits and house mice were the two mammal pest species present. Goats were also previously present on the island, but were eradicated in 1990. There were not many rabbits on the island, but they were considered a major hurdle to the regeneration of trees and shrubs.

The knockdown method used on Montague Island involved a natural outbreak of RHD, followed by two aerial drops of Pestoff 20R brodifacoum cereal bait at 12 and six kilograms per hectare, applied ten days apart. A bait-sowing bucket was used with 80-metre swath and flight lines 35 metres apart.

Both rabbits and house mice were successfully eradicated in this operation.

Questions:

RG: You mentioned concerns about secondary poisoning — are there predators there?

DP: Yes, raptors, which are a high-profile species with the general public.

RG: Did you monitor the raptor population?

DP: Yes, on Montague Island where the population did not decline, despite the drop in their food supply.

Broughton Island 2009

This island is 144 hectares in size, and rabbits and black rats were the two mammal pest species present. The eradication method used in this case involved introduction of RHDV on carrot baits, followed by two aerial drops at 12 kilogram per hectare Pestoff 20R, as used on Montague Island. Early indications are that both species were successfully eradicated.

Question:

EM: What knockdown did you get with RHD?

DP: Obvious, marked knockdown (60–70 per cent maybe) but this was not formally measured.

Advantages of biological control

The advantages of using biological control include:

- confirmed reduction in rabbit numbers
- less chance of secondary poisoning compared with other methods
- more bait is available per target individual (rabbits and other species)
- less chance of failure due to bait aversion, competition or inadequate available bait
- methodology is readily available, inexpensive, simple and effective.

Questions:

JP: Was rabbit breeding status a consideration for the timing of eradication?

DP: No. Eradication was always programmed in winter, as non-targets were the prime consideration for timing. It was likely the rabbits were not breeding but this was not confirmed.

BG: Were there backup plans if brodifacoum didn't work?

DP: Yes, we were prepared for ground baiting, trapping and so on but didn't need this.

EM: Do you see an advantage in using both myxomatosis and RHD?

DP: Why not use both? If myxomatosis is available I would recommend using both. CSIRO provided the fleas.

JP: Why not use biological control on Macquarie Island?

KS: There was an additional logistics cost for getting an additional baiting regime down there without any idea of how well it would work in Macquarie conditions. At the time the decisions were made, RHDV appeared to be not as effective in cooler, moister conditions. We wouldn't know what kill rate we had achieved through RHDV before the shipment of brodifacoum left. We would have had to assume a low success rate and send the same amount of brodifacoum.

RT: Are all rabbits on Macquarie seronegative for RHDV?

KS: Blood samples taken in 2004 indicated they were seronegative, but we now know we would have been better to use intestinal tissue (see Appendix 5).

RT: The disease should spread if the population is seronegative.

KS: Yes, it should spread, but it would have had a logistical knock-on effect that could have increased the shipping costs and helicopter time.

EM: If non-target exposure to poisons is a problem, biological control may be better, but is this the case on Macquarie Island? Are there significant non-targets on Macquarie?

KS: Yes, there are non-target considerations on Macquarie. The logistical costs of using biological controls outweighed any potential reduction in non-target impacts from using them.

BG: If you use biological control on rabbits, is there a behavioural impact that affects the likely result of your brodifacoum drop? If you couldn't do the poison baiting straight away then there could be both behavioural changes and vegetation recovery that compromises your baiting operation.

DP: I couldn't answer that definitively. Our reasoning for the use of biological control was that inadequate availability of bait is likely to make an eradication attempt unsuccessful. Rabbits are relatively large herbivores (compared with rodents), so you need plenty of bait to go around. Biological control is an effective means of reducing rabbit numbers prior to baiting, thereby reducing the quantity of bait needed. So why not take calicivirus to Macquarie Island and inject it directly into trapped rabbits?

KS: The proposal in the initial plan was to use RHDV on carrot bait aerially distributed to get coverage over Macquarie Island (13,000 hectares). The logistics of using carrot bait, preparing it and having choppers were looked at; not the scenario of direct injection.

NT: At the time the decision was made we thought that the cool wet climate was a big factor, but experience since then in the Northern hemisphere suggests it could work.

JP: The general rule is to over-engineer eradications with plenty of bait, but we are now finding that consents require use of pesticides to be minimised. This creates pressure for us to keep the quantities of bait down. Were there survivors on Enderby Island?

NT: Some rabbits survived where there was bait on the ground, so we know that they weren't eating it.

EM: If surviving rabbits are surrounded by dead rabbits do they react to this in an obvious way?

DR: Rabbits surviving a poison operation make themselves scarce. Once you remove rabbits, the feeding patterns change completely. It takes 2–3 months for a new regime to settle in. They get more wary and spend less time feeding. Subdominant rabbits don't normally feed until after the dominant animals feed. If the dominants are gone, the remaining ones don't feed for days, waiting for the dominants to appear. With Pindone and other anticoagulants, the operation can look successful immediately afterwards, then survivors appear over time. With 1080 (an acute poison), if it looks like they are all gone then they are really gone.

NB: Dying rabbits climbed over and died on top of each other in piles at Pindone bait stations trialed in Twizel.

Reference: Priddel et al (2000).

2.2 Rabbit eradication on two Madeiran islands and local control on Lambay Island, Ireland

Roger Trout, Forestry Commission, United Kingdom

Selvagem Grande 2002

Conservation value: The arid Portuguese island of Selvagem Grande (Great Salvage) is an important seabird breeding station in the eastern Atlantic Ocean. Selvagem Grande also provides diverse habitats for an extensive flora, including 11 endemic species.

Threats: European rabbits and house mice were the pest mammal species present and both had adverse impacts on breeding seabirds and island vegetation.

In 2002, the Natural Park of Madeira conducted a rabbit and mouse eradication while mitigating against the impact on non-target species — the Berthelot's pipit *Anthus berthelotii* and the gecko *Tarentola bischofii* were of most concern. The island's response was followed after the operation.

Logistics: The 240 hectare (270 hectare surface area) uninhabited island is 150 kilometres from the mainland and has a difficult landing site. Six tons of Pestoff 20R brodifacoum bait, 400 kilograms of Vertox pellet bait, 750 kilograms of Talon and Klerat wax blocks, an all-terrain vehicle and six tons of other equipment had to be winched 100 metres up from the landing site to the island's plateau. A camp was established to keep ten to 11 people on the island for three weeks. The estimated rabbit population, using data from three two-hour spotlight transects, was over 1000 rabbits. Trapping detected no breeding at that time. Mouse density was estimated at 50–350 mice per hectare from trapping data. After gridding the island at one-hectare units, approximately 17,000 individual baiting points (open piles of 150 or 200 grams of bait, depending on mouse density) were established on a 12.5 by 12.5 metre grid. There were exclusion areas set up for birds. Baits were also applied on steep slopes and cliffs where bait stations could not be placed, by hand 'seeding' (using ropes attached to predrilled anchor points fixed at 30-metre intervals).

Spotlighting rabbits (image: IA CRC)

All rabbits were killed within a month. However, mice persisted for about five months and were especially difficult around where birds were breeding, so wax blocks were installed there in winter when petrels were not present. Subsequent assessments by trapping, bait grids and systematic observation of signs over three years, has confirmed the eradication was successful.

Non-target species: Various mitigation methods were tried to prevent harm of non-targets. Regarding Berthelot's pipit, captive caged groups did not work because birds died. Mouse-proof vitamin K drinkers for birds were provided on tables, and a small number of birds were translocated to another island for the duration of the baiting. Monitoring after baiting showed a rapid decline in pipits on Selvagem Grande from the operation, but the population increased in subsequent years.

110 geckos were kept in captivity as a safeguard but monitoring on 15 plots (100 by 100 metre) showed they were unaffected by the baiting, despite eating insects seen to consume bait, and the population increased in subsequent years.

Overall there was a good island response to the eradication. There has been regrowth of rare plants, good shearwater production and a lizard population explosion. There is, however, a published suggestion (in *Water Birds*) that lizards are attacking shearwater eggs.

Costs: Total monetary cost was €400,000 (approx €2000 per hectare). 4700 kilograms of pellet bait plus 750 kilograms of wax blocks were needed. Planning the operation took up the equivalent of 555 days of work, baiting took 1300 days of work and monitoring took 755 days of work.

Key messages: The key messages from this island operation include the need:

- for teamwork and dedication to the eradication effort
- to plan for flexibility in bait application, to mitigate against non-target effects, and to monitor for a long time after baiting (ie years)
- to maintain island biosecurity.

Question:

EM: What follow-up action was required?

RT: For Selvagem, very little follow-up was needed (maybe five rabbits were killed by hand).

Bugio Island (close to Madeira) 2007/08

Conservation value: This island has a rare seabird Zino's petrel (a burrow nester in topsoil).

Threats: Rabbits, goats and mice are the pest animal species of concern.

This island is 350 hectares in size (actually 500 hectares in surface area), seven kilometres long by 300 metres wide. The terrain is very steep and arid. Using the Modified McLean Scale of Rabbit Infestation, the index was approximately 1–2 (1= no sign or rabbits seen, 2= very infrequent sign present and unlikely to see rabbits). Spotlight counts were done on eight hectares of plateau. There was no initial sampling on the northern two thirds of the island, as it was inaccessible. Index trapping of mice was carried out at the south end of the plateau and on the slopes.

In August 2007 there was a trial on the southern 20 per cent of the island. A small mouse baiting station grid was used together with bait spreading by helicopter (280 kilograms in 400 gram bait bags). Over winter, wax blocks were used at the northern periphery of the island. No rabbits were seen by 12 months after baiting, but mice were found after 11 months (from activity at 35 per cent of bait stations near the plateau).

Aerial baiting (image: NSW Industry & Investment)

In 2008, the complete island was baited with a helicopter using 400 gram bait doses in paper bags about every 50 metres (approximately 5000 kilograms in total), since a helicopter-based spreader hopper system was unattainable. The main green gullies and vegetated scree slopes were especially targeted. A hand-held Global Positioning System (GPS) trace showed reasonable coverage for the first flight. However, a set of repeat sowing lines was carried out instead of an across-island flying operation. The pilot would not cross-track bait lines, preferring to fly the island in one direction. There was an uneven bait drop on near-vertical cliffs. Follow-up action was very difficult (in fact, near impossible for two thirds of the island).

No rabbits were seen in the following five months, but it is likely that mice were not sufficiently targeted. Monitoring continues, although much of the island is too dangerous to be visited on foot.

Monitoring: The southern area has been declared clear (with no signs in mouse bait boxes and no rabbits sighted) but the northern area still has mice present.

Question:

JP: Why not use a bait-spreading bucket?

RT: The appropriate helicopter was not available. The military has appropriate equipment, but using it would be exorbitantly expensive.

Lambay Island, Ireland

On the 250 hectare temperate island of Lambay, resources were not available for eradication of rabbits or black rats, so intensive local control was sought. Rabbits were depleting the vegetation. Some rare birds and wallabies were also present on this island.

Rabbit-proof fencing with drop traps was positioned around much of the intensive cattle-rearing area (a major portion of the island), excluding areas of cliff and rough grazing. Poison in 0.4 metre pipes placed below ground also killed many target animals. A phosphine fumigant was used in burrows on a sandy plain, enhanced by placing sheep wool plugs tightly into the burrow entrances to prevent gas escaping. This control operation resulted in the best conservation forage crop for several years.

Reference: Olivera et al (2010).

2.3 Rabbit Eradication in Mexico: Experiences and challenges

Chema Barredo, Conservacion de Islas, Mexico

Todos Santos 1997–98

The two small uninhabited islands of Todos Santos are 27 and 83 hectares in size. Rabbits and cats were pest mammal species present. The rabbit population size was unknown. Techniques used in the eradication included trapping, hunting and the use of dogs. The eradication of rabbits was successful.

San Benito 1997–99

San Benito consists of three islands, which are 389 hectares, 148 hectares and 48 hectares in size. Rabbits and cats were present pre-eradication, and mice have invaded since then. The population of rabbits on the largest island was estimated to be 400, but the population size was unknown on the other two islands. Techniques used in the eradication included trapping, hunting and the use of dogs. The eradication of rabbits was successful.

Rabbit-detecting dogs (image David Priddel)

Clarion

Clarion Island, located about 1000 kilometres off the Mexican mainland, is much further away than the other Mexican island eradication projects. It is 1948 hectares in size, with a maximum altitude of 335 metres. The Mexican navy was relied on for transport during this project, and Island Conservation helped with the eradication attempt. The island was divided into two control zones (A and B) and eradication was started with Zone A (while Zone B remained uncontrolled).

Eradication of rabbits in Zone A was not completed, due to project funding running out. Ship rats and pigs were successfully eradicated, but the rabbit work is ongoing. During March 2001 to April 2003, trapping, hunting and using dogs (with 6–12 hunters) resulted in 30,107 rabbits being killed in Zone A, but rabbits kept reinvading from Zone B. The project was subsequently stopped to consider other options.

The overall area was too large to manage efficiently using the above techniques; clearly extra tools are needed in future efforts. Options available include fencing, fumigant (Magtoxin), ground poison (eg brodifacoum) and virus (eg RHDV, although Mexico is free of this virus).

In 2009, the rabbit population was estimated at 34,000 total or 18 rabbits per hectare (Valdez-Gómez).

Maria Madre

This island is 14,400 hectares in area, is 100 kilometres offshore and has a maximum altitude of 616 metres. It is a big tropical island and has contained a federal prison since 1905. Cows, goats and cats are the main mammal pest species present. In 2008, 150 rabbits were set free from cages, possibly by one of the prisoners. Endemic mammals include raccoon, mice and cotton-tail rabbits (*Sylvilagus graysoni*). Endemic birds and reptiles are also present on the island.

Questions:

EM: What are the plans for Maria Madre?

CB: Last year there was a small cat project run at the prison that caught 521 cats. Because of the federal prison there are no other animal control projects in place. The National Ecology Institute has some projects running but it is a difficult place to work.

PP: What species of rabbits were released on the island?

CB: They were white European rabbits, and they are easily distinguished from the existing rabbit population.

2.4 Wildlife Management International Ltd (WMIL) rabbit feasibility, control and eradication programs

Elizabeth Bell, WMIL, New Zealand

Eradication of rabbits from Deserta Grande (Parque Natural da Madeira) 1996

Deserta Grande is a very barren 1000 hectare island, which has lost two metres of topsoil in places. There was limited vegetation — some endemic plants grew on cliffs. The terrain is extreme and difficult to traverse. Rabbits, goats and house mice were the mammal pest species there. Rabbits and mice were targeted for eradication, but it was not expected that the mice would be eradicated.

Bait arrived in July (on schedule) and was stored, causing some loss of bait. Grain-based pellets (Wanganui No 7) were hand laid at bait depots on a 25 metre grid and there was also limited spreading via helicopter. Bait was carried in two large satchels on each side of a pack harness by operators on foot (as used by New Zealand Post).

Regular monitoring of the island after baiting was conducted by Parque Natural da Madeira staff, with final monitoring done by WMIL in 1997. No rabbits were detected during this period. There was some recovery of vegetation noted, but the recovery was limited due to herbivory by goats.

Eradication of rabbits from Ilheu da Praia, Azores (Direccao Regional do Ambiente) 1997

This barren 12 hectare island is open to summer visitors, and has had exotic Tamarix trees planted to provide shade. It is an important breeding site for migratory seabirds, including Cory's shearwater and Madeiran storm petrel.

For rabbit eradication, brodifacoum Pestoff rabbit bait was hand laid at bait depots on a 20 metre grid. Eradication was achieved very quickly, with one remaining rabbit shot. Regular post-baiting monitoring was conducted from 1997 to 1999 by Direccao Regional do Ambiente staff, and no rabbits were detected. Seabird populations have increased since the eradication operation.

Feasibility of eradicating rabbits from Lundy Island, UK *(Natural England project)*

Lundy Island is 560 hectares in size, with vegetation consisting of pasture, *Rhododendron* thickets and heath. Black rats were eradicated from the island in 2003/2004. Rabbits had been present since the 11th century (in the 'Royal warren'); they are valued for their historical significance and their rare black coat. The rabbit population was estimated to be 25,000 — having a significant impact on the island's ecosystem and archaeological structures.

Rabbit control and eradication options were considered in a report in March 2006. It was concluded that eradication was not feasible, since it was illegal to use any poison for controlling rabbits in the United Kingdom and steep cliffs made many areas inaccessible. Control options were recommended to reduce rabbit numbers. Three months after the report, an outbreak of RHD temporarily solved the problem, dropping rabbit numbers to less than 500. However, the outbreak was not followed up with immediate control and since then the rabbit population has rebounded.

Ascension Island

Ascension Island is a 9700 hectare volcanic island consisting of mostly barren lava with a forested mountain (Green Mountain). Rabbits have been present since 1820.

The potential for eradicating rabbits from Ascension Island and developing a rabbit control strategy for immediate implementation was assessed in 2008. The final report


Ascension Island (image: startledrabbitt III, flickr)

was produced in September 2008 after site visits in March and April (RSPB, South Atlantic Invasive Species project).

Options for both rabbit eradication and control were assessed. A questionnaire for local residents was designed to determine their views. Residents did not want eradication and felt it was not realistic to target rabbits without targeting rats (*Rattus rattus*). Rabbits were not viewed as a serious problem. There were also legal difficulties regarding the use of poison bait. Residents believed some native plants were affected by rabbits and other pests. Locals said they preferred to trap rabbits in their own gardens, rather than have them totally removed from the island.

Baseline surveys were undertaken using spotlight and pellet counts. The rabbit population was estimated to be 5000. Comparison to a 2004 survey showed that rabbit distribution had increased but overall numbers were similar. Long-term monitoring has been established to detect further changes.

Assessment and advice on the rabbit situation on St. Helena *(RSPB, South Atlantic Invasive Species Project)*

St Helena is a 12,000 hectare island with lush vegetation (mostly weeds) but barren areas around the coast. Rabbits had been present since the 1500's, but were exterminated by feral cats by the end of 16th century. A Mediterranean subspecies was reintroduced in 1770. Rabbit numbers now fluctuate, but are generally increasing as the island gets greener. Native plant revegetation, crops and stock are all affected by rabbits. Feral cats and rats (*Rattus rattus* and *R. norvegicus*) are also present on the island.

A questionnaire was designed and put to local residents. Results showed that they did not want rabbits eradicated, but wanted to trap and shoot them. They felt it was unrealistic to eradicate rabbits alone anyway, given the likelihood of prey switching by feral cats (and the subsequent impact on birds). The final report was produced in September 2008 after a site visit in April.

A baseline survey (using pellet count only) estimated the rabbit population to be 28,000 (ie less than three per hectare). Trapping, shooting and biological control were identified as acceptable control options. Long-term monitoring has been established to detect further change. The control options are still being considered.

Questions:

RT: Why did it take six weeks to treat 12 hectares (for Azores)?

EB: A subtropical cyclone prevented access to the island for two of the six weeks. Bait was on the island but we couldn't get the personnel there. Rabbits were killed within one week, and the rest of the time was used for monitoring.

JP: Using ground-based piles of bait has worked for mice and rabbits. Would this work if rats were present (ie for a combined rat/rabbit eradication)?

EB: Rabbits took baits from bait stations on Lundy Island.

RT: We have experience using four-inch tubes, where rats and rabbits could both access the baits. But it's not clear that you would have enough bait to eradicate both species. If you have bait in piles you can monitor that bait is still being taken.

EB: Rats and hares were present on Mauritius. We found hares were taking rat bait too, so we needed to use larger piles of bait where hares were present.

KC: What condition was the bait at Deserta Grande in?

EB: Some bags were fine. Other bags would be a third liquid gel, middle third mouldy and covered in dusty mites, and top third covered in mould. We sometimes used only the middle third of the bag. We ended up dumping a lot of bait.

EM: In Europe could you apply for exemption to use poisons on rabbits?

RT: This hasn't been tested, but in the whole European Union you cannot use brodifacoum in the open (but it can, for example, be used in bait stations).

References: Bell (2001), Bell and Boyle (2008).

2.5 Enderby and Rose Island rabbit eradication 1993, and St Paul Island 1997-1999

Nick Torr, Independent contractor, New Zealand

Enderby and Rose Islands 1993

Enderby Island (700 hectares) and Rose Island (80 hectares) are part of the Auckland Island Group (460 kilometres south of New Zealand at 50° 40'S, 166° 08'E). Both are quite modified due to farming attempts (mid-1800s) and the continued presence of introduced mammals.

Enderby Island is low lying, with its highest point at 45 metres. There is a small area of dunes (approximately 20 hectares), Rata forest over about a quarter of the island, scattered scrub over about a third, and the rest is open sward. Cattle were eradicated in 1991–93. Rabbit and house mice are the mammal pest species present.

Rose Island is also low lying, with its highest point at 48 metres. Rata forest covers about a quarter of the island and the rest is tussock. Rabbits are present.

In 1991, the rabbit numbers were assessed: the population was calculated as 5000–6000 on Enderby Island and 500–600 on Rose Island (Glentworth 1991). The eradication program was modelled on the Round Island rabbit eradication of 1986 (Merton 1987).


French blue Enderby rabbit, (image: Brian Ahern)

Phase 1 of the program aimed to lower the total rabbit population quickly and substantially with a widespread poison campaign. The timing was set to be outside rabbit breeding season, at the driest time of year: 15 February was chosen for the first bait drop. The chosen bait was Pestoff 20P (brodifacoum 20 parts per million), which has good weathering characteristics and is palatable to rabbits and mice.

Bait was applied in two drops spaced 18 days apart, using a helicopter with a bait-spreader bucket. No GPS was used for positioning grids, so grid lines were manually flagged, sown in 40-metre wide swathes with five-metre overlap. An application rate of five kilograms per hectare was used over both islands, with two applications in high rabbit density areas to give ten kilograms per hectare. 100 hectares in the first drop and 20 hectares in the second drop were treated at this higher rate.

Results: There was less than one millimetre of rain in the ten days after the first drop and 14 millimetres after the second drop. It was four days to the first observed dead rabbit, with peak mortality occurring around ten days after baiting. On Enderby Island there was 99.9 per cent rabbit mortality but Rose Island was not as successful, possibly because of the thick tussock vegetation there. Three days passed before the first dead mouse was seen, but mouse eradication was achieved.

Phase 2 of the program involved hunting down and destroying any rabbits remaining after the poison operation. This phase started one week after the second poison drop. Hunting with a dog and gun, digging up burrows (the most effective method), and spotlighting were used. Gin trapping was used as a last resort.

The duration of Phase 2 was eight weeks in the first year and five weeks in the second year (although no rabbit sign was found). A total of 22 rabbits were caught on Enderby Island and 12 were caught on Rose Island. Approximately 70 per cent showed no obvious sign of poisoning. Four weeks passed on Enderby Island and two weeks on Rose Island between the last rabbit and the end of the hunting trip in first year. No rabbit sign was found in the second year, nor has been found since then. It was estimated that 53 days passed between the final aerial drop to the last rabbit being caught.

Questions:

RG: With the rabbits you targeted in the follow-up, did you find any young rabbits?

NT: There were some smaller animals, but very few really small rabbits.

GW: Did you see many rabbits during spotlighting in the follow-up phase?

NT: Not many — the dog was the main way of finding them. It would have taken much longer without a dog.

EM: Do you think the reason that so many rabbits survived on Rose Island was that they were neophobic?

NT: It’s not really clear why this was the case. It may have been that the bait was getting hung up in the thicker tussock there where rabbits couldn’t access it as easily.

St Paul Island 1997–1999

St Paul Island is 800 hectares in size, located in the mid-Indian Ocean (at 38° 42’30”S, 77°32’30”E). It is a recent volcanic island with no free-standing water. It is 268 metres high and steep in places. Vegetation consists of course grass and thick rush patches. There are no land-dwelling birds. Rabbits, black rats and house mice are the mammal pest species present.

The rabbit eradication was planned for the driest time of year, in late January. The chosen bait was Pestoff 20P (brodifacoum). Problems with bait quality were encountered, with some bait being wet with condensation. A small amount was dumped and the remainder was not in the best condition.

Because of logistical constraints, there was only a single helicopter drop to distribute the baits. No GPS was used for positioning grids, so grid lines were manually flagged. There was a helicopter bucket malfunction: the bucket spinner did not work, so it was necessary to do parallel lines 100 metres apart with no spinner for a large portion of the island. Bait was applied at ten kilograms per hectare (where there were low rabbit numbers), 20 kilograms per hectare (for medium rabbit numbers), or 40 kilograms per hectare (for high rabbit numbers).

There was no rain on the island for two months after baiting. Seven days passed to the first dead rabbit being sighted. Most rabbits were dead by 14 days. Rats were successfully eradicated but mice survived the bait drop.

Rabbit follow-up action was undertaken for two months over February and March 1997 (two weeks after the poison drop), six weeks over November and December 1997, and eight weeks over December 1998–February 1999. Hunting with a dog and gun, digging up burrows, spot poisoning and trapping (in burrows and on buck heaps) was used. No spotlighting was done as there were limited facilities, but in hindsight more could have been done.

The first trip resulted in 48 rabbits being killed (17 of which had eaten bait), the second trip 18 rabbits (including seven young rabbits), and the third trip five rabbits. No sign of rabbits has been seen since then. The eradication was considered to be successful.

Question:

KC: How did you work the dogs?

NT: Usually two or more hunters had one or two dogs. If a rabbit was flushed, hopefully you would get a shot at it. If not, it would be chased to ground where it could be dug up. It could take a lot of time focussing on one rabbit. Sometimes the dog would indicate rabbits in burrows you hadn't seen that would be dug up if possible. Occasionally traps would be set at burrow entrances if digging wasn't an option.

Both operations were fly-by-wire, with not much experience with aerial baiting (being relatively new to eradications) or the follow-up work (it was mostly based on Mauritius work). Today, there are more operations to look at when planning a rabbit eradication. How dogs are used will depend a bit on the situation and nature of the ground and cover being worked.

References: Merton (1987), Glentworth (1991), Micol and Jouventin (2002), Torr (2002).

2.6 Rabbit eradication on Lehua Rock, Hawaii

Karl Campbell on behalf of Chad Hanson, Island Conservation, United States

Lehua is a small, uninhabited, crescent-shaped island (111 hectares, 215 metres elevation) at the end of the Hawaiian chain (off the northern most point of Niihau). It is dominated by grasslands and herblands. Strong currents and very limited access for boats means a helicopter is required for safe/consistent access. The island has an extinct cinder cone with cliff faces 10–40 metres high surrounding most of it. Substrate is loose over the entire island. Rabbits were introduced in the late 1800s and the introduced Polynesian rat (*Rattus exulans*) is also present there.

Conservation interest: Laysan and black-footed albatross, brown- and red-footed boobies, magnificent frigate, Newell's shearwater and two small endemic plants are of conservation interest on Lehua Rock.

Red-footed booby (image: anoldent, flickr)

Project sequence: The following steps were involved in this project:

- 2003: feasibility site visit
- 2004: funding secured, *National Environmental Policy Act* (NEPA) initiated (environmental compliance required in United States)
- 2004: NEPA, operational planning phase
- 2005: NEPA completed, implementation phases
- 2007: eradication success confirmed.

Method: Multispecies eradication was considered for rats and rabbits, but there are no toxins registered for rabbits in the United States. Dogs and guns were the main methods used. Nearly all the rabbits were removed with .17 semi-automatic rifles (Remington). 12-gauge shotguns were also available on the island, although these were used solely by Bill Wood and with limited use while around dogs. Bismuth shotgun ammunition was used with additional stock of steel shot being on site if the bismuth ran out. Birds were often roosting at night, making it preferable to strictly use rifles. Removal efforts ended in a bullet–rabbit ratio of 1:1. Gel cell batteries were used for spotlighting. Halogen hat-mounted lights were used, but there was a high occurrence of bulb burnout (regardless of their proper use).

The dogs used in the project were two Jack Russell terriers with limited previous training. They had been worked in prior operations, although not for a few years before the Lehua project. This led to them focusing on rats rather than rabbits when in the detection phase. At high rabbit densities the dogs proved a helpful tool to flush animals from thick vegetation and reduced hunters' risk of injury while trying to access these locations.

Only four or five traps were ever placed, but with no success. The final animal was witnessed taking refuge in a hole, managing to avoid the trap placed at the entrance (the entrance was covered with rocks leaving a pinhole of light, and the trap was placed right behind the rocks inside the hole). If fumigants had been allowed, the project would have been completed a couple of weeks earlier. The final rabbit had been travelling over one kilometre a night to avoid detection. It was removed with a longer-range gunshot on the western portion of the island (a difficult area to access).

Dogs and rabbit sign (scats, scrapes, herbivory) were used for detection and monitoring of rabbits. No non-targets were harmed during the project.

Duration: Phase 1 of the project's implementation lasted 32 days, over November–December 2005. During this phase, 310 rabbits were shot. About 97 per cent of the rabbits were shot in the first 13 nights. Phase 2 lasted 25 days, over January–February 2006. One rabbit was shot during this time. Phase 3 lasted 15 days over December 2006. Eradication was confirmed by 2007.

Three hunters were used for Phase 1, and two hunters for Phases 2 and 3. Dogs were used in all phases. Dogs were retained by a vet between Phase 1 and 2. International vet certificates were needed for their import. Quarantine, usually taking about 30 days, was waived due to the inclusion of this certificate.

Project details: Overall the control effort worked out at 5.85 hours per rabbit. The project's duration totalled 70 days over 14 months, with 311 rabbits removed at an estimated 2.59 rabbits per hectare. The total implementation cost was US$130,000 or US$1036 per hectare.

Control efforts had taken place prior to the eradication project. As a result, there were a number of educated animals on island, and this slowed the process of removing them as detection was more difficult.

Complications: The island's weather and terrain made access difficult. Weather was windy all the time, causing a number of flights to be cancelled. Rain occurred once while we were on the island, resulting in a significant vegetation response. This response allowed for herbivory to be more easily detected on the green vegetation. There were a number of Hawaiian archaeological sites already registered on the island that had to be avoided. In addition to rabbits, rats were also present, so dogs needed to be retrained to avoid this distraction. Rats also had an impact on the vegetation, which had to be accounted for. Another complication was that the project staff experienced language and cultural barriers.

Lessons learned: Equipment was not adequate for the project's implementation. Cheap .17 calibre rifles were used, and although both hunters were exceptional shots the equipment caused lots of problems. Firearms continued to jam throughout the project. New magazines were purchased, smithed, and so on, but to no avail. Because the firearms were not dependable, a number of preventable escapes occurred (while trying to clear a jam, resituate a magazine, etc), leading to obviously gun-shy rabbits. In addition, the thumb lever on the slide would often fall out, leaving one of the weapons having to have a Leatherman for operation. Optics were not of sturdy quality leading to any fall moving the point of impact from point of aim by as much as 13 centimetres at 25 metres. The lesson learnt from this is that it is important not to cut costs on equipment.

The last rabbits were seen moving over the whole island (more than one kilometre) and avoiding being detected by eyeshine from spotlights. They did not use burrows in the final stages.

Rainfall between the implementation phases washed out all scats that had been deposited in the drainages (these lead directly to the cliff edge). This clearing made a clean slate for future scat detection.

The rabbit breeding season was annual, although it seemed to have peaked during the first visit to the island. The naïvety of animals could be taken advantage of to remove unsuspecting animals.

Future work: Island Conservation is looking at doing eradications on small islands off Chile. These eradications were meant to happen in March/April 2010 but new NEPA requirements have resulted in these operations being postponed. Juan Fernandes and Robinson Cruscoe Islands are also programmed in for future work. First, new baits need to be registered in Chile that do not contain Bitrex, and work is underway with manufacturers (Bell) on palatability trials. There are also heavy restrictions on firearms, which will need to be considered.

Questions:

RG: Was the ammunition subsonic?

KC: No it wasn't. Non-silenced weapons were also used. We are very restricted in the methods we can use in Chile. We have to register specific toxins, a process which can take two years.

RT: If the rabbits were not sitting in burrows, where did they have their young?

KC: My understanding is that there were little ledges or overhangs that they would park under. There were ledges and pockets in the rock where they would hide out.

DB: On Phoenix Island we made similar observations, where rabbits lived under rock jumbles.

2.7 The Rangitoto and Motutapu pest eradication

Richard Griffiths, Department of Conservation (DOC), New Zealand

DOC is undertaking a project to restore Rangitoto (2311 hectare) and Motutapu (1509 hectare) Islands. Rangitoto Island is volcanic and linked by a natural causeway to the much older, non-volcanic Motutapu Island. The islands are in the Hauraki Gulf and are less than 30 minutes via ferry from downtown Auckland City.

A key step in the restoration process is the removal of introduced pests. Possums and wallabies were successfully removed in the 1990s. An operation is currently underway to eradicate the seven remaining animal pest species from the islands. With stoats (*Mustela erminea*), cats (*Felis catus*), hedgehogs (*Erinaceus europaeus occidentalis*), rabbits (*Oryctolagus cuniculus*), mice (*Mus musculus*) and two species of rats (*Rattus rattus* and *R. norvegicus*) spread across the two islands, the project has been described as one of the most challenging and complex island pest eradications DOC has ever attempted. There is also ongoing reforestation of parts of Motutapu Island.

If successful, the project offers outstanding benefits for conservation. It will increase the total area within New Zealand that is free of pests by approximately 15 per cent. More importantly perhaps, the range of habitats and the large area involved on the islands could fundamentally change the status of many resident or locally extinct threatened species, if they are successfully managed.

After mice, rabbits were considered to pose the next greatest risk of failure to the eradication program. Their biology, particularly their rapid breeding, and their behaviour make eradication from Rangitoto and Motutapu a formidable task. Based on other operations it was expected that a residual rabbit population would remain following the aerial poisoning program used for rodents. The operational plan outlined a range of methods for targeting surviving rabbits, ranging from patch poisoning to spotlight hunting.

Prepoisoning rabbit survey: The rabbit population on Rangitoto/Motutapu was surveyed in January–February 2009 to determine population density and subsequently bait application rates for the rodent eradication. Low numbers of rabbits were recorded during the survey, with densities in the most heavily populated areas reaching a maximum of nine per hectare. It is estimated that 200–300 rabbits were present on Motutapu prior to the poisoning operation. Rabbits were also present on Rangitoto, but the size of the population was unknown.

Timing: Three applications of Pestoff 20R (10 millimetre, 2 grams, containing brodifacoum at 20 parts per million) rodent bait were completed on Rangitoto and Motutapu between the beginning of June and the end of August 2009 to target rodents. The first application of bait occurred on 19– 20 June, the second on 9 July and the third on 6 August. The follow-up rabbit eradication program began on 20 July, 11 days after the second application of rodent bait. Spotlight searches were used initially to monitor surviving rabbits, but because only one rabbit was observed with this method, searching with indicator dogs began much earlier than anticipated. Only two rabbits have been trapped following bait application: one on 26 October 2009 and one on 25 March 2010.

The rabbit team: In order to complete a search of the islands within a five- to six-day period, four staff were employed, including a dog handler with three dogs. The maximum time interval that should be left between follow-ups was considered to be seven days for areas with residual rabbit populations. Externally sourced dog handlers have also been used periodically to audit progress. Work hours varied but night work was split into shifts to increase productivity. To allow sufficient time to locate sites and build up knowledge within the team, team members were allocated specific areas. These areas were rotated between team members on a regular basis to provide more variation in the work.

Motutapu (foreground) and Rangitoto (image: John Dowding)

Planned methodology: The operational plan stipulated a range of methods that were to be used to target surviving rabbits. Patch poisoning with carrot and Pindone was to be used if pockets of surviving rabbits remained. Patch poisoning was considered to be the only truly passive technique that minimised the risk of rabbits associating humans with danger. Dogs were brought in earlier than anticipated, but were used cautiously, as it was considered possible they could put rabbits into hiding. Aggressive or targeted methods were planned for when individual rabbits were being found. Spotlight hunting on foot or from an all-terrain vehicle (ATV) was undertaken, but no rabbits were able to be targeted. Silenced .22 rim fire rifles were carried and shots were only to be taken when a rabbit was well within range. Only solitary rabbits were to be shot at.

Burrow gassing using magnesium phosphide was planned, but never used for burrows known to be active. Problems associated with burrow gassing include doubts about whether or not the method has been effective in killing targeted individuals, knowledge

of how many rabbits are inside a burrow and whether all burrow entrances have been identified. These problems meant that this technique was to be used as a last resort.
The young female rabbit caught in October 2009 was caught in a leg-hold trap set for cats. This trap had been baited with fresh rabbit meat with fur attached. The male rabbit caught in March 2010 was deliberately targeted and successfully captured by leg-hold trapping. Traps were placed where rabbit sign had been detected and were lured with male rabbit urine.

GPS and GIS capability: GPS and Geographic Information System capability have been used throughout the operation to monitor search coverage and to ensure all parts of the islands are searched. Rabbit team members carried handheld GPS units at all times when out in the field and this data was downloaded regularly to a laptop. GPS data was mapped and used to plan the future work.

Data collection: A detailed record of completed work was kept by the team leader and used to inform ongoing planning. Nineteen rabbits were found dead after bait application and these were retrieved for DNA reference purposes.

Management of cover: All grassed areas within the boundaries of the farm on Motutapu were intensively grazed right up to the point when stock were removed in June, to minimise the amount of cover available for rabbits. Windfalls and other cover were cleared prior to the operation. Despite these efforts, significant cover was still available for rabbits throughout the operation.

Livestock were removed from Motutapu prior to rodent bait application. Although stock was first reintroduced in December, the island was not fully stocked again until February 2010. Grass growth became a major obstacle when searching for rabbits, hindering both visibility and the ability to use dogs. Sections of the island boundary were mowed to create areas more favourable for rabbits to forage and to make searching for them easier.

Results: Eighteen dead rabbits were picked up over the first three months of searching following the application of rodent bait. Only one live rabbit was seen during spotlight searches (on 24 and 25 July) but disappeared before it could be shot. A young nulliparous female rabbit was captured in a leg-hold cat trap on 26 October. A male rabbit was trapped on 25 March 2010, three weeks after sign was discovered in the area. No further rabbit sign has been observed on Rangitoto and Motutapu despite intensive searching both with and without indicator dogs, including the areas where rabbits were caught.

Discussion: Based on the population estimate made prior to the rodent eradication and the number of rabbits detected subsequently, it is estimated that about 99 per cent of rabbits succumbed to poisoning through eating cereal baits containing brodifacoum. This result is in line with other operations undertaken on islands around New Zealand.

Prior to the discovery and later capture of the two rabbits caught, intensive spotlight searches had been done on both islands. At least three sweeps of both islands with indicator dogs had also been completed. Dogs did show interest in two sites during one stint of monitoring but no definitive evidence was found of surviving rabbits at these sites. While the two trapped rabbits evaded detection by these methods, it is considered they would have been eventually detected by indicator dogs.

Day searches for rabbit sign were used relatively early on in the operation, but in the absence of stock this method soon became inefficient for detecting rabbits. However, with grass length now returning to its prior low (foraged) state, day searches have been reinstated. Along with dogging, this method is now considered the most reliable means of detecting any survivors that still remain. The large amount of sign left made detection relatively simple once grass length had returned to normal. Before the last rabbit was captured, sign was discovered at a range of sites spanning an area of about 100 hectares, suggesting that this individual was ranging widely.

Both rabbits captured were survivors of the rodent eradication and not the progeny of survivors. Although more search effort is required, the absence of any juvenile rabbits provides an early but positive sign that no breeding population persists on Rangitoto and Motutapu Islands.

2.8 Recent large-scale rabbit control in inland Australia

Brian Cooke, Invasive Animals CRC and Institute of Applied Ecology, University of Canberra, Australia

The release and spread of RHDV has kept rabbit numbers in Australia very low for some years. However, since about 2003, rabbits have been increasing steadily in some areas. Higher rabbit numbers are affecting native plant regeneration. It takes only 0.5 rabbits per hectare to prevent buloke (*Allocasuarina luehmannii*) regeneration.

Warren ripping (image: IA CRC)

On the mainland, poison baiting, ripping burrows and fumigating are the most common methods for controlling rabbits. Using both poison baiting and warren ripping maintains lower rabbit numbers for a longer period of time. Fumigation is not as efficient.

Fumigation trial: Warrens were fumigated using Phostoxin®, as well as pressure fumigation with chloropicrin. Some warrens were given a 'null' treatment (ie filled in without fumigants being applied). Many of the null warrens were empty (20 per cent did not reopen) and when results were corrected for this observation, neither fumigant closed more than about 60 per cent of warrens.

Lessons learned include:

- Attention to detail is important when doing initial control work. If too many warrens are missed when ripping burrows, rabbits will quickly increase in numbers.
- As vegetation recovers, it is harder to find rabbit warrens and more rabbits will live above ground.
- It is essential to achieve a high initial reduction with poisoning, rather then hoping that back-up methods will remove survivors.
- Rabbit behaviour can change and this can make ongoing control difficult.

Rabbit biology and control: In the non-breeding season, when it is best to do control, the facts that resources are scarce and rabbits range more widely need to be considered. Individual variability in rabbit behaviour also needs to be considered, including their normal feeding range and territory. Movement patterns include territorial/home range, regrouping as mortality occurs, sources and sinks, and social structure. Population dynamics, food intake, reproductive responses to resource abundance also need to be factored into control operations. Rabbits as young as 14 days will survive if parents die in a control operation, so the age of rabbits at time of baiting is important to consider.

Questions/comments:

DR: Rabbits will always seek better food and better burrows, so will move to find these things.

RT: In the United Kingdom, rabbits will move up to one kilometre to feed each night.

NT: The last rabbit will behave differently because it has survived and hasn't done the 'normal' things you would expect.

Does taking out 95 per cent of rabbits precipitate early breeding?

Is breeding capacity limited on volcanic islands?

The age of rabbits is definitely an important factor when baiting occurs. If rabbits are breeding all year round, poisoning should be done when food is scarcest, unless non-targets are an issue at that time. Factors to consider when deciding on the timing of an operation include non-targets, food availability and breeding season.

After an RHD outbreak, rabbits can regroup in warrens. Outliers come in from neighbouring territories. Rabbits move a lot after big population declines.

NB: You need to find the right approach for each site and should not discount any tools from the tool box. When rabbits declined in the area I was working in, some started climbing to places they hadn't been before (eg bluffs, small ledges). Long-range sniping is often needed to shoot the remaining rabbits.

When is shooting feasible as a strategy? Only when it is the only tool you can use. The site determines which technique to use, such as long-range sniping. One size doesn't fit all. Generally, one would use the more passive techniques first then use more aggressive techniques to search for survivors.

KC: On one island we tried prefeeding and traps, but neither worked. We resorted to shooting rabbits. Our key assumptions didn't hold in this case. Each stage was assessed before going to the next part of the operation.

2.9 Eradication of rabbits and rodents on Macquarie Island

Keith Springer, Parks and Wildlife Service, Tasmania, Australia

Macquarie Island (12,780 hectares) is part of the Australian state of Tasmania, and lies in the Southern Ocean (54°37'53"S, 158°52'15"E) approximately 1500 kilometres from Tasmania and 1000 kilometres from Bluff, New Zealand. Five species established feral populations and caused significant impacts on native flora, fauna and landscapes: ship rats (*Rattus rattus*), cats (*Felis catus*), house mouse (*Mus musculus*), European rabbits

(*Oryctolagus cuniculus*) and weka (*Gallirallus australis scotti*). Weka were eradicated by 1989 and cats were eradicated by 2001.

Rabbits were introduced as a food source in about 1879 from New Zealand and have caused significant damage to the island. Myxoma virus was released annually from 1978 to control rabbits and while highly effective at reducing rabbit numbers for about two decades, it was losing its effectiveness before virus production ceased in 1999.

In planning for eradication of ship rats, house mice and rabbits, concepts and techniques from previous eradications were assessed. These assessments identified that:

- both rodent species would take the same baits
- aerial bait distribution was the only feasible method
- while most rabbits would consume bait, some would not, indicating that rabbits were unlikely to be eradicated by aerial baiting, so comprehensive follow-up hunting would be required to remove surviving rabbits
- trained detector dogs would be a significant advantage in detecting surviving rabbits.

Dog training was expected to take two years for the Macquarie Island operation. Bait, bait pods, shipping and helicopter contracts were also required. Intended rabbit eradication techniques also determined the staffing levels and equipment required to support them. The total allocated budget is AU$24.7 million. Of this, approximately 60 per cent is directly attributable to the expectation that rabbits will not be eradicated by aerial baiting, and that post-baiting hunting and monitoring for a period of up to five years may be needed. A significant early success was the agreement between the Australian and Tasmanian governments to commit to funding the entire multi-year project.

Phase 1: Phase 1 will involve a planned aerial baiting program. Bait will be distributed by four helicopters (there is a contract for 110 days to allow for the weather). About 300 tonnes of Pestoff 20R brodifacoum bait will be dropped over the entire island at rates between 16 and 44 kilograms per hectare. Bait sowing lines will be set by GPS with 80 metre swath with a 50 per cent overlap. The bait drops are to occur during winter of 2010, with two main drops planned about 10–14 days apart, and a third drop planned for areas of high rabbit density.

Phase 2: Phase 2 will involve an on-ground follow-up operation. While all rats and mice should be killed by the bait drops, it is expected that some rabbits will survive (the aim is for less than five per cent survival). Ground hunting teams, some with rabbit-detection dogs, will search the island to locate surviving rabbits. Follow-up techniques will involve dogs, spotlighting, shooting (day and night), trapping, netting and gassing burrows where dogs locate individual rabbits. Night-vision and thermal imaging equipment will be used to assist detection of surviving rabbits.

Rabbit hunting will need to be immediate and intensive after aerial baiting to reduce the number of survivors faster than they can breed. Vegetation regrowth will be rapid in some favourable (lower altitude) locations and will make hunting increasingly more difficult, so there will be a need to cover the island quickly in follow-up activities. The hunting approach used for eradication is very different from that used for rabbit control.

Three dog trainers will be used. One trainer is based in Sydney and the other two are in New Zealand. A total of 11 dogs will be supplied under contract. The decision to procure dogs for the duration of the project helped determine which breeds were chosen: they had to have a strong hunting drive and be amenable to working for different handlers, as these personnel will change over annually. Springer spaniels and labradors have been chosen on this basis.

It is desirable to have as little vegetation as possible present before poison is dropped. It will provide the minimum food for rabbits and make it easier for ground hunters to get around the island.

In addition to the equipment, staff and dogs being brought to the island for this operation, five field huts will be installed to support hunting teams and allow greater proximity to hunting parts of the island.

Challenges: This operation presents a large number of challenges, including:

- inclement weather
- remoteness of the island (only one supply ship per year)
- rugged and isolated terrain
- multiple pest species present
- issues of non-target species
- regulatory issues
- reliance on technology
- ensuring there is full bait coverage over the island

- quality of staff and dogs
- costs.

Regulatory issues: As brodifacoum is not a registered pesticide in Australia for use on rabbits, nor is it registered for aerial application, a permit was required from the Australian Pesticides and Veterinary Medicines Authority (APVMA). An application for a Minor Use Permit was lodged with APVMA in June 2008, and the permit issued in May 2009. The use of a consultant to prepare the detailed information in the required format was critical in having the application assessed without further information being sought by APVMA, which would have extended the timeframe still further.

Brodifacoum is not an approved pesticide for use against rabbits in Tasmania; hence an application was also made to the Animal Welfare Advisory Committee to have it added as an approved substance for this project under the *Animal Welfare Act 1993*.

The scale of the project and the World Heritage status of the treatment area meant that the project needed to be referred to the then Australian Government Department of Environment, Water, Heritage and the Arts under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The Environment Minister would then determine whether the proposed project was a controlled action or not, with the ability to impose conditions on how the project was implemented. An Environmental Impact Statement (EIS) was prepared over an 18-month period, incorporating the 2005–2006 bait and non-target species trials. Subsequent trials undertaken in 2007 and 2008 to further assess non-target species impacts were also included in the EIS, including the results of trial over-flights of king penguin colonies. An EPBC referral was submitted in September 2009 and the decision was received in October 2009 that it would not be a controlled action. (However, this has since been revoked and it will be reassessed as a controlled action with conditions on how it is done.) A state environmental impact assessment process also needed to be completed, and the required Reserve Activity Assessment was approved in July 2009.

Eradication will be declared successful after two years with no evidence of rabbits or rodents on the island.

Line of pods, Hurt Point, and North head baiting team, Macquarie Island (images: Tas Parks & Wildlife Service)

Editors' note: Macquarie Island progress update December 2010

The aerial baiting team completed predeparture training, and departed for Macquarie Island in May 2010. Several days were needed to unload the bait and helicopter fuel at three bait depots on the island, with the first baiting undertaken on 5 June. A 90-hectare peninsula at the northern tip of the island and the adjoining isthmus were baited using four Squirrel helicopters. Rabbits and rodents were observed taking baits later that day, and remote cameras set up around station buildings (which were hand baited the following day) recorded numerous visits of rodents removing bait. The first dead rats were found within four days, with the first dead rabbit found after six days.

Following this, baiting was to commence at Hurd Point, the bait depot at the southern end of the island. However, after some reasonable weather that allowed the site to get set up with huts and refuelling pads, the weather closed in for the next two weeks, with either low cloud or strong winds preventing flying. A few short breaks in the weather in late June enabled work to commence around the coastal area and slopes around the southern quarter of the island, although the plateau was never clear of clouds and baiting could not commence there.

After late June, weather conditions remained unsuitable for flying, with relentless strong winds and frequent low cloud. Weather observations from previous winters had suggested that suitable windows for baiting could be expected. However, this year acceptable conditions did not eventuate and July turned out to be the windiest July since records commenced in 1948.

By mid-July the team had been on the island for over six weeks, and in that time had only been able to bait on four part-days, spreading eight per cent of the bait required for the bait drops. It became apparent that the next six weeks would need to deliver exceptionally good weather to complete the baiting before the return of native wildlife and the onset of pest species breeding. As the likelihood of such a degree of weather improvement seemed very remote, and with an increasing risk of having to abandon the baiting uncompleted, the project steering committee decided to withdraw the aerial baiting team and seek to return for another attempt in 2011.

A number of important lessons were learnt during the 2010 winter, and will enhance the planning for next year's aerial baiting program. Baiting team size will be increased, some improvements will be made to procedural aspects, some amendments will be made to applications of bait, and additional effort will be put into searching for and removing dead animals to reduce the incidence of non-target species mortality.

2.10 Rabbit eradication: improving efficiencies

Neil Bolton, Department of Conservation (DOC), New Zealand

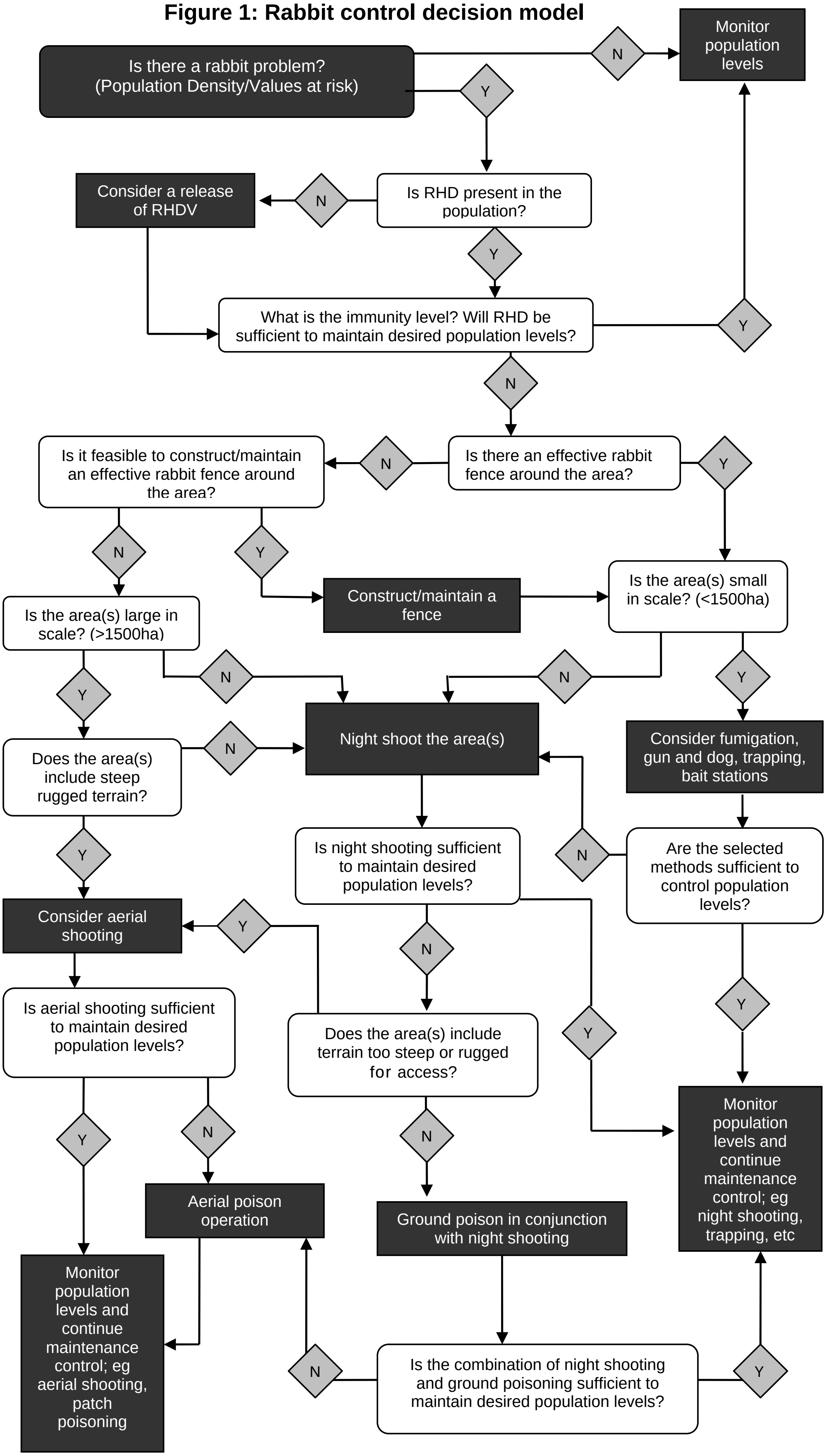
A budget of $100–200,000 per year has been allocated to treat about 17,000 hectares in the central South Island of New Zealand.

Rabbit control decision model: Having the decision model formalised (see Figure 1) helps to refute the perception that DOC immediately chooses to use pesticide-based methods. It illustrates the decision-making process clearly for new staff in the industry (of which there are many) and allows the community to understand the process we work through to determine the best method. It links to DOC best practice and contains hyperlinks to the Operational Planning and Design Considerations in the DOC system.

Assessing rabbit densities: Various methods were used to estimate rabbit densities (see Table 2), since the Modified McLean Scale has limitations. Our team uses night count data, which has been found to be less coarse than this scale. The terrain and vegetation being dealt with are quite consistent, so we have observed some consistent relationships with the Modified McLean Scale and the ecological values.

Where and when to control: Characteristics of the control site and seasonal relationships need to be considered — how can they best be exploited? Topographical features include soil type, aspect, slope angle and vegetative cover. Climatic features include rainfall, snow/frost, temperature and amount of sunlight. Rabbit dynamics that

Figure 1: Rabbit control decision model



need to be considered include male–female interactions, dominant–subdominant relationships, breeding pulses/successes and evening/morning/daytime behaviours.

Table 2. Assessment of rabbit densities on South Island, New Zealand

Modified McLean Scale	Night count data (rabbits per kilometre)	Night shoot data (approx rabbits per night)	Effect on ecological values
1–2	0–1.5	<20	very positive
2	1.5–2.5	30–75	positive
2–3	2.5–5	80–150	can be positive or negative
3–4	5–6	150–250	negative
4	6–12	250–400	very negative
4–5	12–15	>400	severely negative

Technological advances: Advances that have assisted rabbit control include the use of:

- one-person units except for aerial operations (significantly reducing costs)
- ATV instead of 4WD or motorbike for night shooting, night counts and ground-based poisoning
- modern clothing fabric and design (especially for warmth in winter)
- progression through the different types of spotlights (white/yellow to red/green lenses to thermal imaging to infrared) — infrared night-vision equipment is superior and a worthwhile investment, costing $8000 per unit to purchase and about $1 per hour to operate (Appendix 3 has more information on night-vision equipment)
- low-sow and trickle-feed bait distribution to allow zone-specific aerial targeting of rabbits — this method minimises costs and allows some areas to be excluded

Night-vision equipment (image: Neil Bolton)

- Pindone in bait stations — this method has potential and DOC Twizel Area staff would like to develop this option further
- GPS/GIS tracking systems.

Costs: The costs of various control options are listed below.

Fencing:

- rabbit netting of an existing fence = $5–7 per metre
- construction of new fence = $15–20 per metre
- checking and minor maintenance of fencing = $8–10 per kilometre.

Note that mesh size of commonly used rabbit netting allows for young rabbits to walk through, so the smallest available netting size should be requested.

Night shooting: Costs depend on rabbit density and can range widely:

- low–moderate proneness = $0–5 per hectare per year
- moderate–high proneness = $5–10 per hectare per year
- high–extreme proneness = $10–15 per hectare per year.

Ground-based poison options:

- bait station (Pindone)= $5–20 per station per month
- patch poison = $15–30 per hectare
- widescale poisoning with ATV = $30–45 per hectare.

Note that the maximum area recommended for a single ground-based operation is no more than 1500 hectares.

Aerial control: Options are site and population dependant:

- monthly shooting = $20–50 per hectare per year
- patch/trickle poison = $30–80 per hectare
- widescale bait broadcast = $45–80 per hectare.

In summary, although there have not been many technological advances in this field, some new equipment and procedures have assisted eradication and control operations. Pest managers planning an operation are advised to not discount an option until it has been fully evaluated: one cannot take a ‘one size fits all’ approach. It is necessary to build a complete picture of the situation to ensure the best possible control option(s) are used. Small changes in procedure can lead to significant successes. Control activities will all cost money — the question is how much and what value will be gained for the various options being considered?

3. Group discussions

Workshop participants were asked a series of questions and either discussed them as a whole group, or broke up into four discussion groups to provide answers and comments, as listed in the sections below.

3.1 General discussion on aerial hunting

Led by Fraser Sutherland

Aerial hunting of rabbits is worth considering in the evaluation of techniques. It can be useful where poisoning is not an option, or where terrain makes ground shooting difficult. Using pilots to detect rabbits can be useful in the follow-up phase, when rabbits can change their habitat and stay more on the surface.

RG: How effective is aerial hunting for mainland control?

PP: It can be very effective if done well. It can't be used as a knockdown because it causes too much disturbance of the rabbits. The rabbits adapt quickly to the aerial methods. It is a good mop-up technique to get the last numbers (when rabbit density is at McLean Scale 2 or less).

NB: You've got to be professional and have a good relationship with your pilot. The pilot has to be able to handle flying low on variable terrain and in a bit of wind. Good trust between shooter and pilot is essential.

DR: Helicopters can cause rabbits to flush out from their cover.

NB: You can cover 800 hectares an hour using a Hughes 500 model or greater.

RG: Is aerial work done purely by day?

NB: It is at present but John Oakes (of Central South Island Helicopters Ltd) is working with the Civil Aviation Authority of New Zealand with new technology to develop training for night aerial shooting.

3.2 If poisoning is not completely effective

Question: What approach/decisions would you take if the aerial poison operation only killed a) 20 per cent of the rabbits, b) 60 per cent or c) 95 per cent on a large island (eg Macquarie) and a smaller island (eg 500 hectares)?

Group 1

If a 20 per cent knockdown was achieved, Group 1 said that the operation should be audited to determine what went wrong and why. In particular, it should be determined what systems, planning and equipment did not work. Another attempt should be planned and techniques should be reviewed. Information on why the operation was not successful should be disseminated, as it is important for staff working on other projects to understand.

If a 60 per cent knockdown was achieved, the group said that for a large island the project should probably be abandoned, but a thorough assessment of the project resources and risks should be assessed. For a smaller island, if the budget could sustain more staff, then increasing staffing levels should be considered to allow more pressure to be put on the rabbits. Any subsequent decisions made should have peer support. Techniques already intended for use could be repeated in a subsequent operation, but the order should be changed to use those methods that lower rabbit numbers as quickly as possible. Progress should be closely monitored and evaluated. Options for alternative bait and toxin should be investigated.

If a 95 per cent knockdown was achieved, a range of techniques could be used as planned. Generally the least disruptive technique should be used first, but decisions should be based on effective kill rates. Limited use of experimental techniques could also be considered, as they would inform the current and other projects.

Group 2

If a 20 per cent knockdown was achieved on a large island, Group 2 said that the project should be re-assessed before the next rabbit breeding season. Regulatory permits and contract expiry dates should be checked before restarting the operational process. Bait palatability and preference should also be checked.

If a 60 per cent knockdown was achieved on a large island, the same approach as that described above would apply.

If a 95 per cent knockdown was achieved on a large island, the plan should be followed up with a second phase. The trigger level for follow-up action was considered to be 85 per cent knockdown; if less than that, it would be necessary to go back to the start.

If a partial knockdown (20, 60 or 95 per cent) was achieved on a small island, Group 2 said that follow-up action should be carried out if the rabbit population and site accessibility are suited to such action.

Group 3

If there was a high density of rabbits on a large island in a remote area and only 20 per cent knockdown was achieved, Group 3 agreed the project should be assessed for reasons of the failure. They considered it would be unlikely that rebaiting would be useful in the short term and that the cost of any short-term correction would be high. All remaining options should be considered, including whether or not to abandon the project. All reasoning for abandonment or otherwise should be well documented.

If a 20 per cent knockdown was achieved on a small island, options given techniques available on hand should be considered. Techniques with the fastest knockdown rate should be used.

If a 60 per cent knockdown was achieved on a large island, this rate would be considered marginal for a remote island. The approach taken would be similar to that described above for a 20 per cent knockdown. For a small island, the risk of failure would be lower if several eradication options were still available after 60 per cent knockdown.

Questions that would need answering include:

- How many rabbits are left?
- How fast can they be killed?
- Can this be achieved so that population is declining?
- Does monitoring the kill rate show it is decreasing over time?

If a 95 per cent knockdown was achieved, the approach would be to proceed as planned in the original operation, with appropriate follow-up action to remove survivors.

Group 4

Group 4's responses were tabulated as follows:

Kill (%)	Small island	Large island
20	Continue, but change tactics	Abandon project
60	Continue with follow-up action	Success is unlikely, so use the failure as a learning opportunity
95	Continue with follow-up action	Continue if high 90 per cent knockdown

Group 4 said that success of the operation will depend on rabbit numbers left and the distribution of these survivors. The time window available for follow-up action needs to be considered when deciding on the most appropriate approach. The decisions made will depend on the actual island concerned. If the decision is made to abandon the eradication, information should still be gathered to inform for future work.

3.3 Differences between subantarctic, temperate and tropical eradications

Question: What are the differences between subantarctic, temperate and tropical eradications? Are there any generalities?

The main differences noted between subantarctic, temperate and tropical settings are weather, vegetation, presence of non-target hosts and seasonal behaviour of rabbits. The influence of these factors on eradications is outlined below.

Vegetation and weather will influence decisions on bait use. Weather includes rainfall, wind, cloud cover, temperature and relative humidity. These factors will influence how quickly bait will grow mould — pellet baits will last longer in temperate regions. Some tropical islands are wet, with dense vegetation (decreasing the suitability for rabbit habitat), and others are barren/arid. High bait uptake tends to occur on arid islands (near 100 per cent), because of low food availability. If magnesium phosphide toxin is used in tropical and temperate arid situations, water may need to be added to tablets because the soil is too dry.

Questions were raised about toxin efficiency on different island settings — would time to death be quicker in equatorial or high-latitude climates? Differences in efficacy of biological control agents may also be expected in different island settings. For example, if rabbits are stressed, myxomatosis may be more effective. The presence of parasites such as coccidia is also likely to differ and may influence control/eradication activities.

Rabbit behaviour is affected by climate and vegetation. For example, very little activity is observed on hot days and rabbits will seek shade. Differing seasonality factors will determine when rabbits breed, and the availability of food: this will relate to different times of year for tropical and subantarctic islands. Vegetation response to rabbit removal may also differ on subantarctic, temperate and tropical islands.

With regards to non-target species, it was noted that land crabs and hermit crabs extensively take up bait to almost 100 per cent in some cases. On subantarctic islands, non-targets are likely to leave and be absent over the winter months.

Daylight hours will vary on the different island types and this variation will affect operating opportunities such as the use of helicopters and spotlighting. Temperature differences may also influence the effectiveness of thermal imaging (ie contrast in heat signatures). Differences in island characteristics will affect the productivity of eradication operations, in terms of the time window available for mop-up, and recovery of the remaining population.

3.4 Knowledge of mainland control

Question: How can knowledge of mainland control operations help with eradication of rabbits on islands?

Control on the mainland dates back to the late eighteen hundreds. Although initially used for protecting primary production, it is now occurring for biodiversity protection in some areas. Methods that are 'tried and true' have been improved over time, often through years of trial and error and results monitoring. The experience gained and information exchanged on mainland operations will help with island operations. A vast amount of knowledge has been learnt (from both successes and failures) and is available on mainland rabbit control. This knowledge would be applicable to island eradications, although occasionally some tailoring would be required. Sources of information on past mainland operations include:

- historic rabbiting, from ferreting to thistle root baiting
- Ministry of Agriculture and Food, Rabbit Research Group (New Zealand)
- Agricultural Pest Destruction Council (New Zealand)
- Rabbit and Land Management Program (New Zealand 1990–94)
- Australian research.

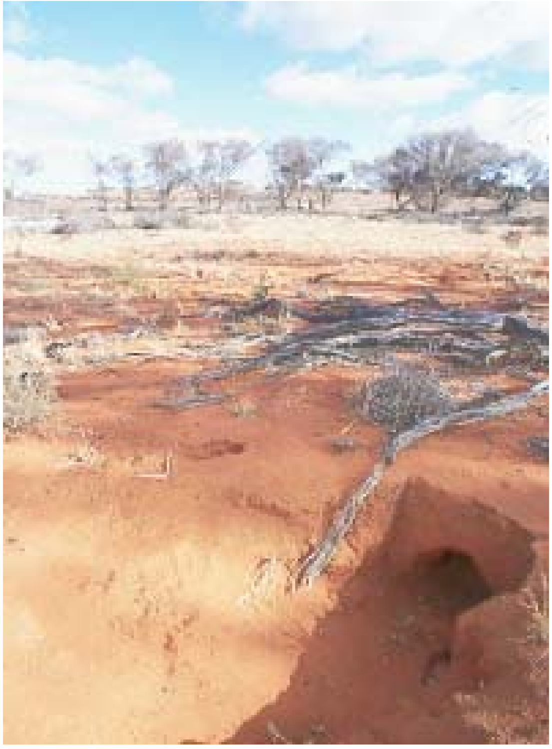
All these sources have information on rabbit biology, physiology, baiting and aversion.

Mainland operations have demonstrated that best initial (primary) population knockdowns are achieved with poison programs. For these to be successful, bait preference and bait acceptance (eg using fluorescent dye) trials should be mandatory to ensure best knockdown is achieved, especially when the objective is eradication. Operational technical standards must be kept to the highest possible level, including:

- bait type and quality — involving preference trials, location limitations, type, storage and handling
- feed rates — tailored to population level, not under- or over-fed (acceptance trials should help with this)
- equipment — newest available technology

- toxin choice and loading — considering acute vs chronic, non-target susceptibility, poison shyness
- methods of application — considering location, topography, logistics.

A suite of secondary control measures should then be implemented to pick up survivors.




Damage caused by rabbits on mainland Australia (images: Brian Cooke)

Newly developed methods of control and novel equipment are often trialed on mainland operations, so the outcomes can be useful to island programs. Personnel also gain direct experience from mainland operations.

Monitoring methods that have been proven successful for determining rabbit population/density on mainland operations include:

- pellet/sign McLean/Gibb indices
- night counts, dawn/dusk counts
- interference plots
- soil disturbance/footprints
- tree bites
- wax tags
- hair blocks (sticky blocks or tunnels to pick up fur).

Biocontrol research priorities were discussed, and the group agreed that further research is needed to determine the best timing and conditions for release. Ideas for new research and development include looking at the behaviour of perturbed populations (to enable removal of the last few survivors) and technology to estimate the ageing of pellet sign on different island types and weather conditions. It is also important for island staff to have training on eradication programs.

3.5 Problems due to vegetation

Question: What types of vegetation are a problem for eradications and using dogs? Are there any tips or pitfalls for programs in different habitat types?

Vegetation issues identified by the group include high food levels, irritants on certain plants, concealment of on-ground hazards, difficulties associated with rabbit detection and removal, and hampering of bait distribution.

High levels of vegetation may result in less bait uptake by rabbits, since more available food means they are less likely to eat bait. High vegetation levels will also decrease rabbit detection and capture rates. Potential hazards on the ground concealed by high vegetation levels include wallows, holes, bogs, seals, wire, poles and wasps. Long grasses can be a problem for dogs, as they are difficult to push through and grass seeds can lodge in the dogs' coats. Labradors for example may tire from having to push through long or dense vegetation. Also, bait can get hung up in long grass and dense scrub. Some plants have irritants such as spikes or sticky sap.

Possible solutions to overcome these issues include:

- Adjust the timing of baiting to periods when vegetation cover is lower.
- Remove vegetation by cutting, burning, mulching or using livestock grazing. This will assist with clean-up techniques and allow for a safer operation. Rabbits have a preference for feeding on short grass with cover nearby: this type of terrain can be created by appropriately cutting or mowing grass patches.
- Use alternative detection methods such as thermal imaging.
- Choose dog breeds suited to the vegetation cover in terms of their size, coat and aptitude. Terriers are a good choice for small runs, whereas spaniels are useful for burrowing.

- Reduce risk of dog injuries by using protective equipment. The use of dog booties will protect dogs' feet from lava, sharp rocky areas and hot ground. An eyewash will help soothe injuries caused by ants (eg fire ants) that can cause blindness.
- Change the baiting strategy or bait type; for example, use heavier or lighter baits, or bait stations.

Establishing detection and capture rates for different vegetation types is recommended, as this information can assist time allocation to certain areas during the eradication.

3.6 Removal of last rabbits

Question: What wacky/off-beat ideas do you have for detecting and getting rid of the last rabbit(s)? What are the risks of using those techniques?

In considering new ideas for detecting small numbers of rabbits remaining after a poisoning exercise on an island, it was noted that methods that both detected and killed rabbits should be preferentially sought. Ideas suggested were as follows:

1. Ferrets and long nets — these methods are widely known but perhaps seldom used on islands where conservation is the main aim (ferrets and seabirds seem a bad combination).
2. Fibre optics for searching in burrows — these have already been developed for looking in seabird burrows but the equipment is cumbersome.
3. Lures for rabbits — such as rabbit urine.
4. Methods of assessing dung freshness are needed (apart from scraping of latrines).
5. Hair tubes and sticky traps — these are already in use for smaller mammals but have not been explored for rabbits (methods that allow detection and killing at the same time would be preferred).
6. The use of Judas rabbits should be explored: hormone implants were suggested. However, there may be little need for implants because female rabbits cycle every four days if not inseminated. Another suggestion was to have resistant or immune 'Typhoid Mary' rabbits that are infective enough to transmit a virus to other rabbits.
7. 'Tarbaby' approach (from the *Tales of Brer Rabbit*, see Appendix 4) — a poison in a sticky paste applied to the walls of rabbit burrows, which rabbits would groom from

their fur (see Appendix 4). Similarly, a powder containing toxin (eg anticoagulant) could be used.

8. Vegetation management — open areas could be created among tussocks to draw in rabbits, or grass could be ‘sweetened’ with an application of fertilizer, providing an area attractive to rabbits where they could be shot or more readily poisoned.
9. Toxins applied to natural baits (similar to the application of 1080 gel to leaves of plants, to eliminate deer).
10. Use of freshly turned earth as a rabbit attractant.
11. Water points could be used on arid islands to attract rabbits to the site (some data on this are available from arid Australia).
12. Wire netting fences could be used around rock stacks to separate rabbits from needed resources or to force them to use pit traps or smeuse traps. Smeuse trapping is a modification of trapping around warrens and uses rabbit-proof netting to enclose the warren with outlets (smeuses) with swinging doors allowing access for rabbits to and from the warren. When it is time to start trapping, the smeuses are converted to one directional doors with traps attached to all exit points.
13. Remote cameras could be used to confirm the presence of rabbits that are otherwise difficult to detect.
14. Monitoring blocks could be used — similar to chocolate-flavoured blocks used to detect rats at low densities.
15. Liquorice is said to be both attractive and toxic for some animals (may need to be tested for rabbits?).
16. Salt pegs can be used in salt-deficient habitats (eg Snowy Mountain plains area in Australia) but are probably not applicable to oceanic islands. Possibly other mineral deficiencies could be exploited?
17. Use of unmanned ‘drones’ with video cameras to detect rabbit holes and deliver baits in areas with extremely difficult access.

3.7 Group discussion on RHDV

EM: Recent research has shown there are a number of benign RHD viruses present (see Appendix 5). If you are planning to use RHDV, you must consider resistance in the rabbit population. Also, you must make sure it is legal to use where you want to use it. Experience gained from New Zealand work shows RHDV works if it is sprayed onto carrot baits, but we don’t know whether it works if applied to aerial baits containing brodifacoum. Live or dead rabbits can be used to seed RHDV and the virus may work

Rabbits resting on warrens (images: Brian Cooke)

for longer in rabbits than when supplied on baits. Freeze-dried RHDV bait is under development by the Invasive Animals CRC. Australia and New Zealand use only one strain of the virus, but other strains exist.

BC: If you are considering using RHDV, you need to determine potential resistance. Ensure that the rabbit population is not resistant by collecting serum from rabbits and getting it tested at Animal Control Commission in South Australia. 20–30 blood samples are needed, well in advance of the operation. It is not a routine service, so you need to allow a lot of time. With this type of sampling you are looking for what percentage is infected. The use of RHDV could still be a viable method if a low proportion of the rabbits are resistant to it. Note that there can be temporary immunity to this disease in the remaining population for one to two months after a biological control operation.

Myxomatosis can only be spread through rabbits directly by injection (ie it can not be applied to bait). It takes eight days for symptoms of myxomatosis to show and it only works for 13 days.

RHDV in freeze-dried form could be spread as a bait application. The freeze-dried form could be useful for island applications, but needs further development. Rabbits die in 48–60 hours of contracting the virus. The rate of spread may depend on the density of rabbits. The freeze-dried product is not currently registered yet, but a liquid form is already available for small-scale use. This liquid form has been imported by New Zealand regional councils at a cost of NZ$180 for 10 millilitres, which is sufficient for use with 10–15 kilograms of carrot bait.

NT: What can you expect in terms of rate and extent of spread of RHDV?
BC: With no vectors, it can spread nine kilometres per month. Very hot conditions can slow down the rate of spread. Also, if there are very few flying insects around, that could slow the spread of RHDV. Rabbit-to-rabbit contact should keep the disease spread in the range of several kilometres per week.

KB: If you are doing multispecies control you need to consider whether the rats will take the treated baits. Also, if you first control rabbits with biological control, rats may then feed on the rabbit carcasses in preference to the toxic bait. This feeding behaviour may compromise your rat control.

3.8 Research priorities

The workshop participants broke up into four groups to discuss future priorities for research. Some groups looked at subject areas in which information is lacking; another looked at short-term versus longer-term research needs; and another group approached the discussion from the perspective of how to maximise effectiveness of rabbit eradication. A common theme was the need to better understand the biology and behaviour of surviving rabbits, in order to develop methods to efficiently detect and remove the remaining survivors. Details of the discussions are presented below.

Group 1

Subject areas that need to be further researched include:

- Rabbit ecology:
  - How much food does a rabbit consume per day?
  - How many baits are required for a 100 per cent lethal dose (LD 100) and a 90 per cent lethal dose (LD 90)?
  - What is the average time it takes for a rabbit to lose its appetite?
  - What is the average, and the range, of time to death after baiting with poison?
- Social changes in rabbit survivors after major and sudden population declines.
- The use and effectiveness of lures (eg is the idea of using liquorice as a lure fact or fiction?).
- Techniques for detecting the last surviving rabbits.
- Research to address the question of why not all rabbits take bait. That is, to determine reasons for the survival of a small numbers of rabbits.
- Telemetry or GPS on surviving rabbits to determine what do they do, and where they go once baiting is done.
- Bait application rates (with and without other target and non-target species removing bait from the site).
- Relative effectiveness of different follow-up techniques.
- Biological controls as precursors to baiting operations.

Group 2

Immediate research priorities were identified as:

- Methods for detection of rabbits at low numbers, particularly post poison operations, to allow eradication to be successful.
- Better methods of bait packaging to prevent bait deterioration while it is in transit. Packaging options should incorporate the need for weather protection, moisture control, and the ability to be nested/stacked when empty to minimise space requirements and to enable package re-use.
- A method of assessing bait quality on site, to ensure that bait has not deteriorated during transit. The question of what to do if the bait is deteriorated is another point to consider.

In the medium term, there needs to be research to develop:

- bait stations that work with rabbits
- kill traps or snares, preferably with the ability to automatically reset for multiple kills
- new baits and lures, possibly using pheromones
- new methods of toxin delivery that do not require a bait (for example the Tarbaby approach – Appendix 4).

Longer-term future research priorities include biocontrol enhancements incorporating:

- new and improved vectors
- identification and use of natural epidemics
- improved use of natural parasites
- use of naturally occurring diseases such as coccidiosis
- use or spread of sexually transmitted diseases such as herpes or chlamydia
- improved timing of releases
- improved methods of biocontrol agent spread
- solutions for non-target issues
- immunocontraception, as proposed for possums in New Zealand
- genome sequencing of rabbits to identify any weaknesses that may be exploited.

Group 3

Research is needed to maximise the efficiency of eradication operations, by:

1. Maximising the knockdown — there is a need to determine what attributes survivors have in common, so this can be targeted in follow-up action.

2. Maximising the speed and efficiency of follow-up techniques — a lethal detection tool (ie a tool that detects a rabbit and then kills it) needs to be developed.
3. Detecting the last survivors needs to be improved. Research is therefore needed to determine what the most irresistible lure is for a rabbit, and how rabbits behave at very low densities.

Erosion and weeds in rabbit-damaged soil (image: IA CRC)

Group 4

Questions that need to be resolved include:

1. Why do some rabbits survive poisoning?
2. How do the survivors then behave?
3. How do we remove survivors?

The main research priority identified was to develop a search/detection model for validating the effectiveness of detecting survivors in the field. This model would combine information on where we look for survivors, with how efficiently we search for them.

4. Conclusions

The workshop proved a valuable opportunity to share and progress knowledge and experience of rabbit eradications with an island focus. The invited papers and group discussions provided a variety of eradication scenarios where strategies, problems and potential solutions could be worked through.

Attendees agreed that the best initial population knockdowns are achieved with poison programs. Operational technical standards for bait type, feed rates and toxin use must be high for the best chance of eradication. Equipment (eg firearms, cameras) should also be of high quality. Varying factors such as island climate, vegetation, topography and other species present mean that each eradication attempt may face different challenges. The method and timing of the operation must consider these factors. In some cases it may be better to use alternatives to poison, such as RHDV or aerial shooting; for example, if the use of poisons is illegal.

Poisoning is generally followed by a suite of secondary measures to kill any remaining rabbits. The biggest single issue identified at the workshop was the problem of effectively detecting and dispatching survivors. Follow-up methods traditionally use sniffer dogs, shooters and traps. In some cases these methods are very effective. Simple additional measures can help, such as mowing/grazing grass to more easily detect rabbit sign. However, dense vegetation, weather extremes and inaccessible locations can all compromise the success of secondary measures. Difficulties associated with non-target animals and neophobia of rabbits can also hamper eradication. Lessons learned from operations on the mainland, and subantarctic, temperate and tropical islands were discussed and showed that a 'one size fits all' approach is not appropriate. Costs and progress/success of each ongoing operation should be monitored to determine whether to continue with an eradication, change tactics or abandon it.

The group suggested innovative methods of rabbit detection that could be trialled in future. The use of fibre optics and remote cameras, rabbit lures (eg pheromones), hair tubes, ferrets and Judas rabbits were suggested. As alternative methods to trap/kill rabbits, the use of sticky traps, robotic devices, aerial shooting, directional netting/traps, water points in arid environments and mineral pegs in nutrient-deficient environments were considered worthwhile to investigate.

Research priorities discussed by the group centred on developing techniques to be able detect and kill rabbits at low densities, particularly post-poison operations. The following areas were considered important:

1. Understanding the biology and behaviour of surviving rabbits.
2. Developing bait stations, multiple-kill traps and snares.
3. New baits and lures, including pheromones.
4. New methods of toxin delivery that do not require bait (eg a sticky Tarbaby approach, as from the *Tales of Brer Rabbit*).
5. Search/detection models for detecting rabbit survivors on islands.
6. In the longer term, use of rabbit genome sequencing to identify potential weaknesses.

5. Acknowledgements

The Invasive Animals Cooperative Research Centre provided funding for this workshop. Attendees are thanked for their input, and the corresponding departments for covering costs of time and travel.

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Appendix 1. Workshop program

Thursday 4 February 2010

9:30	Morning tea and welcome
10:00	Introductions
10:30	Case studies: • David Priddel • Roger Trout • Chema Barredo • Elizabeth Bell • Karl Campbell • Nick Torr
12:30	Lunch
13:30	Case studies continued: • Richard Griffiths • Brian Cooke
14:10	Group Discussion
15:00	Afternoon tea
15:30	Macquarie Island planned rabbit eradication — Keith Springer
16:00	Break-out groups
17:30	Finish Day 1
19:00	Workshop Dinner

Friday 5 February 2010

9:00	Methods: • Neil Bolton — Modern technology to help with hunting rabbits • Peter Preston — Aerial shooting of rabbits
9:30	Break out groups
10:30	Morning tea
11:00	Best Practice — Chair: Keith Broome
12:30	Lunch
13:30	Group discussion on RHDV
13:50	Break-out groups: Priority research areas
15:00	Wrap-up and afternoon tea

Appendix 2. Islands with rabbits, from the top 100 priority list for Australian offshore islands

Island name	**Location**	**Island size (hectares)**
Bribie	Queensland	14,757
Erith	Tasmania	320
Deal	Tasmania	1567
French	Victoria	17,378
Great Dog	Tasmania	358
Macquarie	Tasmania	12,785
Dream	Victoria	368
Sunday	Victoria	1192
St Margaret	Victoria	1889
Phillip	Victoria	10,129
Quail	Victoria	533
Swan	Tasmania	241
Swan	Victoria	289
Three Hummock	Tasmania	6981

Source: Ecosure (2009).

Appendix 3. The use of night-vision equipment in pest and predator control

Neil Bolton, Department of Conservation, New Zealand

Background

Spotlighting has historically been used in control of rabbits during their period of highest activity at night. It is generally accepted as the most effective secondary management tool available. However, professional night shooters have observed that a percentage of rabbits become light-shy and/or change their daily activity pattern. There is a noticeable trend over time that rabbits will not hold in the light, or they move for cover as a reaction to a spotlight working in the area. Recreational spotlighting conducted in a 'less than best-practice manner' may contribute to this effect, as may frequent regular hunting on land of high-to-extreme rabbit proneness that requires a minimum monthly shooting regime.

With night-vision (NV) image intensifiers and associated equipment becoming more available and less costly, a trial period was agreed to, to see if these tools add effectiveness to night-shooting operations. The hypothesis is that the covert nature of NV operations would add to their effectiveness. It is also assumed that this new approach would avoid further education of rabbits to evade spotlights, make their learned habits irrelevant, and therefore increase effectiveness of the follow-up action. This study evaluates the different possible equipment, its cost, durability and its ease of use.

Night-vision equipment (images: Neil Bolton)

Equipment

NV units/intensifiers:

NV units have different generations of development and are available in two distinct genres for either civilian or military application. During an initial trial-and-error period an appropriate unit was found from the following observations:

1. Initial trials with a civilian Generation 1 (G1) unit quickly established its unsuitability due to lack of image quality and definition.
2. Trials with a G2 civilian-style unit showed promise, but still did not provide enough definition. Also, the design of these units does not allow the adjustability and flexibility needed for dedicated professional use.
3. A military housing fitted with a Photones G2+ intensifier was found more suitable, and so was chosen for use in this trial. The Photones G2+ is reputed to sometimes exceed the performance of G3 units, or at least be similar to G3 units. The housing is a robust and waterproof monocular type designed to be helmet mounted for movement by foot/vehicle/aircraft. It can be used in conjunction with a variety of weapon sights including scopes. With a 1x (one power) magnification it offers approximately a 45 degree field of view. It has the full range of 'forward/rear', 'tilt up/down', 'left/right' adjustments, and also focus and dioptre adjustments.

Infrared illumination

Infrared (IR) illumination is required to create 'eye shine' in the target animal, and to provide greater illumination for the NV unit. IR lens filters can be used in conjunction with a normal light source. Alternatively a designated LED or laser-emitter unit can be used. The normal light with IR lens filter and the LED version are both eye safe. However, the laser emitter units are not eye safe at a distance of less than 100 metres, therefore caution is required with their use (ie they are not to be pointed at humans for a period of time at a short range).

The following IR equipment was trialed:

1. Light-force spotlight with IR filter lens — found to be adequate but was superseded as per explanations further on.
2. ATN-450, a LED-based emitter — featuring an adjustable field of view, adjustable power output, low powered in the 40–80mW range and eye safe.
3. IR laser emitter — featuring adjustable field of view, adjustable power output, between 80–250mW, but not eye safe under a distance of 100 metres.

Weapon sights

The following equipment was used in this study:

1. IR laser dot sight — featuring adjustable brightness of aiming dot and point of impact adjustment like a rifle scope.
2. Scope — allowing good quality optics with larger-type objective lens 40+mm, minimum adjustable objective essential for use with NV. The NV manufacturer states this as a requirement, and it allows clarity of images at all ranges.
3. High mount system for scope — it is essential to get the NV unit to align in a good shooting position. This is achieved with a scope mount height of at least 25–30mm above normal position (note: the sight position on military weapons is always high). This positioning allows use in all normal shooting positions (eg standing/sitting/at rest etc).

General

The stock for the rifle needs to suit a higher line of sight (note: military style stocks seem to be perfect, but sporting stock can be fitted with an adjustable height recoil pad for the same result).

Techniques and methodology

Most work was carried out from an ATV on the same variety of terrain one would expect a competent rider to traverse in normal spotlighting operations. Initially, a helmet-mounted light-force spotlight with an IR lens was used. Limitations were as with normal spotlighting, with the unit having to be plugged into the ATV 12 volt source, or if doing 'walk about', needing to carry a large rechargeable 12 volt battery. The spotlight could be focused to a good field of view, but then would not be bright enough in the spot area for target finding and definition at a normal shooting range. Although it was usable, it has been now superseded with the use of dedicated IR light emitters.

Four emitters were used in total with a specific job for each:

1. The ATN-450, a LED emitter unit which is helmet mounted and offers a full 40 degree field of view to approximate 75 metres on full power. This unit matches the NV unit's field of view nicely so everything in the NV field of view is bathed in IR light for good peripheral vision.
2. A first laser emitter is also helmet mounted and provides a spot area similar to spotlighting (approximately ten degrees) in the centre of view. On full power, this emitter lights up objects in excess of one kilometre. It creates eye shine on cats at 750–1000 metres, deer at 500 metres and rabbits, hares, opossums and the like at 250 metres under normal operating conditions.

3. A second laser emitter of the same model as above is attached directly to the scope and set to full constriction (two degrees) to provide a very bright IR light right on target when viewing through the scope, for fullest clarity and definition when taking shots. This also alleviates any ‘aligning issues’ between helmet-
4. mounted light and scope view.
5. The fourth emitter used is a laser sight mounted on the rifle under the barrel. It is used for target finding at short ranges and to assist in defining the distance to the target.

All emitters and the NV unit are powered by one rechargeable CR123 A battery each. Their usable life per charge is stated in Table 1. Purchase and ongoing charging costs equate to about two cents per hour for all batteries used in operation.
The NV unit is mounted to an ATV safety helmet in the same manner as to a military helmet, allowing full adjustability for comfort, optimal positioning and being able to be lifted up away from the eye when not in use. The unit can be positioned over right or left eye depending on preference, and the other eye is left for monitoring the GPS, ATV information console and so on as required. The helmet with everything attached is still very light and can be worn continuously for six to seven hours.

Searching for target species is conducted the same way as in ‘best-practice spotlighting’. When the target is sighted, the rifle is brought to eye in normal position allowing the NV unit to slide over the scope’s ocular lens. The right design rifle stock with the scope mounted high is required for this to be a fluid motion that results in a good shooting position from standing, at rest or sitting.

For rabbits less than 20–25 metres away, the under-barrel laser sight is used. Its IR dot can be placed on the target quickly with no need to look through the scope and the shot

Searching mode (left) and shooting mode (right) (images: DOC Twizel) can be taken. The under-barrel mounting position has the added benefit of the laser being able to be used as a basic triangulation rangefinder. This means the laser dot is set to match the scope's crosshair at 65 metres. If the dot is under the horizontal crosshair, the target is closer than 65 metres. The dot climbs above the crosshair as the range increases beyond 65 metres. With practise, this method allows the ranging of rabbit-size targets up to 150 metres distance at plus or minus five metre accuracy. Otherwise, the range estimation can be difficult due to the single focal plane image of night vision.

Cost

The extra cost over spotlighting is outlined in Table 1. The additional cost including charging of batteries, spread over the expected life span of 10,000 hours, equates to approximate $1 per hour of use.

Table 1. Information regarding cost aspects for one functioning night-vision unit

Equipment item	Current replacement value (AU$)	Expected lifespan (hrs)	Usable battery life per charge (hrs)
NV unit	6000	10,000	30
ATN-450	400	10,000	3
IR laser emitter (2 units)	1000	10,000	2
laser sight	400	10,000	40
rechargeable batteries	200 (20 batteries at $5 each plus charger)	500 charges	
Total approximate cost and lifespan	8000	10,000	

Observations on effectiveness

This evaluation is based on experience of more than 1500 hours of NV use in rabbit control. The eye shine created by IR light emitters viewed through NV is significantly brighter than with normal spotlighting. The presence of target species such as rabbits, hares, feral cats and possums and so on is as obvious as if they were shining back a small torch.

Tallies initially doubled in areas with over ten year's history with normal spotlighting. After light/activity shy numbers were removed, average tallies are still 25 to 30 per cent higher than with normal spotlighting, due to the covert nature of NV. During a bright moonlit night, the tallies are reduced in a similar proportion as to normal spotlighting, so NV tallies still surpass spotlighting in those conditions by about the same percentage.

Many groups of six to ten rabbits are systematically shot, often with the last one still feeding when shot. The ratio 'rounds used to rabbits killed' is excellent, because so many rabbits are shot in a non-disturbed state.

The annual average of kills from NV with subsonic .22 ammunition is nine kills per ten rounds compared to five to six kills per ten rounds with spotlighting.

Eye strain is also considerably reduced and almost nonexistent when using NV. No negative effects were noticed even with continuously long shooting nights.

Having shot in excess of 15,000 rabbits with NV, returning to the use of normal spotlighting is not a viable option.

Conclusions

- Photones G2+ or better is the minimum requirement for an NV unit.
- Military units are far more useful than civilian units.
- IR emitters are essential for 'eye shine' and general lighting of the area.
- The operator remains invisible to animals at all stages of the operation.
- Good quality equipment and rifle are required for dedicated professional use.

Glossary

ATN-450	name of infrared illuminator used in study
ATV	all-terrain vehicle
CR 123 A battery	type of battery commonly called A
dioptre	refractive power of lenses resulting in a specific focal length; adjustment for short or long sightedness
G1	Generation 1
G2	Generation 2
G2+	improved Generation 2
G3	Generation 3

GPS	global positioning system
IR	infrared
LED	light-emitting diode
monocular	with just one eye piece
NV	night vision
Photones	trademark name of used NV intensifier
subsonic .22 ammunition	calibre 22 ammunition remaining below the speed of sound
scope	weapon sight to help target finding

Appendix 4. Tarbaby technique fact sheet

Jim Bell, Landcare Research, Lincoln, New Zealand

'Tarbaby' is a technique devised by researchers in CSIRO Australia. It is experimental and illegal to use this procedure in New Zealand at this stage. Further experimentation requires an Experimental Use permit from the Pesticides Board.

The rabbit, like other mammals, indulges in long bouts of meticulous grooming. Much of this is spontaneous and unstimulated but the presence of mud on the forepaws clearly causes discomfort. The rabbit actively attempts to remove such foreign matter by licking or biting and pulling at it with the teeth and shaking the paws. The same response is not elicited if the rabbit's ears or hind feet are experimentally contaminated.

This behaviour was exploited by a novel poisoning technique, called Tarbaby after the efforts of Brer Fox to trap Brer Rabbit with tar in the story of *Brer Rabbit* by J. Harris.

Application method

The Tarbaby technique consists of laying a trail of greasy substance carrying a poison along the floor of a burrow. Various devices were tried, all based on a grease gun body with an extended nozzle to reach into the burrow. Rabbits tread on the trail, then onto the soil, and ingest the poison when they clean their forepaws.

This technique is not new — rodent tracking powders utilise this behaviour and an edible mixture of molasses, wheat flour, margarine and glycerine has proven to be the most acceptable and stickiest of a number of materials tested for rat and mouse control. The technique has obvious advantages where animals do not readily consume bait because of an abundance of alternative food or bait shyness.

Small-scale Australian trials

Experiments have tested mixtures of lanolin and 15–25 grams 1080 per kilogram grease extruded down a rabbit burrow in a five track strip 10cm long and established it was effective in killing rabbits walking over the mixture. Disappearance was complete in the warrens over about three days and visiting rabbits from uncontrolled warrens were also killed. It was suggested that the technique could be used among stock as the poison was placed well down burrows and so specific to rabbits. One man in a day treated a maximum of 800 holes.

Large-scale Australian trials

The small trials were followed up by larger-scale trials to assess the safety and limitations under field conditions when the work was carried out by local labour or farmers. Trials first established that poison concentrations had to be 30 grams 1080 per kilogram of sticky multipurpose grease for consistent results.

Detailed observations showed that two treatments were sufficient to reduce rabbit numbers dramatically but the area cleared was rapidly reinvaded by rabbits from adjacent untreated areas. The mean area treated was three hectares per hour, but on one property where a motorcycle was used for transport and with a scattered rabbit population, one man treated 22 hectares in an hour. Approximately 5 grams of poison grease per entrance was applied. A heavy-duty grease proved best as it stayed tacky the longest, did not become dry or brittle or soak into the soil and rock.

The major problem for this technique was that success depended on finding and treating all the warrens. The work was physically strenuous, demanding and boring. Rabbits avoided treated warrens if possible, and the first few through a burrow entrance often removed the poison on their paws or covered the grease with soil. Authorities in New South Wales felt that the technique was not amenable for general use because the toxic material was too dangerous; rather they saw it under the control of a trained team following up major control operations.

A further series of trials established there were no risks to domestic stock and retreatment was cheap and effective. Residue levels were low and the amount of 1080 in the environment was many kilograms less than conventional poisoning operations. Researchers believed Tarbaby was a very useful technique for local infestations in difficult country.

New Zealand trials

A trial in New Zealand confirmed the Australian experiences of warren population reduction and the rapid re-invasion by satellite animals. The need for alternative sticky tars without the associated smell was obvious, as were easier dispensing methods. A possibility is the sticky gel developed by the Forest Research Centre and Animal Control Products. The gel contains a maximum of five per cent 1080 and is smeared on palatable plant leaves in forest or shrub associations for the control of deer, wallabies or goats. The material's smell does not repel deer, wallabies or goats, so it should have no adverse affects on rabbit acceptance.

Potential problems

The gel or tar has a very high concentration of toxin and is placed down the burrow. This positioning reduces the risk of stock having access to the toxic material but increases the risk to predators investigating the burrow during their search for prey. Ferrets, other mustelids and cats would be vulnerable as they also are fastidious groomers. High levels of 1080 may occur in the carcases of rabbits poisoned with this technique and pose a high risk to farm dogs. Dead foxes were commonly found in the Australian trial areas indicating that the rabbit carcases were toxic to canids.

References: Hale and Myers (1970), Ryan and Murray (1973).

Appendix 5. Information on RHDV

Brian Cooke, Invasive Animals Cooperative Research Centre, Australia

Rabbit haemorrhagic disease virus (RHDV, also known as rabbit calicivirus RCV) as a rabbit-specific pathogen can be potentially useful for control of rabbits on islands. However, it is important to evaluate how it fits into a bigger program for rabbit eradication and its likely efficacy if used in this way.

In Australia, the impact of RHDV was highly variable from one region to the next and was generally seen to be correlated with climate variables, being more effective in warm, dry winter-rainfall regions than in cooler, coastal regions where rainfall was higher and more evenly spread across the year. Similar observations were made in New Zealand where RHDV was more effective in the dry areas of Central Otago than in coastal areas and the North Island. However, it is becoming increasingly clear that the underlying cause is not just climate itself, but is also the presence of a non-pathogenic lagovirus (RCV-A1) that occurs widely in rabbits, especially in Australia's cooler coastal regions (Strive et al 2009). Antibodies raised by rabbits following infection with the non-pathogenic virus have been shown experimentally to temporarily protect against acute RHD (Strive et al 2010). Field epidemiological studies also support the idea that prior infection with the non-pathogenic virus protects sufficient numbers of young rabbits in the field to enable good recruitment into the adult breeding population and thereby maintain populations, despite the presence of an acute pathogen (McPhee, unpublished data).

Rabbit dissection (image: Tanya Strive)

Although work to find out more about non-pathogenic RCV-A1 is continuing, we still do not have specific ELISAs to detect specific antibodies against the virus. As a result, it is difficult to precisely identify whether or not non-pathogenic viruses like RCV-A1 are present in some island populations. For now, it is only possible to say that such viruses are likely to be present based on limited reactivity in ELISAs designed to assay RHDV antibodies (eg Cooke et al 2000, 2002).

In the case of rabbits on the subantarctic Kerguelen Archipelago, for example, Cooke et al (2004) found enough serological evidence to suggest that non-pathogenic viruses are present. However, because titres were low and antibodies present in only a few rabbits, it was considered that non-pathogenic viruses would be unlikely to inhibit RHDV if it was used for reducing rabbit numbers. Nonetheless, Marchandeau et al (2010) have since used a more general ELISA capable of detecting antibodies to both non-pathogenic lagoviruses and RHDV to show that antibodies to non-pathogenic caliciviruses are more widespread in the Kerguelen Archipelago than first thought; about 35 per cent of rabbits are seropositive. Given that RCV-A1 in Australia gives partial protection against RHDV (Strive et al 2010), these later records from Kerguelen suggest that it would be unwise to assume that a release of pathogenic RHDV would automatically produce high mortality.

Despite potential benefits from RHDV, when considering island rabbit control, where eradication is the aim rather than mere reduction in rabbit numbers, the use of the virus is limited. We know that at best it reduces rabbits by about 90–95 per cent and on that basis it would need to be used in conjunction with other methods, such as poisoning or warren fumigation, to bring rabbits down to levels where the last few could be mopped up.

In that context, using RHDV first to reduce rabbits before poisoning is one option but needs to be considered in terms of overall operations. For example, one of the ideas in poisoning rabbits on subantarctic islands in midwinter is related to the fact that food is short at that time and baits are likely to be more attractive. Use of RHDV prior to poisoning may reduce rabbit numbers, but in turn leave the remaining rabbits with more resources and thereby reduce the efficacy of poisoning. We have no practical experience in this and as a consequence have no simple recipes for closely integrating the use of RHDV with other control measures for island rabbit control.

Nonetheless, with improved ELISAs to detect non-pathogenic viruses, RHDV could be used as a biocide to severely reduce rabbit numbers on specific islands where poisoned baits may not be acceptable (eg where other endemic mammals are at risk from poisoning). With the numbers of rabbits reduced, subsequent efforts to remove rabbits by trapping or shooting could be greatly reduced. In that sense, it is potentially a useful first step in eradication of rabbits from small islands. It has been used in eliminating rabbits from Cabbage Tree Island, New South Wales, although not specifically assessed given that myxomatosis and other control methods were also employed (Priddel et al 2000).

Assessing potential for using RHDV on islands

Apart from collecting serum samples for assay to detect antibodies (mentioned above), Dr Strive has suggested sampling of rabbit tissues to identify non-pathogenic viruses by detecting and sequencing their genome.

The best samples are from the duodenum (the first 4 cm of the small intestine adjacent to the stomach). These samples need to be frozen immediately and also transported frozen. A second option for the field is to collect the samples in a fixative called RNA-later. The duodenum pieces can be collected into this fixative and then handled and sent at room temperature. RNA-later is quite expensive, but costs need to be weighed against transport costs on dry-ice (which is also expensive).

Samples are best collected from freshly killed rabbits (cage-trapped or ferreted) but shot samples are also acceptable. A minimum of 20 rabbits, or ideally 60, would be best; preferably taken during the breeding season when it is possible to collect a cross-section of the population. An additional serum sample from each rabbit would be useful, but is not absolutely necessary.

References: Cooke et al (2000, 2002, 2004), Priddel et al (2000), Strive et al (2009, 2010), Marchandeau et al (2010).

Appendix 6. Current agreed best practice for rabbit eradication on islands

Keith Broome, Department of Conservation, New Zealand

Introduction

This document is the result of information presented and subsequent discussion at a two-day workshop on the eradication of introduced rabbits on islands. Although it forms part of the proceedings for that workshop, it is also a stand-alone advisory document for wildlife managers planning to eradicate rabbits. This version (1.2) was produced in July 2010 following circulation of a draft at the workshop. New information and suggested improvements to this document can be made to Keith Broome (email kbroome@doc.govt.nz).

This document can be cited as:

Broome KG and Brown D (2010). Current agreed best practice for rabbit eradication on islands. *In*: Murphy E, Crowell M and Henderson W (eds), *Workshop Proceedings: Improving the Efficiency of Rabbit Eradications on Islands.* 4–5 February 2010, Christchurch. Invasive Animals Cooperative Research Centre, Canberra, Australia.

1. Eradication process

Once a project becomes a priority, the first step is to undertake a feasibility study to determine the costs, benefits and risks of the project and allow an informed decision about the scope and scale of the project. Step 2 is to create a project management document that outlines the objectives, governance, project decision making, resources and timeframes of the project. Step 3 is the operational planning phase, which is where this best-practice document is designed to help.

2. Eradication design

Overview

1. Rabbit biology, particularly their ability to breed rapidly and their behaviour, makes their eradication from islands a formidable task. If placed under pressure, rabbits can reduce their scent trail and become secretive to a point where they are virtually undetectable. For these reasons passive (low disturbance) techniques need to be used initially to minimise the risk of forcing animals into hiding. These techniques should pave the way for more aggressive (high disturbance) techniques such as dogging and shooting later in the program. Failure to adhere to this strategy (ie beginning with low disturbance techniques) risks greatly increasing the cost of the project through a long drawn out campaign to detect and eliminate the final animals who have survived previous disturbance.

2. Following a feasibility study and a meticulous planning stage, the fieldwork should comprise three distinct phases:
   i. the relatively short-and-sharp 'knockdown' phase (where as many individuals are removed as quickly as possible)
   ii. the more extended 'mop-up' phase where the surviving individuals are targeted, often individually, until no further sign remains
   iii. prolonged islandwide monitoring for any further sign being detected, before any declaration of success.

3. In some cases the initial knockdown poisoning has successfully eliminated the population, but in many cases it has not, so plan the project with the expectation of there being survivors after knockdown. If 100 per cent kill is achieved in the knockdown, little is lost compared with being unprepared for survivors.

4. Biocontrol agents such as RHDV (rabbit haemorrhagic disease virus) may be useful in contributing to the knockdown, but consideration needs to be given to the time

this may take and any consequent changes in the habitat that may favour surviving rabbits. Investigate the population immunity status during the feasibility study if RHDV is an option.

5. Rabbits can be targeted at any time of year, but any knockdown baiting should take the following factors into consideration (in descending order of importance):
   i. when natural food resources are at a seasonally low level (per capita) — typically this is winter to early spring, but may vary from island to island according to the climate, range of habitats and foods available (ie feed them baits when they are most hungry)
   ii. when the low point in the population breeding cycle occurs
   iii. the optimal date to begin the follow-up (ie final poison application date should avoid a long period of inaction on survivors post baiting due to factors affecting the deployment of mop-up activities).

6. Managing the habitat where possible can be an important part of managing the rabbits' vulnerability to detection and capture. Prior to the knockdown operation, clear all windfalls, piles of cut vegetation or other large collections of debris, inorganic rubbish and so on to minimise cover for rabbits. Minimise areas that rabbits can access but dogs cannot.

7. If domestic stock are present, intensively graze grassed areas right up until the point when stock are removed from that area, to minimise the amount of cover available for rabbits. Alternatively, mow strips within grass areas with a tractor/brushcutter to enable sign and rabbits to be detected, as these strips become preferred feeding areas for the rabbits. The trade-off with mowing is that it provides more food for rabbits, so this technique should not be used until the population is in low numbers.

Knockdown by poison baiting (where rabbits are the only pest animal being targeted):

8. For knockdown baiting, use carrots or cereal-based baits laced with Pindone or 1080, aerially spread where possible, using GPS and techniques for laying bait swathes as per aerial applications for rodent operations. Whole island coverage with sufficient bait to allow all individuals easy access to a lethal dose is important in the knockdown. Aim to realise the potential to eliminate the population in the knockdown rather than adopt a 'get them later in the follow-up' attitude, which leads to less-than-optimum knockdown.

9. If using bait that is vulnerable to weather conditions, do not begin deployment of bait until a forecast of three fine nights is predicted. Bait affected by bad weather may either become less palatable to rabbits or may be destroyed by the weather conditions.

10. For further details on knockdown see Methods section below.

Mop-up

11. Follow-up methods should be commenced as soon as possible after knockdown effects have fully manifested. That is, within one week if 1080 has been used and three to four weeks after first baiting if using anticoagulants. This timing is to minimise the chances of surviving rabbits breeding before they are eradicated.

12. Begin mop-up by gathering information to form a post-knockdown picture of surviving rabbits. Where practical, conduct comprehensive night counts using spotlights and map each surviving individual rabbit or group. Expect most survivors to be in areas of prime rabbit habitat. Usually this habitat is associated with cover near feeding areas.

13. For details on survey methods see Methods section below.

14. Beginning with the groups identified from surveys, use lower disturbance techniques such as ‘patch poisoning’ of specific areas. Where possible, use an alternative bait type to that used in the knockdown. Anticoagulant toxins are preferred for this work as they are less prone to generating bait shyness.

15. Hunting using silenced rifles and night-vision equipment is a relatively passive technique if done correctly. A high level of skill and quality equipment combined with suitable terrain and (a lack of) vegetation cover are necessary before this technique can be considered a better option than patch poisoning for early stages of follow-up.

16. In other circumstances, hold off shooting until poisoning gets the population down to groups of less than three rabbits. Do not shoot at individuals within a group of rabbits, or where more than one rabbit is in view at any time. Not all rabbits in the area are above ground at once, so repeat shooting over the same ground in the same night can be effective.

17. Once numbers of rabbits are low, dogs can be used to assist with the location of individual survivors. If the terrain/soils are suitable and all entrances can be located, toxic gas-generating pellets can be inserted into burrows where rabbits have been seen to enter and entrances have been blocked. Smoke generators may be helpful to ensure all burrow entrances have been identified. Rabbits will usually sit tight underground despite smoke. After a safe period, dig and retrieve dead animals to confirm kills.

18. Known individual rabbits can also be targeted using traps laid in burrow entrances or other areas of fresh sign. Rabbits can escape leghold traps, so the following precautions should be taken:
    i. Use traps only when better (less risky) options are not available.
    ii. Use traps only when all traps set can be regularly monitored.
    iii. Use highly skilled trappers familiar with the type of trap being used.
    iv. Where practical, use two or more traps at every set to target more than one limb on a caught rabbit.

19. Dogs can be used either for hunting rabbits or for detection. However, dogs must be used cautiously in the early stages of the mop-up and only where rabbit numbers are very low, as they are a technique that could put rabbits into hiding. Wherever possible, use dogs only for detection, as in most island situations the chance of a rabbit escaping from hunting dogs is relatively high, and the rabbit will become very wary and more difficult to target later. Once an area/pattern of presence has been detected, target the individual rabbit with selected control options (traps, toxins, etc) appropriate for the situation (bearing in mind past control options the rabbit may have encountered).

20. For further detail on mop-up techniques see Methods section below.

Monitoring

21. The last surviving rabbits (or other animals in any eradication) are often those that behave abnormally. Therefore, do not presume animals remaining after knockdown will follow normal rabbit behaviour. Have available as great a range of baits, lures and techniques as practically possible to detect and eliminate rabbits remaining.

22. Rabbits can remain undetected for many months on large islands despite intensive searching. A monitoring period deploying a range of techniques needs to be

determined in the planning and kept under review as the project progresses. As the time increases since the last possible rabbit sign, the intensity of search effort may be scaled down, provided that a rapid response capability is maintained to target any fresh sign of rabbits. The timeframes of some successful rabbit eradication projects are provided in Table 1 below as a general guide. The norm for islands over 100 hectares is at least three months of intensive monitoring after the last known rabbit or sign has been accounted for. This is followed by periodic islandwide surveys for a full year — if there is no further evidence of rabbit presence, it can be safely concluded that rabbits have been eradicated.

Table 1. Timeframes of monitoring in successful rabbit eradications

Island	Size (ha)	Period of intensive monitoring beyond last sign	Comments	Reference
Ilheu da Praia	12	2 days	One rabbit shot.	E. Bell this proceedings
Cabbage Tree	30	6 months	Knockdown 100%.	D. Priddel this proceedings
Rawaki	46	6 days	Further monitoring undertaken the following year.	Pierce et al 2008
Rose	80	2 weeks	Further monitoring undertaken the following year.	N. Torr this proceedings
Motuihe	179	8 months		DOC internal document
Salvegem Grande	240	7 months	Further monitoring undertaken, focussed on mice.	R. Trout this proceedings
Enderby	700	4 weeks	Further monitoring undertaken the following year.	N. Torr this proceedings
Motutapu	1509	3 months	Further periodic monitoring planned.	R. Griffiths this proceedings

23. For further detail on monitoring techniques see Methods section below.

Eradication design if also targeting rodents

24. If rodents are being targeted concurrently with the rabbits, the knockdown poisoning has to be designed to achieve both the knockdown of rabbits and the complete eradication of rodents. Follow-up techniques for surviving rodents are usually not necessary if done correctly, and usually not practical on large or rugged islands anyway.

25. Use aerially or hand-spread Pestoff 20R bait. Follow best practice for rat eradication, but allow for extra baiting density based upon rabbit density information:

- If maximum rabbit density is less than ten per hectare, no additional bait is required.
- For densities of 10–20 rabbits per hectare, raise baiting rates to 15 kilograms per hectare for each application.
- For higher densities (20 or more rabbits per hectare), raise bait rates to 20 kilograms per hectare for both applications.

26. The two separate bait applications should be seven to ten days apart (guided by requirements for rodents).

27. Mop-up methods should commence three to four weeks after first baiting, using a sequence of techniques as described above.

Eradication design if associated with feral cat eradication:

28. As above, but unless there are major non-target species or potential prey-switching issues, do not target cats until rabbits are on the verge of eradication. Cats can exert some useful control pressure on the remaining rabbits, especially as it is likely that they will be hungry through removal of the bulk of their rabbit prey.

29. Store rabbit carcasses for later use as bait in cat trapping.

3. Planning

30. Have the operational planning peer reviewed before beginning the operation. The strategy for eradicating rabbits is considerably more complex than for rodents, and requires a careful consideration of the sequence of methods that takes into account:

    - any other pest species being simultaneously targeted (eg rodents or feral cats)
    - the size, vegetation and terrain of the island
    - the size, density and general ecology of the rabbit population
    - other factors such as any prior control efforts.

For this reason, it is very important to obtain input and advice from experienced rabbit eradication specialists and ecologists.

31. When costing and planning for projects, allow for contingencies. Money shortages affect morale and raise operational risks which, if they lead to failure, will prove more expensive in the long run.

32. It is vital that eradication strategies (especially baiting) take account of rabbit densities. Prior work is highly desirable to accurately determine rabbit densities over the entire treatment area, and particularly any areas of high population density that may require site-specific additional bait levels or repeat baiting to ensure all individuals have access to lethal doses.

33. Plan for probable techniques well in advance of the operation. Establish what trapping and poisoning options are legal and appropriate bearing in mind the island's specific circumstances (eg presence of vulnerable non-target species), and obtain all necessary approvals to allow deployment without delays during project implementation.

34. Dog teams should be selected and trained well in advance of commencement of the project, to ensure they are fully operational when needed. Where possible, especially later in the project when rabbit numbers may be very low, they should be occasionally 'refreshed' off the island in areas of higher rabbit density. Where this is not possible, dead rabbits can be collected prior to eradication commencing and stored frozen for later refreshing of dogs to rabbit scent. If planning to use dogs, be aware of the risks of prior use of 1080 to the dogs. This risk may affect the choice of toxin.

35. Rabbit dogs should be trained to a recognised standard to ensure they can focus on rabbits and can safely operate in the presence of other wildlife species. Dogs should be capable of locating sign and scent as well as live rabbits. At all stages of the operation, do not overuse dogs so that rabbits start avoiding areas where dogs have been.

36. For follow-up work, plan on a conservative area of 100 hectares searched per day per person (this will vary greatly depending on factors such as the terrain and vegetation, and if a 4WD motorbike or dogs are used). All areas of the island that need to be covered should be checked inside a period of five to six days. This turn-around period must also accommodate the down time resulting from bad weather, leave and time off the island for staff and dogs.

37. Once every few months, the mop-up team should be taken off the island to spend time in an area where rabbits are abundant to hone skills and freshen dogs. Work hours may vary but night work can be split into shifts to increase productivity. To allow sufficient time to locate sites and build up knowledge of individual rabbits, allocate team members to specific areas for set periods (eg a roster period of five to ten days). However, rotate these areas between team members on a longer-term basis to provide more variation in the work.

38. Maximise the number of skilled hunters in the early part of the mop-up phase as far as possible without 'crowding' or causing undue disturbance to the remaining rabbit population. Maximum effort is required early to reduce the capability of the surviving rabbits to increase in population (through breeding).

39. Hunters need to be cautious and accurate shooters, and these characteristics need to be established during selection and training. Larger islands obviously require more hunters, but care is needed to ensure the skill and motivation of each person is maintained. For larger projects, dog handlers from elsewhere should be used periodically to audit progress.

40. Working a five-day week and two-day weekend may not be the best option. Later in the project a cycle of ten days on, four/five days off may prove more effective for detecting, prefeeding and poisoning remaining rabbits and then giving survivors a chance to settle down.

4. Information review and data management

41. Consistent monitoring information is critical to project success. It demonstrates progress (or lack of it), which is important in triggering a change in technique or a continuation of effort.

42. Any problems throughout the rabbit eradication program should be discussed in regular debriefs with the project manager. The project manager must make decisions on how these problems will be resolved.

43. Use GPS and GIS capability to ensure no parts of the island are excluded from the search area. Mop-up team members should track routes taken at all times when in the field with a handheld GPS and download data on a daily basis. GPS trackers on dogs may be useful. Use the daily downloaded GPS data to plan the next day's

work. Collate and review all data on a weekly basis to identify areas missed. Unsearched areas should be the priority in the following week's schedule.

44. All team members should keep a detailed record of the work completed and this record should be used to inform ongoing planning in the latter stage of mop-up phase and during monitoring phase. It is vital that the search effort and coverage of the island is adequately recorded and reviewed.

45. Information should be collected from all dead rabbits in the mop-up phase. The following variables are the minimum information requirements to record: date, observer, species, gender, age, reproductive status, location, easting, northing, gut contents, and cause of death if known. Each sample should be labelled and deposited in the freezer, and a DNA sample obtained. This information will aid the management process by establishing for example if breeding is occurring. If a young rabbit is located, it may suggest others of the litter may also need to be accounted for. It also builds a picture over time of where rabbits have commonly been found and can inform redirecting resources to pressure those spots before breeding escalates the remaining population.

46. Collect DNA samples from a subset of individuals killed or found dead and store them as a reference dataset of the gene pool on the island. Rabbits found near the end of the project or after completion can be compared with this data to determine if they are more likely to be survivors or immigrants.

5. Methods

Knockdown methods

Poisoning

47. If the toxin used for knockdown is 1080, apply two prefeeds of non-toxic carrot bait prior to toxic baiting (0.04 per cent 1080 in carrot bait). Each baiting should be two to four weeks apart. Prefeed application rates should trial the intended toxic baiting rate. Prefeed rates should be sufficient to allow all rabbits opportunity to feed on bait (eg if it disappears overnight, apply more in subsequent baiting). As a rule of thumb, apply 10 kilograms per hectare for densities of less than ten rabbits per hectare, 20 kilograms per hectare for densities of 10-20 rabbits per hectare, and up to 35 kilograms per hectare for exceptional densities (20–100+ rabbits per hectare).

48. For Pindone baits (Pindone Rabbit Pellets RS5) [also for Pestoff 20R brodifacoum baits if registered], apply in two separate applications approximately two to three days apart (without prebaiting) at rates according to maximum rabbit density. Rabbits may require several feeds of Pindone within a short period of time to receive a toxic dose (although a single large dose will also be lethal), so ensure bait rates and re-applications are appropriate. Typical application rates for Pindone are given in Table 2 below:

Table 2. Typical application rates for Pindone

Estimated rabbit density/ha	Typical application rates kg/ha (2 applications)
<10	15 + 10
10–20	20 + 10
>20	30 + 30

49. If hand broadcast is required, use a 25 metre by 25 metre grid system to ensure adequate coverage.

Shooting

50. Rifle shooting with dogs has been used successfully on some small islands in Mexico up to 389 hectares. However, attempts to deploy this method of knockdown on the much larger island of Clarion failed.

Mop-up methods

Poisoning

51. Poisoning small groups (one or few individuals) of surviving rabbits is best done using anticoagulant toxin (eg Pindone) applied to chopped carrot bait. Carrot is highly palatable to rabbits and may be eaten by individuals that avoid cereal baits. Lay a quantity of bait matching the estimated number of rabbits two or three times over an eight-day period. Depending on the extent of rabbit distribution, bait should either be hand spread across the area or placed onto a scrape cut into the ground approximately ten centimetres deep and 12 centimetres wide. Record the number and placement of the bait for later checking, and subsequent removal of uneaten baits. Make a record of the bait taken, and cover over any scrapes made.

52. Mop-up using acute toxins requires prefeeding at least twice before using toxic bait. Prefeeding should mimic the planned presentation of later toxic bait. Preferably it should be presented on a small spit of overturned turf or scraped soil. Record the amount of prefeed put out and the amount consumed. Ensure all prefeed bait is removed before laying toxic bait.

53. If individual rabbits are being targeted with poison carrot baits, ensure each bait is carefully presented to enable minor marks left by rabbits nibbling bait to be identified.

Shooting

54. Use silenced .22 rifles. In some situations the .17 HMR could be considered as a feasible alternative, as it is gaining in popularity due to higher killing power and flat trajectory. This offers confidence in accuracy over greater distances. The .17 HMR can also be fitted with a silencer. If spotlighting, use with a 30–50W spotlight and detachable red filter. If searching from an ATV, the red filter should only be used to search for rabbits and take the shot once stationary. Operators lose depth perception under red light and this can cause safety risks on a moving bike.

55. Spotlight hunting on foot or from an ATV should be used to target rabbits when surviving animals are being encountered at very low numbers (less then three individuals per spotlighting transect). Use helmet- or rifle-mounted spotlights as the light source and use red filters once a rabbit has been sighted, to minimise disturbance.

56. Night-vision equipment is expensive, but could play a vital role in detecting surviving rabbits. It is more effective at finding rabbits at night than spotlights with red filters. When used with silenced rifles this technique can cause relatively low disturbance. Infrared lights are another useful addition for light-shy animals.

57. Thermal imaging cameras can detect a heat source in a given area, especially at night, and allow hunters to follow up to identify the source of heat. Thermal imaging gives best results in cooler climates or times of day as it relies on the differentiation between the body heat of target animals and their surrounding cover. Shooters should be vigilant to the risk of bullet deflection by surrounding vegetation when using thermal imaging. Lighting the target with a conventional spotlight is recommended to ensure positive target identification and a clean shot.

58. Larger calibre (centre-fire) rifles may be used for longer distance shots, but should only be used where other options have proven unworkable, as disturbance is high.

59. Shotguns are high disturbance so should not be used if better options are available. However, they can be useful in situations where a rabbit may be flushed from a known location (eg burrow gassing), or as a last resort in combination with dogs.

60. Only shoot when very confident of achieving a killing shot: make each shot a killing shot. Otherwise, it is best to observe the individual in a 'non-threatening' manner and make another attempt in future, rather than to potentially scare the individual and educate it to avoid human activity. The patience and judgement to know when not to take a shot is important. Identifying a rabbit in a specific location is the most important thing, as specific strategies can be developed to target known individuals if a confident kill is not assured at first sighting. Do not shoot animals in a group; only target solo animals.

61. Test-fire rifles to ensure scopes are 'sighted in' accurately. Retest this daily or whenever the rifle or scope has received a jolt. Load ammunition carefully to avoid damage to projectiles (eg scraping of wax coating) that may affect reliable accuracy of bullet trajectory.

62. Use good quality firearms and optics and choose ammunition with reliable precision and expansion in the target animal. Using substandard equipment risks missing rare opportunities to eliminate final survivors and may end up costing far more money in wages than saved on equipment purchase.

Trapping

63. Traps must be set in pairs. Steel-jaw traps are recommended where their use is legal (eg Victor #1 hard-jaw).

64. Any opportunity to collect urine and faecal material (eg from any rabbit shot or caught in traps etc) should be taken. Gloves should be worn to avoid placing human scent on such material. If necessary, the material could be frozen until use and used sparingly as an attractant to lure rabbits to prepared trap sites (eg camouflaged leg-hold traps).

65. Rabbit does (preferably a domestic pet variety, not wild-sourced animals) in cages can be used late in eradication projects to target remaining rabbits by putting them near rabbit sign, with several traps around the cage. Great care is required to ensure escapes are not possible and animal welfare obligations are met.

Fumigants

66. Burrow fumigants (eg Magtoxin®, magnesium phosphide) may be used where rabbits are known or suspected to occur in burrows. However, confirmation of suspected kills from fumigation is highly desirable, so where possible, burrows should be excavated later (when risk of fumigant residue is negligible) to retrieve carcasses. In dry conditions, water can be added into burrows to ensure the Magtoxin pellets turn to gas quickly. Prior to gassing a burrow, securely seal off all burrow entrances with hard-packed earth and have someone with a shotgun present in case a burrow entrance has been missed. Before starting work, any inexperienced staff should be trained in how to prepare a burrow for gassing. Burrow gassing is not effective where the substrate is porous (eg scoria, gravel or boulder jumbles).

67. Problems with burrow gassing include:

- the level of doubt after the technique has been used, about whether or not it has been effective in killing the targeted individuals
- how many rabbits are inside a burrow and whether all entrances have been identified.

It is therefore only recommended when other options are not practical in that circumstance.

Other methods

68. Rabbit long-netting (use of 50-metre double-mesh nets to surround a warren or across a flush line) is used in United Kingdom with some success. There are a number of books and websites available on the subject. Purpose-designed nets, skilled setting and constant monitoring to extract captured rabbits are required.

69. Shooting from a helicopter is a potential option if the equipment and skilled staff are available. While this is a high disturbance technique, it could be used as a last resort on steep inaccessible terrain.

Monitoring methods

70. For passive survey by spotlight searches at night, use 30–50W spotlights with red filters where possible. Such survey will accustom rabbits to spotlights with no ill effects associated with them. Walked transects at dawn or dusk can also provide information, but less reliably and with a greater risk of rabbits reacting to human disturbance.

71. During pre-operational monitoring, make spotlight counts and recounts of identified hotspots. These points can then be revisited following each subsequent bait application with the aim of identifying the rate of decline and/or the relative number of surviving rabbits.

72. Where spotlighting is impractical due to vegetation cover or terrain, non-toxic bait interference can be deployed. For example, on Cabbage Tree Island fresh whole apples were used as they were known to be attractive to the rabbits and to clearly show teeth marks if partly eaten.

73. Droppings ('latrine' sites or buck heaps) are a key indicator of remaining rabbits, although accurate ageing of pellets is often difficult (and varies with climate), so prior age-determining experience is valuable. Use GPS or another method to record the precise location of known dropping sites. Do not remove or destroy 'buck heaps' as they may be an attractant to any remaining rabbits. Pay careful attention to details so that further activity at those sites can be detected.

74. Place small sticks or similar into the ground directly in the entrances of suspected 'active' burrows. Subsequent displacement of sticks may indicate rabbit movement in or out of the burrow. The presence of spider webs can also be used as a sign of a disused burrow entrance.

75. Kick in disused burrow entrances, except where burrows are shared with burrowing seabirds.

6. Skills required

76. The Project Manager needs a good working knowledge of the general ecology of rabbits and their local seasonal and behavioural traits to manage operations effectively. Experience or support in aerial baiting techniques is also needed if this technique is to be used.

77. Staff using or handling toxins need to have the appropriate training and certification.

78. Staff using rifles require firearms licences and should demonstrate competency in marksmanship and firearm maintenance.

79. Careful sharpshooting needs to be emphasised to avoid educating rabbits from non-lethal shots.

80. Hunting skills are needed — especially observation, patience and judgement.

81. Staff setting traps need to be experienced or have significant training and supervision from experienced operators.

82. Staff involved in the operation need to understand that eradication is different from control operations, as all individuals of the pest species must be put at risk. It requires commitment from the whole team to achieve this.

83. For those projects involving extended stays on remote islands, all people involved on the island need the ability to live and work harmoniously in such an environment. Poor group dynamics can lead to mistakes that can affect the success of the project.

84. Supervisors in the field need to provide effective leadership to maintain morale and focus on the priority tasks. The ability to collate and process field information from hunters is important to maintain an accurate 'situational awareness' of the project.

Table 3 lists documented examples of rabbit eradication operations on islands.

Table 3. Rabbit eradications on islands using anticoagulant and/or 1080 baits

Island location and date	Rabbit density /ha	Toxin	Bait rate	% Kill	Reference
Motuhora (Whale) (NZ Bay of Plenty, 143 ha) 1986	low at the time Talon 20P baits aerially spread	1080 brodifacoum	Several applications of several poisons 1985-1987, including Talon 20P aerially spread in two drops 2.4 kg/ha and 6 kg/ha, and hand spread on rabbit sign. Norway rats also targeted.	2 rabbits trapped post-poisoning. Successful eradication after follow-up work.	Jansen 1993
Round (Mauritius, 151 ha) 1987	16	brodifacoum	Talon 20P bait hand spread two drops on 10m grid at 4 kg/ha and 5.7 kg/ha.	>99% (14 survived). Successful eradication after follow-up work.	Merton 1987
Verte (Kerguelens, 148 ha) 1992	9	chlorophacinone	8.1 kg/ha	90%	Chapuis et al 2001
Enderby (Auckland Islands, 700 ha) 1993	7	brodifacoum	Wanganui #7 baits aerially applied in two applications, both 5 kg/ha but 10 kg/ha used in both applications for high-density areas. Mice also targeted.	"In excess of 90%", prob. >99% (22 survived, approx 70% of survivors showed no obvious sign of having taken bait).	Torr 2002
Rose (Auckland Islands, 80 ha) 1993	4	brodifacoum	Wanganui #7 baits aerially applied two applications, both 5 kg/ha.	"In excess of 90%", but probably 96-97% (12 survived). Successful eradication after follow-up work.	Torr 2002
Guillou (Kerguelens, 148 ha) 1994	9	chlorophacinone	9 kg/ha	90%	Chapuis et al 2001
Deserta Grande (Madeira, 1000 ha) 1996	?	brodifacoum	20 kg/ha over two applications.	100%	Bell 2001
Cochons (Kerguelens 165 ha) 1997	16	chlorophacinone	9.7 kg/ha	80%	Chapuis et al 2001
Ilheu da Praia (Azores, 12 ha) 1997	8–17	brodifacoum	16 kg/ha over three applications (7.5, 5.8 and 2.5 kg/ha).	99%+	Bried et al 2009
Cabbage Tree (NSW, Australia 30 ha) 1997	<10	brodifacoum	11.5 kg/ha, single aerial application.	100% (rabbit population had been reduced prior through introduction of myxomatosis and RHD).	Priddel 2000
Quail (Lyttelton, 81 ha) 1997	very high 50–100	Pindone	Three applications of Pindone, 7-8 days apart (4.3, 3.4, then 2.27 kg/ha).	>99% Approx 12 rabbits survived. Successful eradication after follow-up work.	Derek Brown (pers comm)
Motuihe (NZ Hauraki Gulf, 179 ha) 1997	high	brodifacoum	Talon 7-20 2 gm baits, aerially applied two drops at 8 and 4 kg/ha. Norway rats, mice and cats also targeted.	<50% (Insufficient bait for density of rabbits). Eradication failed for rabbits and cats (succeeded for rats and mice).	Broome & Cromarty 2007

Island location and date	Rabbit density /ha	Toxin	Bait rate	% Kill	Reference
St Paul (Southern Indian Ocean, 800 ha) 1997	?	brodifacoum	10-40 kg/ha used, ship rats and mice also targeted. Pestoff Rodent Bait aerially applied at various rates according to rat and rabbit densities. 10–40 kg/ha plus some hand spreading. Total bait over total area equates to approx. 17 kg/ha.	? 95% or more (71 survived). Successful with follow-up work.	Micol & Jouventin 2002
Motuihe (NZ Hauraki Gulf, 179 ha) 2002	very high (up to 106)	1080	Two prefeeds of 25 kg/ha carrot, followed by a single drop of 25 kg/ha 0.04% 1080 in carrot.	Approx. 80% kill (observations suggest an extra 10kg/ha would have created much higher kill rate). Successful eradication after follow-up work.	Broome & Cromarty 2007
Salvegem Grande (Madeira, 240 ha) 2002	4–5	brodifacoum	19.6 kg/ha. Mice also targeted. Bait applied by hand using 12.5 x 12.5m grid.	99% or more (approx. 5 rabbits killed by other methods).	Olivera et al 2010
Ohinau Island (NZ Coromandel, 46 ha) 2006	low	brodifacoum	Pestoff 20R 10mm, two drops both at 8 kg/ha plus some Pindone pellets hand laid. (kiore and mice also targeted).	100%. Island was mostly forested so rabbit population low.	Chappell 2008
Rawaki (Kiribati, 46 ha) 2008	11–63	brodifacoum	Pestoff 20R 12mm, two hand-spread applications, 25-50 kg/ha then 12-25 kg/ha.	>95% (43 survived). Sowing rates were higher than needed to be, crab take was lower than anticipated.	Pierce et al 2008
Motutapu (NZ Hauraki Gulf, 1509 ha) 2009	0.2	brodifacoum	37.7 kg/ha over three drops (16, 8, 8 kg/ha). Other species targeted concurrently.	99% or more (2 survivors so far).	Griffiths, this report (p24).

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Invasive Animals Cooperative Research Centre
University of Canberra
Kirinari Street
BRUCE ACT 2617
Phone: +61 2 6201 2890
Fax: +61 2 6201 2532
Email: contact@invasiveanimals.com
Web: www.invasiveanimals.com