The Quail Island story – thirteen years of multi-species pest control: successes, failures and lessons learnt

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Abstract. Quail Island (Ōtamahua) is an 85 ha island in Lyttelton Harbour, Banks Peninsula, New Zealand. Since 1997, community volunteers have eradicated rabbits (*Oryctolagus cuniculus*), cats (*Felis catus*), hedgehogs (*Erinaceus europaeus*), and ship rats (*Rattus rattus*) from the island as preliminary steps towards ecological restoration. At present, a network of traps on the adjacent mainland and a stepping-stone island successfully intercepts mustelids and other unwanted vertebrate pests en route to Quail Island. However, the public use of the island, its close proximity to, and inter-tidal link with, the mainland makes this island a significant risk to reinvasion, particularly by rodents. Lessons learnt from 13 years of pest work are outlined.

Keywords: Rodents, mouse, ship rat, hedgehog, mustelids, stoat, eradications, *Erinaceus europaeus*, *Rattus rattus*, *Mus musculus*, *Mustela erminea*, brodifacoum, ecological restoration

INTRODUCTION

Quail Island (Ōtamahua) is an 85 ha Recreation Reserve administered by the Department of Conservation, located in Lyttelton Harbour (43° 38′ S, 172° 42′ E), Canterbury, New Zealand (Fig. 1). The island is dominated by improved exotic grasslands, including cocksfoot (*Dactylis glomerata*), browntop (*Agrostis capillaris*), Yorkshire fog (*Holcus lanatus*) and several *Bromus* species (Burrows *et al*. 1999), with areas of native restorative planting across the island.

Quail Island is considered a 'mainland island' rather than a true island, as exposed mudflats provide a land bridge at low tide from Moepuku Point on the mainland via King Billy Island to Quail Island (Fig. 1). Consequently, the island is vulnerable to invasion by mammal pest species. It is unknown whether the introductions of these pests were deliberate or accidental.

In 1997, the New Zealand Department of Conservation, representatives of local Maori Te Rūnanga o Ngāti Wheke and dedicated volunteers began provisional planning for the ecological restoration of Quail Island (Burrows and Leckie 2001; Bowie *et al*. 2003; Norton *et al.* 2004; Bowie 2008). A major impediment to the restoration process was the presence of mammalian predators and the potential for ongoing reinvasion across the land bridge.

In this paper we describe a programme to eradicate mammalian pests from Quail Island (see Fig. 2) and the on-going control of reinvading mustelids (stoats, *Mustela erminea*; ferrets, *M. furo*; and weasels, *M. nivalis vulgaris*), hedgehogs (*Erinaceus europaeus*) and feral cats (*Felis catus*). The experience and knowledge we have gained over the 13 years since this multi-species pest eradication programme began are also discussed. As the pest control work was carried out by volunteers, robust scientific design was not a high priority; however, sufficient planning was carried out and records taken to ensure lessons could be learnt throughout the programme. We believe other groups undertaking future eradication operations such as those attempted on Quail Island could benefit from our experiences.

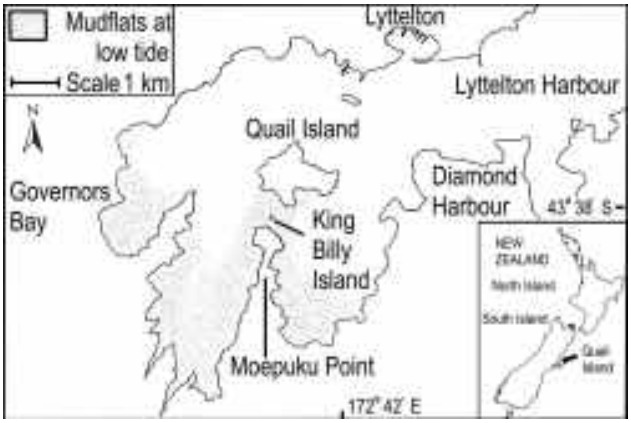

Fig. 1 Lyttelton Harbour showing Quail Island, King Billy Island and Moepuku Point.

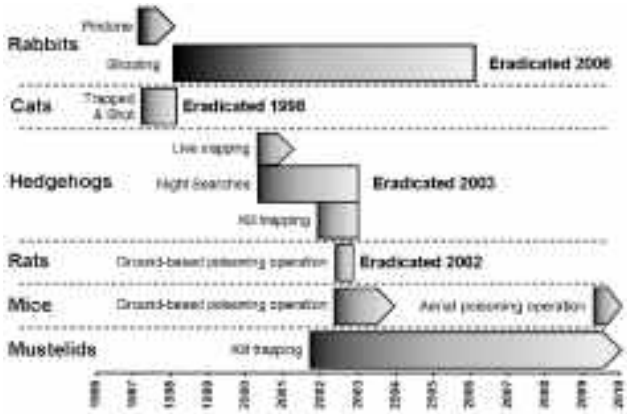

Fig. 2 Timeline of eradications undertaken on Quail Island and King Billy Island between 1997 and 2010.

METHODS AND RESULTS

Possum, rabbit and cat eradication

Possums (*Trichosurus vulpecula*) were eradicated from Quail Island in 1988, before the current project began (Brown 1999).

In 1997, pindone cereal bait (0.25g/kg pindone) was aerially applied twice to reduce the existing rabbit (*Oryctolagus cuniculus*) population (Brown 1999; Burrows and Leckie 2001), with remaining survivors shot or accidentally trapped. The last known rabbit on Quail Island was a male caught in a Fenn trap (Mk 6) (FHT Works, Redditch, England) set for mustelids in 2006.

Pages 157-161 In: Veitch, C. R.; Clout, M. N. and Towns, D. R. (eds.). 2011. Island invasives: eradication and management. IUCN, Gland, Switzerland.

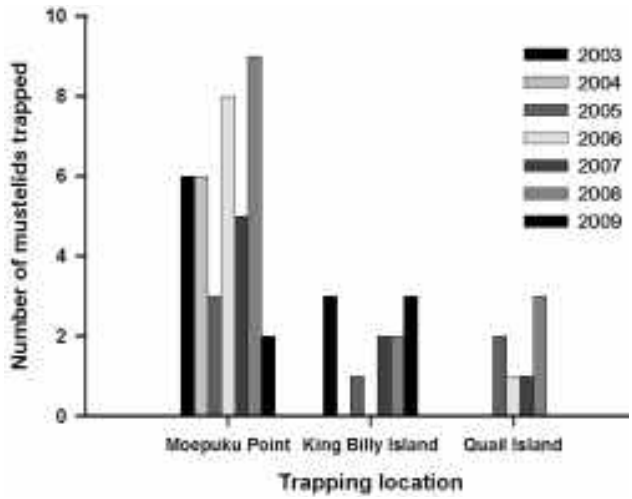

Fig. 3 Number of mustelids trapped on Quail Island, stepping-stone King Billy Island and adjacent mainland site Moepuku Point between 2003 and 2009.

The last feral cat was removed following a shooting and Fenn trapping regime in 1998. In total, 10 cats were removed from Quail Island at a cost of 68 worker hours. Since 2003, seven cats have been captured on Moepuku Point; however, none have been sighted or captured on King Billy Island or Quail Island.

Mustelid control

In 2001, wooden trap boxes, each containing two Mk 6 Fenn traps, were set up in a 120 m × 120 m grid over Quail Island (n = 62) and King Billy Island (n = 6). Traps were set primarily for mustelids and baited with hen eggs. It was anticipated that hedgehogs and rats would also be caught as by-catch. In 2002, an additional six trap boxes were placed on the northern-most tip of Moepuku Point, the closest mainland site to Quail Island, to intercept invading predators. All trap boxes were labelled and GPS coordinates recorded for monitoring purposes. Traps were repositioned or concentrated, depending on relative catch success. Detailed methods are described in Kavermann *et al.* (2003).

Analysis of data collected show that 39 mustelids were trapped on Moepuku Point between 2003 and 2009 (21 ferrets, 16 stoats, and two weasels). During the same period nine stoats and three weasels were trapped on King Billy Island, while four stoats, one weasel, and one possible ferret were caught on Quail Island (Fig. 3). Cats, hedgehogs and rats were also trapped on Moepuku Point (Table 1).

Table 1 Comparison of pest species trapped on Quail Island, stepping-stone King Billy Island and adjacent mainland site Moepuku Point between 2003 and 2009.

Pest Species	Moepuku Point	King Billy Island	Quail Island
Ferret	21	0	1#
Stoat	16	9	4
Weasel	2	3	1
Hedgehog	2	0	1*
Cat	7	0	0
Rat	11	8	0

#The animal was in a poor state for identification and we suspect it was misidentified as none have been trapped on King Billy Island.
*Evidence from tracking tunnels and scats suggest this animal was a survivor from the original Quail Island population and not a recent immigrant from the mainland.

Hedgehog eradication

Live trapping for hedgehogs was conducted for 11 consecutive nights in January 2000, using wire cage traps and wooden treadle traps baited with dog roll. Traps were set 150 m apart near tracks and fence lines and checked daily (see Thomsen *et al*. 2000 for detailed methods). Hedgehogs were also trapped in the Fenn traps set for mustelids.

Spot-lighting for hedgehogs took place on 13 occasions since 2000. Searchers wearing headlamps walked tracks between 17:30 hrs and midnight, collecting hedgehogs and recording their location. Live-captured hedgehogs were humanely euthanased and stomach contents stored for analysis (for details see Thomsen *et al*. 2000). The density of hedgehogs was estimated as 0.69/ha by dividing the total number caught by the size of Quail Island.

A total of 59 hedgehogs were removed from Quail Island between January 2000 and October 2003. The initial 11 nights of cage trapping removed 24 hedgehogs and represents an average of 2.2 captures/night. Spot-lighting over the first six nights of searching collected 23 hedgehogs or 3.8 captures/night. Fenn traps captured an additional 10 animals, including the last known hedgehog removed in 2003.

Rat eradication

In August 2002, the eradication of rats from Quail Island commenced with the establishment of 555 bait stations placed in a 40 m × 40 m grid over the island. A combination of yellow Pestoff bait stations (n = 351) and custom made Novacoil stations (450 mm lengths of 110 mm diameter black non-perforated plastic Novacoil drain pipe; n = 204) were used (see Kavermann *et al.* 2003 for further details). In December 2002, the dominant vegetation in a 20 m radius surrounding each bait station was recorded as grass, trees or scrubland, and this information was used to assess bait take in different habitats.

At the commencement of the operation, ten cereal Pestoff 20R rodent pellet baits (0.02 g/kg brodifacoum) were placed in each bait station. In the first seven days, stations were checked daily and bait replenished or increased to 20 pellets in cases where all bait had been removed. In the subsequent five weeks, all stations were checked every two days and bait replaced as required.

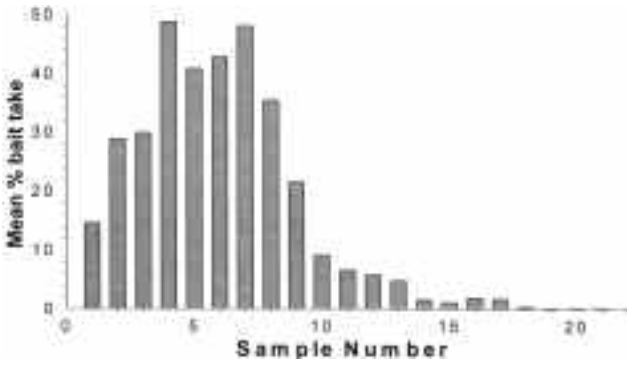

Fig. 4 Percentage bait take for all bait stations during the initial 21 samples (37 days).

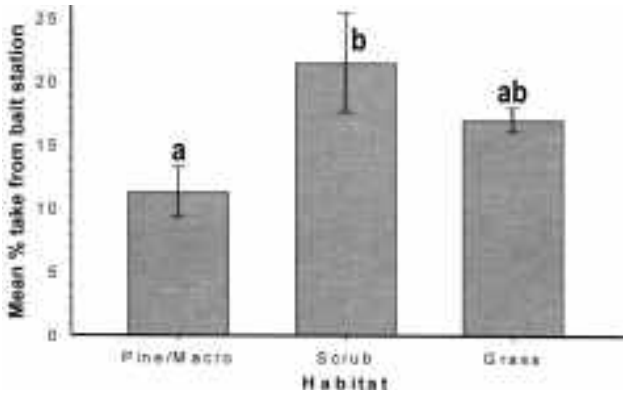

Fig. 5 Mean percent bait take (±SEM) in stations by rodents in three habitats on Quail Island. Differing letters above bars denote significance at 5% level of probability using LSD test.

In late September 2002, when bait take ceased, a single 20 g Talon 50 WB wax impregnated cereal 'egg' (0.05 g/kg brodifacoum) and five 20R Pestoff baits were placed in each station to overcome any possible aversions to the original baits. The higher concentration of poison in the new bait also meant that a smaller amount was required for target animals to consume a lethal dose. After one week the cereal 'egg' baits were wrapped in tin foil to minimise the effects of slugs (*Deroceras* spp.), insects and decomposition due to moisture and returned to each bait station for any remaining rodents.

Bait take was used to assess rodent presence and activity during the baiting operation. Preliminary eradication was considered achieved when bait take stopped. Detailed descriptions of bait take calculations for rodents during the operations were provided by Kavermann *et al.* (2003).

Overall, percentage bait take from Novacoil bait stations was significantly higher ($F_{1,418} = 16.83$, $P < 0.001$) than from the Pestoff bait stations for the entire poisoning operation. A steady increase in bait take occurred in the first four days of the operation, peaking at 49% at sample 4 (day 4) and again at 48% at sample 7 (days 8 and 9). This was followed by a steady decrease in bait take with minimal interference after sample 18 (days 30 and 31) (Fig. 4). Rats were considered eradicated at day 38.

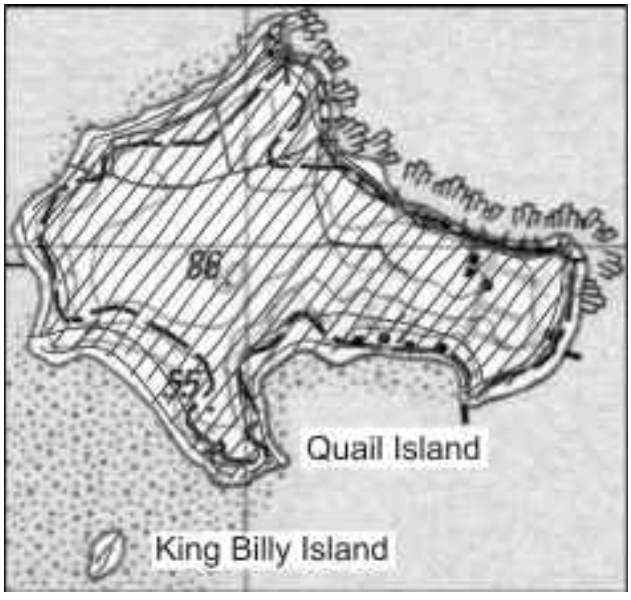

Fig. 6 GIS generated flight lines from first helicopter baiting on Quail Island and King Billy Island on 26 July 2009.

Percentage bait take on Quail Island was significantly ($F_{2,534} = 16.72$, $P < 0.001$) different between habitats. Pairwise comparisons of means (LSD test; $\alpha = 0.05$) indicated that bait take in scrubland was significantly higher than in mature pine (*Pinus* spp.) and macrocarpa (*Cupressus macrocarpa*) stands (Fig. 5).

Mouse eradication

Although rats were successfully eradicated using a bait station operation in 2002, mice were not. Subsequent aerial operations to eradicate mice were undertaken on Quail Island and King Billy Island on the 26 July and 6 August 2009. To ensure thorough bait coverage across cliff faces, the helicopter pilot baited the island by flying twice around the coast, and the then by flying in several northeast-southwest sweeps (Fig. 6). The second sowing (6 August 2009) was identical, except that flying was carried out in a northwest-southeast direction. The intended bait-sowing rate of 8 kg/ha was monitored on mown tracks using 50 m^2 transects. Where possible, tracks perpendicular to the flight line were used and included a selection of locations both coastal (six transects) and central (nine transects). The mean sowing rate around coastal areas was 8.2±0.8 kg/ha, while sowing rates in the island centre averaged only 3.2±0.3 kg/ha.

Pre- and post-eradication operation mouse populations were monitored following Gillies and Williams (2002), using 99 Black Trakka tracking tunnels (Connovation, Auckland Ltd) baited with peanut butter and placed in a 100 m grid over Quail Island. The tracking tunnels were placed out one week before the first drop, and repeated thereafter from one week after the first drop. Standard snap-back mouse traps baited with unheated popcorn and peanut butter were also placed in the centre of rat/mustelid trap boxes on King Billy Island and Quail Island as another monitoring tool. To determine whether subsequent mice found on Quail Island were new invaders or survivors of failed eradication, mouse tail tips were collected from the island prior to the poisoning and stored frozen in 100% ethanol as reference DNA for future molecular analysis (Dilks and Towns 2002; MacKay *et al*. 2007). Mouse activity was recorded on 83% of tracking cards one week before the first aerial poison drop but were eliminated a week after the last aerial poison drop. No signs of mice were recorded on either island for six months after the drop, until a mouse was caught in a trap box on King Billy Island on 23 February 2010.

DISCUSSION

Rabbits and cats

Only a few rabbits survived the initial Pindone poisoning operation, possibly going underground for a period of time (Brown 1999). The final few rabbits proved elusive and it was unexpectedly a Fenn trap set for mustelids that removed the final individual in 2006. The nine cats intercepted on Moepuku Point highlights the value of these traps for maintaining the integrity of Quail Island as a refuge for native species.

Mustelids

A large number of mustelids have been trapped on Moepuku Point, though few have made it to Quail Island. This demonstrates the importance of interception trapping on the mainland to reduce the threat of mammalian pests

invading the island. However, traps are still needed on Quail Island to kill those animals that may reach it. Furthermore, ongoing monitoring of capture success is vital for reviewing trapping strategies and maximising trapping success.

Hedgehogs

The eradication of hedgehogs from Quail Island is the first reported success of its kind achieved on a New Zealand island. At an estimated density of 0.69 hedgehogs/ha, Quail Island hedgehog habitation was very low compared to other studies which show as many as 1.1-2.5 hedgehogs/ha (Brockie 1974). Most (93%) of the 59 hedgehogs were removed from the grassland areas, indicating it may be a preferred habitat. Night searches were particularly successful at track intersections and close to the stock dam, the only open body of water on Quail Island. Hedgehogs appeared to prefer the mown tracks for ease of movement and feeding, and were observed by searchers to feed on invertebrates, particularly slugs and slaters (*Porcellio scaber*). Brockie (1990) proposed that hedgehog densities reflected invertebrate food availability, a finding supported by Bowie (unpublished) who found invertebrates to be more abundant in exotic grasslands compared with other habitats on Quail Island. Grasslands also provide a greater abundance of skinks (*Oligosoma* spp.), another known food source of hedgehogs (Moss and Sanders 2001) and found in the stomachs of specimens taken from Quail Island (Kavermann *et al*. 2003). The absence of hedgehog scats on tracks and lack of prints from tracking tunnels since the last trapped individual (27 October 2003) suggest that hedgehogs have been successfully eradicated from the island.

Rats

The eradication of rats in 2002 was another successful operation, although mice were not similarly eradicated. We had anticipated challenges in successfully eradicating rodents from Quail Island because of the thick exotic grasses and the chances of rodents encountering bait stations. We therefore used 40 m spacing between bait stations, which was closer than other successful island bait station eradication operations for rats (eg. 50 m spacing used by Taylor and Thomas 1993). The greater success of the Novacoil bait stations may have been due to their wider entrance, making them easier to locate and access by rodents. Novacoil stations entrances were also positioned at ground level and did not require animals to step up into them, unlike the Pestoff stations. The significantly lower bait take from the Pestoff bait stations (Kavermann *et al*. 2003) would support this hypothesis. Recent work by Spurr *et al*. (2007) supports the view that entrance size is important for rats. Based on our results, we recommend the use of Novacoil stations or other similar-sized bait stations to increase the probability of rodents encountering more bait. Novacoil bait stations were also cheaper, more robust and the material is readily available.

Mice

Several factors may have contributed to the failure to eradicate mice using the bait stations. First, the 40 m bait station spacing was likely too wide for mice, as they have smaller home ranges than rats (Ruscoe and Murphy 2005). As such, all mice were unlikely to encounter at least one bait station, which jeopardises a key component of eradication in that every individual must be put at risk (MacKay *et al*. 2007). In contrast, several successful mouse eradications from islands have used station grid spacing of 25 m (Thomas and Taylor 2002). While the 40 m spacing was the likely cause of the failure, other factors may also have contributed. For example, during their study on Hawea Island, Taylor and Thomas (1989) noticed that large male rats defended bait stations from smaller rats, a behaviour also likely to deter mice. This dominant behaviour observed by Taylor and Thomas (1989) may also help to explain the prolonged bait take on Quail Island when compared with similar eradication attempts on other islands. After the dominant animals succumb to poison, the less dominant individuals (both rats and mice) can access the bait stations. It appears this may be the case with Quail Island as bait take continued for 37 days.

The use of aerially applied baits for eradication attempts of rodents on islands has historically given the best rate of success, particularly where cliffs make it difficult to use alternative control strategies (Howald *et al*. 2007). Aerially applied brodifacoum is the most widely used poison for mice on islands. Although this has a record of successful eradications, the overall success rate of mouse eradications on islands is only 49% (MacKay *et al*. 2007). Bait coverage, particularly where extensive exotic grassland is present, seems to be critically important for success. The lower bait coverage in the interior of Quail Island (3.2 kg/ha) may have allowed mice to survive. Also, the mixture of thick exotic grasses offers ground cover for mice to move through and may prevent them from encountering baits. Furthermore, grasses provide a good seed source for mice, therefore individuals may not require any supplementary food source encountered in baits.

Unfortunately the mouse caught on King Billy Island and a mouse track recorded on Quail Island suggests mice may have reinvaded Quail Island from the mainland. For future management of mice it is essential to know whether they are survivors from the aerial eradication attempt or recent invaders. DNA collected from the mice will hopefully provide this answer.

KEY LESSONS

1. Interception of mustelids and rats on Moepuku Point and King Billy Island is helping to reduce the number of invaders reaching Quail Island.

2. Monitoring trap catch locations with well labelled traps and keeping thorough records is essential for managing efficient reinvasion strategies so that traps can be repositioned or concentrated, depending on relative catch success.

3. A mixture of eradication methods for hedgehogs (eg. cage trapping and spot-lighting on tracks) is useful to initially reduce numbers, but kill traps may be most successful at lower population densities. Mowing tracks in exotic grassland may also be a strategy to allow more effective spot-lighting.

4. We recommend using unheated popcorn as an alternative mouse bait, as peanut butter is often also eaten by invertebrates.

5. Bait stations with larger entrances, such the 110 mm Novacoil, have better bait take than bait stations with smaller entrances, particularly in thick exotic grasses.

6. A bait station grid spacing of 40 m achieved the goal for eradicating rats.

7. Given molecular advances, keeping DNA from pest species being eradicated will be important to distinguish between new invaders and survivors of failed eradications.

8. The use of GPS on helicopters does not guarantee correct bait sowing rates and deposition on the ground. Transects should be used on open areas such as wide tracks to check how much bait is present on the ground to confirm adequate bait application.

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