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# THE RISKS, COSTS AND BENEFITS OF USING BRODIFACOUM TO ERADICATE RATS FROM KAPITI ISLAND, NEW ZEALAND

**Summary:** In 1996 an eradication operation against two species of rats (*Rattus norvegicus* and *R. exulans* was conducted on Kapiti Island (1965 ha) and its small offshore islands. Trials with non-toxic baits had been carried out to help determine the risks to non-target species, and research was undertaken to collect baseline data for measuring the response of vegetation, invertebrates, reptiles and birds to the removal of rats. Talon 7-20 bait (containing 0.002% brodifacoum) was distributed over Kapiti Island in September and October by helicopter and by hand, while bait stations were used on the offshore islands. Impacts on birds and reef fish were investigated. Although there were non-target bird deaths as a result of the poisoning operation, post-eradication monitoring indicated that the toxin had no deleterious effect on breeding and most losses would be rapidly made up by recruitment of new individuals into the breeding population. There was no evidence that reef fish were negatively affected.

The successful removal of rats has apparently resulted in a significantly improved survival rate for stitchbirds (*Notiomystis cincta*) and saddlebacks (*Philesturnus carunculatus*). Benefits to other taxa are expected and will be documented as follow-up studies are completed.

**Keywords:** Rat eradication; non-target species; risk assessment; brodifacoum; poisoning impacts; monitoring techniques; benefits; Kapiti Island; birds; reef fish.

## Introduction

In 1996, the Department of Conservation undertook the largest rodent-eradication campaign ever attempted in New Zealand, the removal of Norway rat (*Rattus norvegicus*[1]) and Pacific rat (*R. exulans*) from Kapiti Island. The scale of the operation and the importance of Kapiti Island as one of the last major havens for several species made it essential that the risk to non-target species be assessed in fine detail. This paper presents information on trials undertaken to determine risk to, and the short-term effects of the operation on non-target species. The short-term responses of non-target species to rodent removal are also discussed.

Kapiti Island (1965 ha) is located in eastern Cook Strait, 5.2 km from the mainland of the North Island (Fig. 1). Oriented NE-SW it has very steep exposed slopes and cliffs on the western side rising to the 520 m summit, with more gentle slopes and sheltered catchments on the eastern side.

Most of the island is a nature reserve administered by the Department of Conservation under the Reserves Act 1977. Three offshore islands and 14.9 ha of land at the northern end are privately owned, and an additional 190 ha is administered by the Commissioner of Crown Lands under the Land Act 1948.

Kapiti Island has a history of considerable modification. Maori introduced the Pacific rat or kiore probably on or soon after their arrival, and Norway rats are presumed to have been introduced in the early 1800s. Cattle (*Bos taurus*) were also introduced about this time, and the island was farmed for more than a century, with over half of the island cleared and grassland maintained by regular fires. Sheep (*Ovis aries*), goats (*Capra hircus*), pigs (*Sus scrofa*), deer (*Axis axis* and *Dama dama*), cats (*Felis catus*) and brushtail possums (*Trichosurus vulpecula*) have also been present on the island.

Despite the extensive habitat modification, the potential value of Kapiti Island as a bird sanctuary was recognised early and in 1897 the Kapiti Island Public Reserve Act gave protection to the island. From 1906 the island had a caretaker, considerable plantings of various tree species were undertaken and the exotic animals were progressively removed (goats were eradicated in 1928, cats in 1935 and brushtail possums in 1986; Cowan, 1992). By 1990 the two rat species were the only introduced mammals remaining.

[1] Nomenclature for mammals follows King (1990) and for birds follows Turbott (1990).

The most widely reported damage by rats is predation. Rats have been observed eating eggs and chicks of a range of birds in New Zealand and elsewhere (Atkinson, 1985). Rats also eat lizards, invertebrates and a wide range of plant material (flowers, fruit and seedlings). They can influence the abundance and distribution of plants, particularly of those species that they prefer (Campbell, 1978).

Research on Kapiti Island has documented the effects of rats on populations of kaka (*Nestor meridionalis*); Moorhouse, 1991) and saddleback (*Philesturnus carunculatus*); Lovegrove, 1992). Up to 50% of kaka nests within 1 m of the ground were preyed on by rats (Moorhouse, 1991). While survival of saddlebacks on Kapiti Island improved with the use of artificial nest and roost sites, population modelling indicated that recruitment was still insufficient to replace losses, mostly due to rat predation, and that the population was likely to decline gradually to extinction over a period of about 60-70 years (Lovegrove, 1992). Potential benefits of rat removal from Kapiti Island included improved survival and viability of these species and other threatened species present on the island, restoration of more natural ecosystem processes (e.g., regeneration, competition and predation), and increased potential for introductions of other native species, unable to co-exist with rats, that are threatened with extinction elsewhere.

Aerial poisoning operations to eradicate rodents (e.g., on Tiritiri Matangi, Red Mercury and Stanley Islands) have indicated that, although the lethal dose for most birds is unknown, the effect of brodifacoum on many native birds is minimal (Robertson, Colbourne and Nieuwland, 1993; Towns, McFadden and Lovegrove, 1993). However, a ground-based operation on Ulva Island (L. Chadderton, *pers. comm.* Department of Conservation, Invercargill) and an aerial operation in the Chetwode Islands (Brown, 1997a) indicated that the weka (*Gallirallus australis*) is at risk from brodifacoum.

Following a study to determine the feasibility and likely effects of undertaking a rodent eradication operation on Kapiti Island, the eradication programme was carried out in 1996. Mitigation measures to minimise effects on fauna at risk were implemented and included the capture and holding in captivity or release elsewhere of 243 weka, and transfer of 66 New Zealand robins (*Petroica australis*) to nearby Mana Island. The eradication operation entailed distribution of green-dyed 16-mm diameter Talon 7-20 pollard baits (cereal-based pellets containing 0.002% brodifacoum manufactured by Animal Control Products Ltd (ACP), Wanganui) over Kapiti Island and rock stacks by helicopter and by hand, and a bait station operation on each of the three small (<2 ha) offshore islands. Two applications of poison bait were made on Kapiti Island, the first on 19-20 September, and the second on 15 October 1996. The total amount of bait used in the first application was 20 500 kg. At an average aerial discharge rate of 9.16 kg $ha^{-1}$, the bait density, taking into account slope, averaged 9.0 kg $ha^{-1}$. The bait density for the second application averaged 5.1 kg $ha^{-1}$, with a total of 11 400 kg distributed.

Monitoring programmes were implemented to measure the effects of the poison on non-target species and the response of birds, lizards, invertebrates and vegetation to rodent removal. A rodent survey undertaken in 1998 confirmed that the eradication operation was successful.

# Methods

## Risk assessment

### *Aerial distribution trials using non-toxic baits*

To assess the effects of an aerial operation on non-target species, two trials were undertaken on Kapiti Island in 1993 in two adjacent study areas of *c.*150 ha each using non-toxic Wanganui # 7 baits (cereal-based pellets manufactured by ACP, Wanganui). The first trial began on 8 March, with aerial distribution of 16-mm diameter baits surface coated with red Rhodamine B biotracer. The second trial began on 31 July with the aerial distribution of 12-mm diameter baits impregnated with Pyranine 120 biotracer and surface coated with green dye. Both Rhodamine B and Pyranine 120 are flourescent under ultraviolet light, even when present in small quantities. Bait consumption by non-target species was assessed by checking mouth-linings of birds caught, and by viewing their faeces under ultraviolet light. Bait was distributed in both trials at a target rate of 5 kg $ha^{-1}$ in one area, and 10 kg $ha^{-1}$ in the other, to determine whether or not there were any differences in bait take by non-target species at the different bait densities. Transect surveys of actual bait density indicated that many of the smaller 12-mm baits got caught in the canopy and did not reach the ground. Steeper slopes received less bait due to their larger surface area exposed to the same nominal distribution rate.

The first trial assessed the risk of bait take by weka and little spotted kiwi (*Apteryx owenii*) by catching a sample of birds from each study area after bait distribution, and examining their faeces for biotracer to determine whether or not they had eaten the bait. The second trial assessed the risk of bait take by New Zealand robins and saddlebacks in addition to weka and little spotted kiwi. Weka were caught with hand-nets and in baited cage-traps; kiwi were caught by tracking radio-tagged birds to their day-time roosts and by hand-capture at night; robins were caught with clap-nets baited with mealworms (*Tenebrio molitor* L.); and saddlebacks were caught with mist-nets. Sample sizes for all four species are given in Table 1. Faeces from supplementary feeding stations located within the study area and visited by up to 50 different kaka were also examined.

***Aquarium and bait disintegration trials***

There is no known information on the toxicity of brodifacoum to marine fish. The fate of any baits dropped into the sea was assessed to determine whether or not there was likely to be any consumption by fish. Non-toxic baits were distributed into the sea about 30 m offshore at 10 m depth and monitored by a diver (P. de Monchy *pers. comm.*). Fish that approached the baits were observed until the baits had disintegrated.

The risk to three marine fish species (blue cod *Parapercis colias* (Bloch and Schneider), spotty *Notolabrus celidotus* (Bloch and Schneider), and variable triplefin *Forsterygion varium* (Bloch and Schneider)) was assessed by undertaking aquarium trials. Live fish were caught and held in experimental fish tanks at the National Institute of Water and Atmospheric Research's (NIWA) Mahanga Bay laboratory for 24 h without food, before being exposed to baits. Fish were held solitarily (15 spotties, 12 triplefins, 9 blue cod) or in groups of 5 (30 spotties) or 4 (24 triplefins). Fish were exposed to baits (either toxic or non-toxic) for one hour before being transferred to clean communal holding tanks for 23-31 days. Solitary fish were exposed to a single bait while groups of fish were exposed to three baits. Fish from different treatments were kept separate after the feeding trial and maintained by daily feeding with green-lipped mussels (*Perna canalicus* (Gmelin)).The spotty experiment was terminated after 23 days when the water supply to their tanks was accidentally turned off and all remaining fish died. The other experiments were terminated after 30 days (blue cod) and 31 days (triplefin) when the fish were anaesthetised and killed. All fish were examined internally for signs of brodifacoum poisoning and liver samples from 15 fish were collected for brodifacoum analysis.

## Assessment of the effects of the poisoning operations on non-target organisms

***Call counts of nocturnal species***

Counts of little spotted kiwi, weka and morepork (*Ninox novaeseelandiae*) calls were collected from four sites on Kapiti Island before and after the poisoning operations to determine whether or not there were any detectable changes in call rates.The sites monitored were selected as part of a national kiwi monitoring programme (Waiorua Valley, Rangatira Helipad, Trig/Wilkinson Junction and Seismometer Hut; see Fig. 1 for locations). The weka and morepork counts were carried out at the same time as the kiwi counts. All kiwi, weka and morepork calls heard in the first two hours after sunset were counted, and counts were repeated for at least six nights per site between January and April. No attempt was made to obtain baseline counts of calls of weka remaining in the wild following the capture and removal of 243 birds in July 1996 and before the poisoning operations in September-October 1996. Changes in call rates at the same sites at the same time of year before and after the poison drops were compared using paired Student's *t*-tests.

***Five-minute counts of diurnal forest birds***

To determine whether or not the rat eradication operation had any adverse effect on conspicuousness of diurnal forest birds, 5-minute bird counts were conducted by members of the Ornithological Society of New Zealand (OSNZ) and Department of Conservation staff. Counts were conducted before

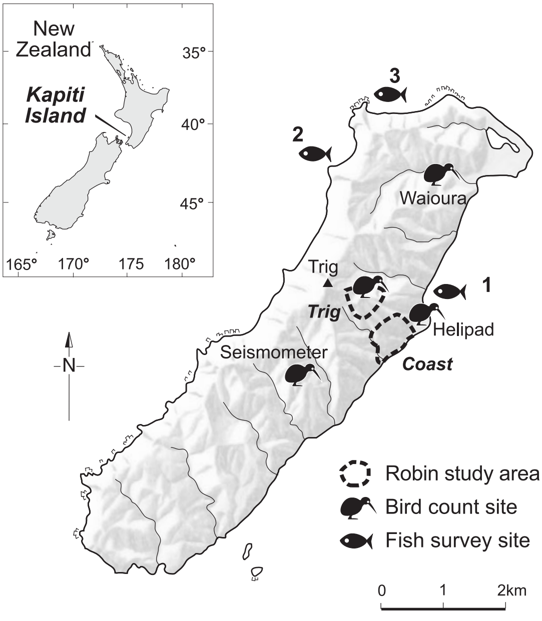


Figure 1: *Map of Kapiti Island, with locations of study areas of New Zealand robins, nocturnal bird count sites and marine fish survey sites shown.*

the poisoning operations on 6-7 July 1996, and afterwards on 25-28 October 1996 and 18-19 January 1997, to allow comparisons with counts undertaken in July, October and January between July 1991 and January 1994 by members of OSNZ. During each count session 256 standard 5-minute counts (Dawson and Bull, 1975) were conducted at 64 stations located on six tracks traversing all the main forest types on Kapiti Island. All birds seen and heard during each 5 minutes were identified and counted, with separate tallies kept for species seen or heard. The proportion of birds heard against those seen in 1996/97 was compared with previous years to investigate the possibility that a decline in numbers following poisoning might have led to an increase in call rates, for example to attract new mates or to establish new territorial boundaries.

Changes in conspicuousness, and the proportion of each species heard versus seen for diurnal forest birds at the same time of the year before and after the poison drop were compared using $\chi^2$ tests. Analyses are presented for the 11 bird species recorded most frequently; these were (in descending order of conspicuousness in the 5-minute counts): whitehead (*Mohoua albicilla*), bellbird (*Anthornis melanura*), tui (*Prosthemadera novaeseelandiae*), New Zealand robin, kaka, red-crowned parakeet (*Cyanoramphus novaezelandiae*), New Zealand fantail (*Rhipidura fuliginosa*), New Zealand pigeon (*Hemiphaga novaeseelandiae*), New Zealand tomtit (*Petroica macrocephala*), silvereye (*Zosterops lateralis*), weka, saddleback, and blackbird (*Turdus merula*).

### *Radiotelemetry studies*

To determine the actual effect of the poisoning operations on kaka and kokako, a sample of each population had transmitters attached prior to the operation so that they could be monitored during and after the poisoning.

Twenty kaka fitted with mortality transmitters were monitored after the first toxic operation and for at least 12 weeks following the second toxic drop. When any dead bird was located, the cause of death was determined where possible. Three kokako (*Callaeas cinerea*) released on Kapiti Island early in 1996 still had functioning transmitters at the time of the poisoning operation, and these birds were regularly monitored during and after the poisoning operation. Results of a telemetry study on little spotted kiwi will be reported elsewhere.

### *Surveys of banded birds*

Searches for banded non-radio-tagged kokako were undertaken before and after the poisoning operation using standard survey methodology - birds were located at dawn by listening for their territorial calls and their identity confirmed by sight if possible. Other, usually non-territorial, birds were surveyed using taped calls played at regular intervals to evoke a response and facilitate the identification of the bird(s) concerned.

Supplementary feeders for stitchbirds (*Notiomystis cincta*) were installed from July 1996 and regularly checked to determine the identity of birds using these feeders before and after the poisoning operations.

The survival and breeding of New Zealand robins on Kapiti Island was monitored in two study areas: coastal forest just south of Rangatira, and mid-altitude forest east of the trig station at Tuteremoana (Fig. 1). Robins within both these areas were caught and individually colour banded, and survival and breeding success were monitored before and after the poisoning operation.

### *Marine fish surveys*

Attempts to quantify the impacts of the poisoning operations on marine fish were complicated by the low densities of most fish species at the three study sites selected within Kapiti Marine Reserve (Fig. 1). A power analysis of results from a previous fish survey (C.N. Battershill *et al., unpubl. data;* NIWA, Wellington, N.Z.) indicated that only spotties were sufficiently abundant to detect a change in density of 50% or more if 15 transects were undertaken at each site. Spotties are known to scavenge on a wide variety of food types (Ayling and Cox, 1982) and were expected to feed on baits if any fell into the sea. Counts were undertaken by the same diver within 25 m x 2 m x 2 m tape transects, with 15 transects per site for the first survey, and 16 per site for subsequent surveys. Surveys were undertaken on 16 July (Site 1) and 19 September (Sites 1-3) (before the poisoning operation) and compared with data collected at the three sites after the poisoning operations on 6 December and 16 December 1996 (R.G. Cole and R.J. Singleton, *unpubl. data*; NIWA, Nelson, N.Z.).

## Short term benefits of rat eradication

### *Stitchbird monitoring*

Stitchbirds were monitored on Kapiti Island as part of a PhD study between late 1991 and early 1994 (Castro, 1995). Since then a monitoring regime has been implemented as part of a management programme involving supplementary feeding. As many juveniles as possible have been individually banded each year to maintain a banded population for on-going monitoring. Survival and breeding outcomes were determined by identifying birds visiting the supplementary feeders, and by locating nests and recording their fate.

***Saddleback monitoring***

Saddlebacks were monitored on Kapiti Island as part of a release programme and PhD study in the 1980s and early 1990s (Lovegrove, 1992). Two surveys were carried out after the eradication operation to assess numbers of adult saddlebacks surviving the operation and subsequent survival of young. The surveys involved searching all areas where saddlebacks had previously been found. Birds were located by listening for song, particularly in the early morning, and playing back taped song to elicit responses. One hour was spent with single birds to confirm their status.

***New Zealand robin monitoring***

The survival and breeding success of robins before and after rat eradication was determined by monitoring banded birds in the two study areas described earlier.

# Results

## Risk assessment

***Aerial trials***

The majority of weka (70%) and robins (56%) monitored, plus three saddleback (27%) and two little spotted kiwi (7%) took the non-toxic bait during the aerial trials (Table 1). Only a few flecks of biotracer were found in kaka faeces at supplementary feeders used by up to 50 kaka after both aerial trials, indicating that most kaka did not eat the bait.

***Aquarium and bait disintegration trials***

The non-toxic baits distributed in the sea disintegrated within 15 minutes. Assuming that accidental discharges were likely to occur only in the coastal fringe, it seemed unlikely that baits would withstand wave action and remain intact for more than a few minutes. Three species of fish were seen to eat non-toxic baits in the sea: spotties, banded wrasse (*Notolabrus fucicola* Richardson) and unidentified triplefins (*Fosterygion* sp.) (P. de Monchy *pers. comm.*). No blue cod were present at the study site during this trial.

None of the three species of fish tested in the aquarium feeding trials showed much interest in the pollard baits (Table 2), but they all readily consumed mussel flesh immediately after the trials. Although 6 of 24 (25%) of the triplefins exposed to toxic baits died, none was observed to eat the bait and no brodifacoum was detected in livers of the 5 triplefins analysed. Six spotties ate toxic bait, but only one of them died of brodifacoum poisoning. Two other spotties that showed clinical signs of brodifacoum poisoning after death were not seen to eat toxic baits

Table 1: *Percentage of birds showing positive signs of bait consumption relative to average estimated density of non-toxic baits and bait colour. L.s. kiwi = little spotted kiwi. Sample sizes in parentheses.*

| | Species | | | |
|---|---|---|---|---|
| Bait colour & density | Weka | L.s. kiwi | N.Z. robin | Saddleback |
| Red, 5.4 kg $ha^{-1}$ | 70 (*n* = 10) | 10 (*n* = 10) | - | - |
| Red, 11.6 kg $ha^{-1}$ | 80 (*n* = 10) | 0 (*n* = 4) | - | - |
| Green, 2.9 kg $ha^{-1}$ | 100 (*n* = 2) | 0 (*n* = 9) | 60 (*n* = 20) | 33 (*n* = 6) |
| Green, 5.9 kg $ha^{-1}$ | 50 (*n* = 8) | 17 (*n* = 6) | 50 (*n* = 14) | 20 (*n* = 5) |
| Total | 70 (*n* = 30) | 7 (n = 29) | 56 (*n* = 34) | 27 (*n* = 11) |

Table 2: *Summary of aquarium feeding trials. "No. poisoned" are the number of fish that showed clinical signs of brodifacoum poisoning and had brodifacoum residue in their livers. V. triplefin = variable triplefin.*

| | | Fish species | | |
|---|---|---|---|---|
| | | V. triplefin | Spotty | Blue cod |
| | Duration of trial, days | 31 | 23 | 30 |
| Non-toxic bait | No. fish exposed | 12 | 15 | 3 |
| | No. that died | 0 | 1 | 1 |
| | No. seen to eat bait | 1 | 1 | 0 |
| | No. poisoned | 0 | 0 | 0 |
| Toxic bait | No. fish exposed | 24 | 30 | 6 |
| | No. that died | 6 | 2 | 1 |
| | No. seen to eat bait | 0 | 6 | 0 |
| | No. poisoned | 0 | 2 | 1 |

and are thought to have absorbed the toxin through their skin or gills, an unlikely outcome in the sea where toxin would be quickly and considerably diluted.

The results indicated that populations of three of the commonest fish species around Kapiti Island were unlikely to be significantly affected by the poisoning operations.

## Effects of the poisoning operations on non-target organisms

### *Call counts of nocturnal species*

There was no significant difference in little spotted kiwi call rates following the poisoning operation. The mean call rate in 1994 - 1996 was 12.4 calls $h^{-1}$ (155 h) compared with a mean call rate in 1997 of 13.7 calls $h^{-1}$ (54 h) (paired *t*-test, $P$=0.27) (Table 3a).

Mean weka call rates dropped from 12.8 calls $h^{-1}$ to 2.3 calls $h^{-1}$ in 1997 (paired *t*-test, $P$=0.05) (Table 3b). This indicated that weka call rates were substantially affected by the weka removal and/or the poisoning operation, but because no monitoring was done in the period between the removal and the poisoning it is not possible to determine the relative importance of these two effects. However, no weka had been released from captivity before the monitoring began in 1997, and these results showed that some weka survived the poisoning operation. Before the call counts were completed, several weka were released in two areas (Waiorua and Helipad) and the call rates in these areas showed a marked increase (Table 3b).

Mean morepork call rates dropped from 15.6 calls $h^{-1}$ (68 h) before the poisoning operation, to 11.9 calls $h^{-1}$ (54 h) (paired t-test, $P$=0.57) after the operation (Table 3c). One dead morepork was found following the second poison drop and brodifacoum in the liver (0.8 mg $kg^{-1}$) confirmed a necropsy examination suggesting brodifacoum poisoning as the cause of death.

### *Five-minute counts of diurnal forest birds*

Counts of birds in July 1996 before the poisoning operations were similar to those recorded in July 1991-93 (Table 4a), with the exception of tui, New Zealand pigeon and kaka, which were all recorded significantly less often in 1996. The October 1996 counts were conducted 36-39 days after the first poisoning operation, and 10-13 days after the second. The only species that had declined significantly in conspicuousness compared to October 1991-93 was weka (none recorded during 5-minute counts in October 1996; Table 4b). Five species were significantly more conspicuous in October 1996 compared to previous years: kaka,

Table 3: *Average number of nocturnal bird calls heard at four sites on Kapiti Island, expressed as calls $h^{-1}$ (total no. hours listened). The 1997 counts were undertaken 3-6 months after the poisoning operations.*

| Species, location | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|
| **A. Little spotted kiwi** | | | | |
| Waiorua | 12.5 (12) | 7.3 (12) | 13.6 (14) | 11.6 (12) |
| Helipad | 6.7 (12) | 10.0 (14) | 6.3 (12) | 10.9 (14) |
| Junction | 9.4 (14) | 8.8 (13) | 8.5 (14) | 8.3 (14) |
| Seismometer | 23.2 (12) | 23.3 (13) | 19.6 (13) | 23.6 (14) |
| Total | 12.8 (50) | 12.4 (52) | 12.1 (53) | 13.7 (54) |
| **B. Weka** | | | | |
| Waiorua | - | 17.5 (8) | 9.4 (12) | 0.5 (8) / 5.8 (4)[1] |
| Helipad | - | 10.0 (8) | 9.3 (12) | 3.6 (10) / 9.5 (4)[2] |
| Junction | - | 7.0 (2) | 6.0 (12) | 1.1 (14) |
| Seismometer | - | 7.8 (4) | 29.3 (12) | 3.6 (14) |
| Total | - | 11.4 (22) | 13.5 (48) | 2.3 (46)[3] |
| **C. Morepork** | | | | |
| Waiorua | - | 18.4 (8) | 24.3 (12) | 6.6 (12) |
| Helipad | - | 14.7 (6) | 17.0 (12) | 21.0 (14) |
| Junction | - | 1.5 (2) | 3.0 (12) | 7.5 (14) |
| Seismometer | - | 7.5 (4) | 21.7 (12) | 11.7 (14) |
| Total | - | 13.4 (20) | 16.5 (48) | 11.9 (54) |

[1] 1997 weka counts = separate averages of counts pre/post release of 2 weka (remaining in area)
[2] 1997 weka counts = separate averages of counts pre/post release of 8 weka (remaining in area)
[3]Total 1997 weka count excludes 8 hours of counts undertaken post release of 10 weka at two of the sites.

robin, red-crowned parakeet, tomtit and New Zealand pigeon (Table 4b). These latter five species had returned to baseline levels of conspicuousness by January 1997, when no species was recorded more often than in 1992-94, and only weka and whitehead were recorded significantly less often (Table 4c).

Comparisons of the proportion of birds heard to seen for each species in 1996 revealed some more subtle apparent effects of the poisoning operations than shown by the total counts (seen + heard) alone. Call rates for most species in July 1996 (expressed as percentage of birds recorded that were heard but not seen; Table 4a) were comparable with 1991-93 baseline counts. The only exception was tui, which were relatively more vocal in July 1996, although less conspicuous overall. However, by October 1996, four species were relatively more vocal than in previous years: kaka, tui, robin and whitehead (Table 4b). Kaka and robin were both far more conspicuous in October 1996 than in previous years (78.4% and 67.9% increases, respectively; Table 4b); the highly significant increase in "percent heard" for both these species clearly shows that their increased conspicuousness following the poisoning operations was due to an increase in vocalising rather than any population increase *per se*. Tui maintained their pre-poisoning pattern of being 11-12% relatively more vocal in 1996 than in previous years (Table 4a, b), while the increased vocalisation rate of whiteheads in October 1996 was only marginally significant ($P$= 0.041; Table 4b).

By January 1997, none of the species recorded in the 5-minute bird counts had call rates that deviated significantly from the baselines established in January 1992-94 (Table 4c; though note that only a single weka was recorded during the January 1997 counts).

In summary, the 5-minute bird counts revealed that the poisoning operations, combined with the capture of birds for translocation and temporary holding in captivity, had a catastrophic impact on the weka population on Kapiti Island. Impacts on other species were more subtle, but the poisoning operations apparently caused increased call rates in kaka and robin. These effects were either minor or were masked by successful breeding in 1996-97, as by January 1997 only weka and whitehead were recorded as being less conspicuous than previously, and no species was relatively more vocal. The results of these 5-minute bird counts will be presented more fully elsewhere.

***Radiotelemetry studies***

Twenty-seven kaka were captured between May and September 1996; 20 of these were carrying transmitters and were known to be alive at the time of the first poison drop.

All 20 kaka were alive at the time of the second drop but four birds were found dead on 25, 26, and 29 October and 10 December 1996 (H. Aikman, *unpubl. data*; Department of Conservation, Wellington, N.Z.). The livers of the three birds found in October were analysed for brodifacoum and confirmed the necropsy assessment that brodifacoum poisoning was likely. These kaka had 4.1, 3.3 and 1.2 mg $kg^{-1}$ of brodifacoum detected in their livers and those with the highest levels of brodifacoum died first. The fourth bird that died (an adult female) was too decomposed to be assessed for brodifacoum poisoning. It was last recorded as alive on 14 November 1996 but was not located until December. The cause of death of this bird is unknown. All 16 remaining transmittered kaka were known to be alive at least 3 months after the final drop. At least 11 of these birds were alive in 1997, when caught to have transmitters removed (three in March, six in July and two in August 1997).

More adult kaka died (1/6 possibly 2/6) than juveniles (2/14) but there is no apparent correlation of kaka deaths with sex, with 1/8 (possibly 2/8) females and 2/12 males monitored succumbing to brodifacoum poisoning.

All three kokako with transmitters were located alive at least 14 weeks after the second aerial operation, although one bird was detected by radiotelemetry only in late January 1997. The other two birds have been seen as recently as November 1997 and February 1998 (T. Thurley, *unpubl. data*; Nelson, N.Z.).

***Surveys of banded birds***

Ten non-radiotagged kokako were identified in the month before the first poison drop. However, two of these (a territorial pair), were not relocated after 31 August 1996, 19 days before the first drop, and so their status at the time of the drop was uncertain and therefore they were excluded from the assessment. Two birds were alive on 16 September 1996, but have not been seen since and so are presumed to have been accidentally poisoned. Six birds were confirmed alive following the second poison drop and an additional two birds have been located in surveys since then. This brought the known survivors, including the radiotagged birds, to 11/13 birds (or 85% survival). All five captive-bred birds known to have been exposed to the poisoning operation survived, so their origin and previous exposure to unnatural food items did not appear to increase their risk of accidental poisoning.

Table 4: *Summary of 5-minute bird counts undertaken before and after the Kapiti Island rat poisoning operations in September/October 1996 compared to baseline counts undertaken between July 1991 and January 1994. "% difference from 1991-93" (or 1992-94) shows whether (and how much) the 1996/97 total count fell outside the range recorded in the same month in 1991-94. "% heard in 1996"(or 1997) gives the proportion of each species that was heard but not seen during the counts. "D in % heard from 1991-93" (or 1992-94) shows whether (and how much) the 1996/97 percent heard fell outside the range recorded in the same month in 1991-94.*

| A. July | Total recorded in 1996 | % difference from 1991-93 | $X^2$ | P | % heard in 1996 | D in % heard from 1991-93 | $X^2$ | P |
|---|---|---|---|---|---|---|---|---|
| Weka | 97 | - | - | n.s. | - | - | - | - |
| New Zealand pigeon | 46 | - 54.9 | 30.75 | < 0.001 | 45.6 | - 9.8 | 1.78 | n.s. |
| Kaka | 88 | - 29.6 | 10.95 | 0.001 | 87.5 | - | - | n.s. |
| Red-crowned parakeet | 122 | - 15.3 | 3.36 | n.s. | 89.3 | - | - | n.s. |
| Blackbird | 8 | - 11.1 | 0.11 | n.s. | 75.0 | - 1.9 | 0.03 | n.s. |
| Whitehead | 768 | - | - | n.s. | 70.4 | - | - | n.s. |
| New Zealand fantail | 104 | - | - | n.s. | 69.2 | - | - | n.s. |
| New Zealand tomtit | 29 | - 12.1 | 0.48 | n.s. | 83.3 | - | - | n.s. |
| New Zealand robin | 148 | - | - | n.s. | 68.2 | - | - | n.s. |
| Silvereye | 111 | - | - | n.s. | 68.5 | - | - | n.s. |
| Bellbird | 549 | - | - | n.s. | 92.2 | + 2.0 | 2.32 | n.s. |
| Tui | 313 | - 29.8 | 39.66 | < 0.001 | 86.6 | + 11.7 | 22.65 | < 0.001 |
| Saddleback | 10 | - | - | n.s. | 90.0 | - | - | n.s. |

| B. October | Total recorded in 1996 | % difference from 1991-93 | $X^2$ | P | % heard in 1996 | D in % heard from 1991-93 | $X^2$ | P |
|---|---|---|---|---|---|---|---|---|
| Weka | 0 | - 100.0 | 80.0 | < 0.001 | - | - | - | - |
| New Zealand pigeon | 115 | + 23.7 | 5.20 | 0.023 | 59.1 | - | - | n.s. |
| Kaka | 248 | + 78.4 | 85.47 | < 0.001 | 93.9 | + 14.7 | 32.65 | < 0.001 |
| Red-crowned parakeet | 140 | + 70.7 | 41.02 | < 0.001 | 90.1 | - | - | n.s. |
| Blackbird | 26 | + 8.3 | 0.17 | n.s. | 92.3 | + 1.4 | 0.07 | n.s. |
| Whitehead | 1119 | - | - | n.s. | 87.4 | + 2.2 | 4.19 | 0.041 |
| New Zealand fantail | 71 | - 1.4 | 0.01 | n.s. | 71.8 | - | - | n.s. |
| New Zealand tomtit | 130 | + 28.7 | 8.33 | 0.004 | 93.8 | + 2.7 | 1.23 | n.s. |
| New Zealand robin | 262 | + 67.9 | 72.03 | <0.001 | 80.1 | + 9.3 | 11.16 | 0.001 |
| Silvereye | 41 | - | - | n.s. | 78.0 | + 3.5 | 0.25 | n.s. |
| Bellbird | 573 | + 3.6 | 0.72 | n.s. | 94.8 | + 2.2 | 3.81 | n.s. |
| Tui | 284 | - | - | n.s. | 86.3 | + 11.4 | 19.43 | < 0.001 |
| Saddleback | 25 | - | - | n.s. | 92.0 | - | - | n.s. |

| C. January | Total recorded in 1997 | % difference from 1992-94 | $X^2$ | P | % heard in 1997 | D in % heard from 1992-94 | $X^2$ | P |
|---|---|---|---|---|---|---|---|---|
| Weka | 1 | - 98.6 | 72.01 | < 0.001 | - | - | - | - |
| New Zealand pigeon | 73 | - 5.19 | 0.21 | n.s. | 57.5 | - | - | n.s. |
| Kaka | 162 | - | - | n.s. | 94.4 | + 3.6 | 2.53 | n.s. |
| Red-crowned parakeet | 135 | - | - | n.s. | 89.6 | - | - | n.s. |
| Blackbird | 8 | - | - | n.s. | 100 | - | - | n.s. |
| Whitehead | 871 | - 13.07 | 17.13 | < 0.001 | 90.0 | - | - | n.s. |
| New Zealand fantail | 112 | + 15.5 | 2.31 | n.s. | 60.7 | - | - | n.s. |
| New Zealand tomtit | 65 | + 8.3 | 0.41 | n.s. | 75.4 | - | - | n.s. |
| New Zealand robin | 143 | - | - | n.s. | 68.5 | + 2.4 | 0.38 | n.s. |
| Silvereye | 25 | - | - | n.s. | 64.0 | - 4.0 | 0.18 | n.s. |
| Bellbird | 400 | + 4.7 | 0.84 | n.s. | 90.5 | - | - | n.s. |
| Tui | 323 | - 8.0 | 2.23 | n.s. | 54.5 | - | - | n.s. |
| Saddleback | 12 | - 14.29 | 0.29 | n.s. | 100 | + 6.3 | 0.80 | n.s. |

Of 16 adult stitchbirds known to be alive at the time of the toxic operation, one female disappeared shortly after the first drop (she was last seen 28 September 1996) and a male disappeared in early December (Table 5). This survival rate is not significantly different from that recorded during 1992-1995 ($\chi^2$= 1.99, $P$= 0.16). Three juveniles known to be alive at the time of the operation all survived until the end of December 1996. One additional juvenile was alive at the beginning of September 1996, but was not seen after 3 September, prior to the operation, and so its status at the time of the poisoning operation is unknown. The juvenile survival rate (75%) for the period September to December 1996 was identical to the mean survival rate of the previous three years (Table 5).

New Zealand robin survival data in the presence of toxic baits (1996) and in the absence of toxic baits (1994 to 1995) are given in Table 6. Survival rate in the Coast study area after poisoning was not significantly different from the mean for 1994 and 1995 ($\chi^2$= 1.33, $P$=0.25). Survival rate in the Trig study area was significantly lower than the mean for 1994 and 1995 ($\chi^2$= 55.77, $P$<0.001) and significantly worse than in the coastal area in 1996 ($\chi^2$= 35.3, $P$<0.001).

The majority of robins that disappeared following the poisoning operation disappeared after the first drop: 90% in the Coast study area (n=10) and 94% in the Trig study area (n=33). Prior to the poisoning operation it had been observed that robins along public tracks were more willing to sample new foods (such as cheese) than robins away from these areas. The majority of robins in the Trig study area were close to public tracks, whereas about a third of robins in the coastal area were located well away from these influences. To try to determine why there should be such a difference in survival between the two study areas, the survival of coast birds relative to exposure to public tracks was examined. Sixty percent of robins adjacent to tracks (n=25) survived until the end of December, more than two months after the second drop, compared with 100% of robins away from tracks (n=13).

Table 5: *Survival of adult and juvenile stitchbirds on Kapiti Island during the period September - December. Toxic baits were present in 1996.The table excludes unbanded birds and birds transferred in the same year.*

| | Adults alive | | Juveniles alive | |
|---|---|---|---|---|
| Year | Sept. | Dec. | Sept. | Dec. |
| 1992 | 19 | 13 | 5 | 3 |
| 1993 | 26 | 22 | 1 | 1 |
| 1994 | 20 | 16 | - | - |
| 1995 | 18 | 15 | 2 | 2 |
| 1996 | 16 | 14 | 4 | 3 |
| 1997 | 17 | 16 | 7 | 7 |

Table 6: S*urvival of New Zealand robins in the Coast and Trig Track study areas on Kapiti Island during the period September to December in years with (1996), and without the presence of toxic baits.*

| | Study areas | | | |
|---|---|---|---|---|
| | No. alive on Coast | | No. alive on Trig Track | |
| Year | Sept. | Dec. | Sept. | Dec. |
| 1994 | 24 | 20 | 37 | 37 |
| 1995 | 34 | 27 | 46 | 43 |
| 1996 | 38 | 28 | 50 | 17 |

***Marine fish surveys***

The surveys carried out on 16 July and 19 September 1996 were undertaken before fish could have been affected by the poisoning operations, while the last two surveys were carried out 1-2 months after the poisoning operations were completed. At Site 1 spotty densities declined over the first 3 surveys and then increased in the fourth survey to levels greater than those initially recorded (Table 7). At Site 2 spotty densities remained fairly constant throughout the three surveys. At Site 3 spotty density decreased from the second to the third survey and then increased in the fourth survey (Table 7). The surveys provided no evidence that spotty densities were affected by the poisoning operations. At the one site where spotty densities did apparently decline (Site 1), this decline was already occurring before the first poisoning operation. Furthermore, the divers noted no dead or moribund organisms, nor changes to benthic assemblages suggestive of poison entering the food webs. Incidental observations of other fish species did not suggest any alterations in densities of those species either (R.G. Cole and R.J. Singleton, NIWA, *unpubl. data*).

Table 7: *Densities of spotties (fish 100 $m^{-3}$ ) recorded at three sites in Kapiti Marine Reserve during surveys before and after poisoning operations in September and October 1996. Results of 15-16 transects per site are given as mean density (standard error). The first two surveys were undertaken before the poisoning operations. Unpubl.data provided by R.G.Cole and R.J. Singleton, NIWA.*

| | 16 July | 19 Sept. | 6 Dec. | 16 Dec. |
|---|---|---|---|---|
| Site 1 | 4.4 (2.0) | 2.0 (0.62) | 0.13 (0.09) | 5.56 (1.21) |
| Site 2 | - | 7.60 (3.11) | 7.94 (2.02) | 6.88 (2.35) |
| Site 3 | - | 13.07 (2.44) | 9.38 (1.77) | 14.75 (2.83) |

Table 8: *Annual survival of adult and juvenile stitchbirds on Kapiti Island in the presence (1992-96) or absence (1997) of rats. Table excludes unbanded birds and birds transferred in the same year.*

| Year | Adult No. alive Jan. | Adult No. alive Dec. | Juvenile No. alive Jan. | Juvenile No. alive Dec. |
|---|---|---|---|---|
| 1992 | 26 | 13 | 9 | 3 |
| 1993 | 37 | 22 | 4 | 1 |
| 1994 | 24 | 16 | - | - |
| 1995 | 19 | 15 | 6 | 2 |
| 1996 | 21 | 14 | 9 | 3 |
| 1997 | 18 | 16 | 9 | 7 |

## Short-term benefits of rat eradication

### *Stitchbird monitoring*

Both adult and juvenile stitchbirds had significantly higher survival rates in 1997 than in the previous five years (Table 8). Adult survival in 1997 was 88.9% compared to a mean of 63.0% during 1992-96 ($\chi^2$=5.17, $P$=0.02). Juvenile survival in 1997 was 77.8% compared to a mean of 32.1% in previous years ($\chi^2$=8.61, $P$=0.003)

Stitchbird nesting success and productivity from 1994/95 onwards has improved compared with previous years, with the least successful years being 1992/93 -1993/94 (Table 9). This may be due to stress associated with food availability, particularly the supplementary feeding regime - in 1994/95 the number and distribution of feeders was increased and has been maintained since. Nesting success in 1996/97 immediately after the poisoning was one of the best recorded on Kapiti Island, with an increase in the percentage of females attempting to breed and 100% nesting success. Nesting success in 1997/98 was 73%, lower than expected.

### *Saddleback monitoring*

In the first post-eradication survey of saddlebacks undertaken in March 1997, T.G. Lovegrove (*unpubl. data;* Auckland Regional Council Parks Service, Auckland, N.Z.) found 41 birds, including 9 pairs, 10 juveniles and 13 single males. He concluded that there should be sufficient birds on Kapiti Island to form the nucleus of a new population.

M. North (*unpubl. data;* Nelson, N.Z.) found 60-65 birds, including 20 pairs, 14 juveniles and 9-11 single males during a survey undertaken in January 1998, a 120% increase in the number of pairs and the first significant natural population increase since saddleback were released on Kapiti Island. The increased numbers of pairs in 1998 indicated that survival of juveniles in 1997 (after the rat eradication) was good.

### *New Zealand robin monitoring*

Survival of robins in the presence and absence of rats is given in Table 10. Robin survival in 1997 was not significantly different from that in 1995-1996; either in the Coast ($\chi^2$=0.520, $P$=0.47) or in the Trig study areas ($\chi^2$=1.285, $P$= 0.26).

Even though robin survival appears to have been affected by the use of brodifacoum, there is no evidence that the eradication operation had a deleterious effect on breeding success. Both areas had improved nesting outcomes in 1996/7 and there was an increase in the number of nests per female in the Trig study area (Table 11).

Table 10: *Survival of New Zealand robins (January to August inclusive) in the Coast and Trig study areas in the presence (1995-6) or absence of rats (1997). The period September to December has been excluded to eliminate the effects on survival of robins from the poisoning operation in September/October 1996.*

| Year | No. alive on Coast Jan. | No. alive on Coast Sept. | No. alive on Trig Jan. | No. alive on Trig Sept. |
|---|---|---|---|---|
| 1995 | 20 | 17 | 38 | 33 |
| 1996 | 37 | 31 | 50 | 33 |
| 1997 | 29 | 23 | 22 | 18 |

Table 9: *Stitchbird breeding success before and after a poisoning operation in September/October 1996 on Kapiti Island.*

| Breeding season | % females attempting to nest | Average no. nests/nesting female | Nest success, %[1] | Productivity[2] |
|---|---|---|---|---|
| 1991/92 | 82 ($n$=11) | 1.0 ($n$=9) | 78 ($n$=9) | 2.3 ($n$=7) |
| 1992/93 | 56 ($n$=27) | 1.4 ($n$=15) | 60 ($n$=15) | 1.8 ($n$=9) |
| 1993/94 | 72 ($n$=18) | 1.0 ($n$=12) | 70 ($n$=10) | 1.4 ($n$=7) |
| 1994/95 | 66 ($n$=12) | 1.4 ($n$=8) | 100 ($n$=4) | 2.3 ($n$=4) |
| 1995/96 | 60 ($n$=15) | 1.0 ($n$=9) | 88 ($n$=8) | 2.8 ($n$=5) |
| 1996/97 | 91 ($n$=11) | 1.2 ($n$=9) | 100 ($n$=9) | 2.9 ($n$=8) |
| 1997/98 | 94 ($n$=18) | 0.9 ($n$=17) | 73 ($n$=15) | 2.3 ($n$=11) |

[1]Of known outcomes only
[2]Measured as average number of fledglings per successful nest

Table 11: *New Zealand robin breeding success before and after a poisoning operation in September/October 1996 on Kapiti Island.*

| Breeding season | Trig study area: Average no. nests/nesting female | Trig study area: Nest success, %* | Coast study area: Average no. nests/nesting female | Coast study area: Nest success, %* |
|---|---|---|---|---|
| 1994/95 | 1.1 ($n$=10) | 40 ($n$=10) | - | 33 ($n$=3) |
| 1995/96 | 1.1 ($n$=16) | 83 ($n$=12) | 1.7 ($n$=15) | 50 ($n$=10) |
| 1996/97 | 1.4 ($n$=9) | 100 ($n$=11) | 1.7 ($n$=13) | 57 ($n$=21) |
| 1997/98 | 1.9 ($n$=11) | 33 ($n$=21) | 1.9 ($n$=16) | 57 ($n$=30) |

* Of known outcomes only

New Zealand robin breeding success was different from year to year and between study areas (see Table 11) with fewer successes and more nesting attempts in the Coast study area between 1994 and 1997. The least successful year in both areas before eradication was in 1994/95. The Trig study area had poorer than usual nesting success in 1997/98, although the number of nests per female increased.

# Discussion

## Risk assessment

The lethal dose of brodifacoum for most native birds is unknown, but the results of poisoning operations on Ulva Island and the Chetwode Islands indicated that an aerial or ground based operation would pose a significant risk to weka (Brown, 1997a; L. Chadderton, *pers. comm.*). The risk to little spotted kiwi, robins, kaka and saddlebacks was deemed to be minimal based on poisoning operations at Tiritiri Matangi, Red Mercury, Whatapuke, the Chetwodes, and Stanley Islands (Robertson *et al.*, 1993; Towns *et al.*, 1993; Pierce and Moorhouse, 1994; Walker and Elliott, 1997).

Pre-eradication trials were undertaken to identify which species found on Kapiti Island were at risk from a poisoning operation. Of particular interest were threatened species such as kaka and kiwi, and the trials were useful in indicating the level of risk, even though we were unable to distinguish birds that would consume a sublethal dose of toxin from those that would eat enough bait to receive a lethal dose. The trials identified which species needed mitigation measures (such as robins and weka), and which ones required monitoring through the poisoning operation (such as robins and kiwi). Most species were thought to be at minimal risk but species of particular interest (such as kaka, kokako, stitchbirds and reef-fish) were monitored to confirm the risk assessment and document any changes due to the operation.

Minimal risks were predicted for marine fish based on trials undertaken before the rat eradication. Follow-up surveys confirmed that the poisoning operation had no discernable effect on reef fish, although quantifiable surveys were only possible for a single species (spotty).

## Effects of the poisoning operations on birds

Non-target bird deaths occurred, but estimated mortality rates differed depending on sample size and monitoring method. For example, radiotelemetry data on 10 little spotted kiwi indicated a mortality rate of 10-20%, whereas recapture data from a search for 50 banded birds gave an estimated mortality of 2-5% (H.A. Robertson and R.M. Colbourne, *pers. comm.)*. This indicated that caution is required in interpreting results of short-term monitoring studies where sample size is small and/or only a single method is used for measuring the effects of a poisoning operation.

The results of the 5-minute bird counts and nocturnal bird call counts should be interpreted cautiously. As the entire island was treated with brodifacoum simultaneously and there was no appropriate control site available, it is not possible to determine whether changes in conspicuousness of both nocturnal and diurnal birds over time were due entirely or in part to the poisoning operations.

Five-minute counts detected a change in kaka and robin behaviour in October 1996, following the second drop, but by January 1997 counts for these species were back to normal. An increased proportion of birds heard for these species probably resulted from an increase in vocalisation by birds trying to attract mates or establish new territories following the deaths of resident birds. Behaviour of both species had returned to normal levels by January 1997 and there was no detectable decline in the kaka population even though it was too early for replacement by breeding to occur. Any robin losses due to the poisoning operation or tasks associated with it (such as the robin transfer) may have been replaced by January 1997, when there was no detectable difference in robin behaviour and conspicuousness from previous counts. This indicates that results of five-minute counts need to be viewed with caution unless they are undertaken soon after the likely time-frame for bird deaths, c. 10-20 days after a poisoning operation using brodifacoum, and there is a good baseline for comparison. These criteria were met on Kapiti Island, and the results of five-minute counts indicated that populations of most bird species, with the exception of weka, were relatively unaffected by the poisoning operation.

Call counts of nocturnal species undertaken between January and April 1997 recorded a significant decline in overall call rates of weka but no significant change in call rates for little spotted kiwi or morepork. However, changes in call rates differed from site to site for morepork and kiwi, with increases at two sites for both species. A decrease for both species was detected at one of the two lowland sites (Waiorua), and an increase was detected at the other (Helipad); neither of the higher altitude sites (Junction and Seismometer) had consistent trends. Interpretation of the results of call counts for these species is problematic but they at least confirmed the survival of many birds of both species following the operation.

The risk to kaka was assessed as minimal because trials on Kapiti Island indicated that few kaka were likely to take the baits, and poisoning operations elsewhere supported this assumption (Robertson *et al*., 1993; Pierce and Moorhouse, 1994). However, although all kaka on Kapiti Island that had a transmitter fitted survived the first poison drop, 15-20% of radiotagged kaka died after the second poison drop. The reasons for the later susceptibility to poisoning on Kapiti Island are unknown.

The risk to kokako was underestimated. It was regarded as minimal because non-toxic bait trials elsewhere indicated that kokako rejected green-dyed cinnamon-lured bait by sight rather than by taste; of a total of 215 kokako individually monitored through 1080 operations using pollard baits, only 2 birds appear to have been accidentally poisoned (J. Innes, *pers. comm.*; Landcare Research, Hamilton, N.Z.). The probable loss of 15% of kokako in the Kapiti Island poisoning operation compared with minimal losses in 1080 operations using pollard bait might be due to the fact that mainland 1080 operations use pollard baits laced with cinnamon lure for the target species (possums), while no cinnamon lure was incorporated in the pollard baits used on Kapiti Island. Despite the assessment that kokako rejected baits visually and thus were unlikely to take baits even without cinnamon lure (J. Innes, *pers. comm.)*, the absence of cinnamon may have increased the risk to kokako on Kapiti Island. Alternatively, kokako may be more susceptible to brodifacoum poisoning than to 1080.

The risk to New Zealand robins and the actual losses may have been overestimated because the trials and most banded birds monitored during the poisoning operation were located adjacent to public tracks. The survival rates for robins differed in the two study areas, and the difference in behaviour of robins adjacent to or away from public tracks may have been a major contributing factor. Therefore robin survival on Kapiti Island as a whole is likely to have been far higher than the 51% recorded in the two study areas, as most of Kapiti Island is not accessible to the public. This was supported by the five-minute bird count results, where there was no significant difference in the number of robins recorded in October 1996 compared to October 1991-93 (although call rates increased).

Weka were expected to be affected by the poisoning operation due to primary and secondary poisoning, and so precautions were taken to ensure that a population of weka would survive on Kapiti Island after the rat eradication programme. It is not possible to estimate the number of weka that perished due to the poisoning operation, but at least some weka survived and they, together with the birds released after the operation are now distributed throughout Kapiti Island and breeding prolifically.

**Short-term benefits of rat eradication**

Fecundity did not appear to be negatively affected by the toxic operation. Stitchbirds and robins had highly successful breeding seasons immediately after the operation and the increased number of saddleback pairs detected in 1998 indicates that this species too had a good breeding season in 1996/97.

Stitchbirds had a less successful breeding season in 1997/98 (Table 9) but there are several possible reasons:

- 1997/98 was an El Niño year and there was poor breeding for other species such as kaka, kereru and kokako. Stitchbirds may have been similarly affected, although a higher number of females attempted to nest than ever before;
- The ratio of females:males was 2:1, a ratio not previously recorded on Kapiti Island. Most males had two mates but only provided nest assistance (chick feeding) at one nest site. The high survival of juveniles, mostly females, resulted in a greater

proportion of inexperienced females in the population compared to previous years. The inexperienced females tended to nest later than their older conspecifics, and most received no assistance from the already occupied males. The number of fledglings produced per successful nest was 2.0 fledglings per nest for the young females compared to 2.5 fledglings per nest for the experienced females.

New Zealand robin breeding success varied from season to season and between study areas. Nesting outcomes improved immediately after the eradication operation, but nesting outcomes in 1997/98 were less successful (Table 11). The reasons for this are unclear but might be due to several factors:

- Considerably more morepork, a predator at robin nests (Brown, 1997b), were counted in the lowland coastal forest than the higher altitude forest (Table 3c where counts for the Helipad and Junction are indicative of the Coast and Trig study areas, respectively).
- The 1997/98 breeding season coincided with an El Niño year and the poorer breeding success in the Trig study area in this season may be a reflection of this. However, the increase in nesting attempts suggests that there was an improved food supply for robins compared with previous years.

The rat eradication operation was successful. There were losses of kaka, kiwi, robins, morepork and possibly kokako, but none was catastrophic. Weka also died as a result of the poisoning operation, but no pre-eradication counts were undertaken after the removal of weka, so the effect of the poisoning operation on weka is not quantifiable. The loss of kaka was unexpected but only occurred after the second poison application in October, and the impact on robins is likely to have been overestimated. Any losses that have occurred due to the poisoning operation will be offset by the removal of two significant predators of eggs and chicks, which is likely to result in improved productivity and recruitment.

Mitigation measures to ensure that sufficient weka survived to recolonise the island were successful, and weka are now present throughout Kapiti Island. Fecundity does not appear to have been affected by the poisoning operation, with improved breeding success for those species monitored closely (robins and stitchbirds) immediately after the poisoning of rats. Improved survival of juvenile stitchbirds and saddlebacks may also be due to the eradication of the rats. Benefits to other taxa will become clearer as follow-up studies are completed or undertaken in the future.

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