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Impact of brodifacoum poisoning operations on South Island Robins *Petroica australis australis* in a New Zealand *Nothofagus* forest

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Summary

South Island Robins *Petroica australis australis* were monitored through two different brodifacoum (Talon 20 P, 20 ppm) control operations targeting stoats *Mustela erminea* and ship rats *Rattus rattus* in a *Nothofagus* forest. Repeated observations of banded and radio-tagged territorial adult Robins were used to monitor survival from 6 to 8 weeks after poisoning. Where poison was deployed in bait feeders, 96.7% (29/30) of marked Robins definitely survived, whilst where poison was freely broadcast, only 52.2% (12/23) of marked Robins definitely survived. At the non-treatment site 85.7% (18/21) of marked Robins definitely survived. This study demonstrates that individual Robins are at risk from poisoning from exposed brodifacoum on the forest floor and therefore, probably from aerial application of brodifacoum. Further research is required to determine whether the benefit to Robin populations from successful predator control outweighs the loss of some Robins from poisoning. Conservation managers must take a wide view of the ecological community impacts when controlling introduced mammalian predators.

Introduction

South Island Robins *Petroica australis australis*, like other New Zealand native birds, are vulnerable to predation by introduced mammals such as ship rats *Rattus rattus*, stoats *Mustela erminea* and brushtail possums *Trichosurus vulpecula* (Moors 1983, Innes and Hay 1991, Murphy and Bradfield 1992, Brown *et al.* 1993, in press, O'Donnell 1996). Predation is probably the main cause of ongoing population declines of several New Zealand bird species (Innes and Hay 1991, Brown 1994, Clout and Saunders 1995, Clout *et al.* 1995, Innes *et al.* 1996, McLennan *et al.* 1996, O'Donnell 1996) and the onslaught of alien predators threatens biodiversity world-wide (Atkinson 1985, Soulé 1990). Development of a cheap, effective environmentally safe predator control method is an international and urgent need.

Intense predation of Robin eggs, young and incubating females at the nest can threaten population viability (Brown 1994). In addition, Robins are much less widespread than last century (Flack 1979) and anecdotal evidence suggests that declines are continuing in some areas (R. Buckingham pers. comm.). Therefore, restoration of Robin and other forest bird populations will depend on effective predator control.

Poisoning is much more cost effective than trapping in the control of predators (Moller *et al.* 1992, Ratz *et al.* unpubl.). Brodifacoum (Talon 20 P, 20 ppm) poisoning operations are very effective at killing stoats, ship rats and possums (Henderson *et al.* 1994, Alterio 1996, Brown *et al.* 1997, Alterio *et al.* in press). Accordingly, multi-predator control using brodifacoum is potentially a very valuable technique for restoration of native bird communities, provided it does not also kill a significant number of non-target native species such as birds, lizards and invertebrates.

This study investigated the survival of adult territorial Robins through two different predator control operations using brodifacoum in beech *Nothofagus* forest; one when Talon 20 P pellets were contained in bait feeders and another when pellets were hand broadcast and left exposed on the forest floor. This study also compared the value of radio-tagging as opposed to "roll calling" banded Robins as a monitoring tool to detect the accidental poisoning of Robins.

Study area

South Island Robins were studied at three 160 ha *Nothofagus* beech forest sites at Station Creek (42°13'S, 172°15'E), 5km SE of Maruia, South Island, New Zealand. The three sites were 2.5–4 km apart and were dominated by virgin red *Nothofagus fusca* and silver *N. mensiezii* beech. Each site contained approximately 20 ha of regenerating, previously logged forest along road edges. The topography was moderately steep hill country containing some river terraces.

Methods

Robins were located from 13 August to 21 September 1996, prior to predator control by poisoning, by approaching singing individuals and by attracting Robins to tape calls. They were individually colour banded after being caught using an electronically triggered "clap-trap" baited with commercially cultured meal worms *Tenebrio molitor*. Robin territories were revisited and banded individuals located at least twice prior to poisoning and repeatedly every 1–2 weeks for 6 to 8 weeks after poisoning. Meal worms were provided during subsequent visits to encourage Robins to appear quickly. When an individual could not be located, territories were revisited five or six times and neighbouring territories searched to maximize the chances of locating the missing individual.

A subsample of Robins was radio-tagged and banded from 1 September to 6 October 1996, prior to predator control. A 1 g transmitter pulsing at 20 pulses per minute (expected maximum transmission life of 31 days) was glued with Ados F2 contact adhesive to a patch of skin clipped bare of feathers on the backs of Robins. The same frequency of return visits was used to monitor radio-tagged Robins as banded only Robins. Radio-tagged Robins that could not be found after transmitter failure but before the end of monitoring were treated as having disappeared.

Robin survival was monitored through two different poison treatments. One hundred and fifty pelleted cereal Talon 20 P baits were placed in each of 170 "Philproof" bait feeders (manufactured by Phil Thomson, Bankier Road, RD1, Taupiri, New Zealand) at a 100 m grid spacing (0.32 kg/ha) at Site A on 29

September 1996. Bait feeders consisted of a durable plastic container designed to be nailed to trees approximately 30 cm above ground level. A tapered entrance of approximately 14 × 14 cm at the base of each feeder allowed bait to be removed by possums and rodents. For this study the feeders were adapted to exclude possums but allow ship rats and mice *Mus musculus* access to bait by reducing the feeding entrance to 3 × 12 cm using a tinplate pot riveted to feeders and anchoring feeders to the ground. At the end of the study bait feeders were removed and bait take was visually scored (empty, 1–25 pellets, 26–50, 51–100, 100–150 present).

At Site B Talon 20 P was broadcast by hand at 3 kg/ha (simulating an aerial operation) on 9 October 1996. Handfuls of pellets were scattered widely on the ground at 10 m intervals and thrown left and right by people walking along transects 25 m apart. Site N acted as a non-treated control.

After the poisoning operations all dead birds found while searching for poisoned mammals were frozen. Bird liver, gut and maggots were sent to the National Chemical Residue Laboratory (New Zealand Ministry of Agriculture and Fisheries) for brodifacoum assays using the Anticoag.v2 method (developed by the Shell Company 1989) with detection levels of ± 0.01 mg/kg.

Survival estimates are minimal because some Robins that disappeared may have been alive but undetected rather than having died. Binomial confidence intervals (95%) were fitted to survival estimates (Mainland *et al.* 1956). Comparisons of survival were made using Fisher's Exact test (two-tail).

Results

Eighty-one Robins were caught and individually colour banded at the three sites. Seven Robins disappeared before poisoning and the remaining 74 Robins were monitored from six to eight weeks after poisoning. Thirty-four banded Robins were also fitted with radio transmitters before poisoning, but six Robins dropped their transmitters, one Robin definitely died before poisoning and another disappeared before poisoning. At the commencement of poisoning, 26 Robins had transmitters and 48 Robins were banded only (Table 1). Banded birds at Site B were caught on average 42 days before poisoning compared with radio-tagged birds that were caught within 10 days of poisoning.

Combined radio-tagged and banded birds' survival gave minimum estimates of survival of 96.7% (95% CI = 83–100%), 52.2% (95% CI = 31–73%) and 85.7% (95% CI = 64–97%) for Sites A, B and N, respectively. Survival was significantly less (banded and radio-tagged combined) at Site B compared with Sites A and N ($P < 0.001$ and $P = 0.045$ respectively) but there was no significant difference in survival between Sites A and N ($P = 0.29$) (Table 1).

No significant difference in survival of banded birds compared with radio-tagged birds was found ($P = 1.000$, $P = 0.193$, $P = 0.586$) within Sites A, B and N, respectively. Significantly fewer banded birds survived at Site B when compared with Sites A ($P < 0.001$) and N ($P = 0.014$) but no significant difference was found when Sites A and N were compared ($P = 1.000$). No significant difference in survival of radio-tagged birds was found between sites.

Bodies of the two disappeared radio-tagged Robins were not recovered at Site B but eaten feather remains of one radio-tagged Robin were found there shortly

Table 1. Summary of the number of Robins banded (only) and radio-tagged (as well as banded) throughout the study (August–November 1996) at Maruia, South Island, New Zealand.

Outcome	Site A (bait feeders)	Site B (hand application)	Site N (non-treatment)	Total
Total banded and radio-tagged Robins	35	23	23	81
Robins that disappeared before poisoning	5	0	2[a]	7
Robins monitored before and after poisoning	30	23	21	74
Banded Robins monitored before and after poisoning	22	15	11	48
Banded Robins that survived	21	6	10	37
Banded Robins that disappeared	1	9	1	11
Banded Robin survival (%) (95% CI)	95.5 (77–100)	40 (16–66)	90.9 (59–100)	77.1
Total number of radio-tagged Robins	14	8	12	34
Radio-tagged Robins monitored before and after poisoning	8	8	10	26
Radio-tagged Robins that survived	8	6	8	22
Radio-tagged Robins that disappeared	0	2[a]	2	4
Radio-tagged Robin survival (%) (95% CI)	100	75 (35–97)	80 (44–97)	84.6
Total Robin survival (%) (banded and radio-tagged) (95% CI)	96.7 (83–100)	52.2 (31–73)	85.7 (64–97)	79.7

[a] One Robin preyed upon.
CI, binomial confidence intervals (from Mainland *et al.* 1956).

after the poison operation. It was not known whether the Robin died from poisoning or was preyed upon. Statistical tests reported above treat this Robin as disappeared but no substantive change in the acceptance or rejection of the null hypothesis results if it is excluded. The second missing radio-tagged Robin at Site B survived at least 12 days after poisoning but was not detected 27 days after poisoning. An unbanded male occupied the missing radio-tagged male's territory which suggests that the missing male probably died. Neither of the two radio-tagged Robins lost from Site N were recovered probably because their transmitter batteries had failed.

Two Chaffinch *Fringilla coelebs*, one Blackbird *Turdus merula* and one Silvereye *Zosterops lateralis* were found dead at Site B, after poisoning. A Chaffinch gut sample contained 0.66 mg/kg of brodifacoum and another Chaffinch gut and liver sample contained 0.83 mg/kg; the Blackbird maggots sample contained 0.27 mg/kg; and the Silvereye maggots sample contained 0.13 mg/kg.

Detectable levels of poison bait were taken from 60% of bait feeders at Site A. Many bait feeders were disrupted and possum fur was often found adhering to the plastic feeder and tin plate at bait feeder entrances. The average amount of bait remaining at Site A was between 0.22 kg/ha and 0.17 kg/ha, therefore bait take was between 0.10 and 0.15 kg/ha, based on the range possible when visually scored. Only six instances of pellets spilled onto the ground near feeders were observed.

Discussion

Methods of measuring survival

Repeated visits or "roll-calling" have been used elsewhere to monitor banded Robin survival through poison operations (Alterio *et al.* 1996, D. Brown, R. Empson, K. Owen, H. Speed and R. Powlesland pers. comms.). However, disappearance of individuals from old age, predation, emigration and secretive behaviour can confound detection of poisoning impacts over prolonged periods. In this study, female Robins that re-nested after fledging chicks were often difficult to relocate. It is also feasible that females with dead mates could emigrate to male territories elsewhere. Therefore, disappeared female birds may have remained alive and undetected on the study area or moved outside the study area.

The roll-calling technique may therefore be unreliable when monitoring the impact of a slow-acting cumulative poison such as brodifacoum. Results obtained from trials with acute poisons such as sodium monofluroacetate (1080) are far simpler to analyse because death occurs within hours rather than potentially weeks following poisoning. The main advantage of using banding and resighting as a monitoring method is the increased statistical power from being able to monitor more birds. Each radio-transmitter cost $US155, so logistic constraints could limit sample sizes if only radio-telemetry is used.

Radio-telemetry can provide a direct measure of poisoning because bodies can be recovered and tissue analysed for the presence of poison. The technique proved successful in that most transmitters stayed on for at least three weeks, which is approaching the transmitter battery life and Robin activity was not obviously affected. However, some aerials were lost and some transmitters failed prematurely which increased the difficulty of finding live birds and prevented the finding of bodies. A transmitter life of 31 days may not be effective for determining long-term poison impacts. In addition, two of 34 Robins probably died within three days of capture and fitting of transmitters (before poison was deployed). One Robin died from an unknown cause but the second could not be located because its transmitter frequency was dominated by a high-pitched noise, probably caused by local radio interference (K. Lay pers. comm.).

The two monitoring techniques provided different results at Site B where brodifacoum was broadcast by hand and left exposed on the forest floor. Significantly more banded Robins but not radio-tagged Robins disappeared at

Site B. A possible reason for the difference was a bias towards radio-tagged single males at Site B. Single males may have been less vulnerable to poisoning than breeding pairs that spend more time foraging for food (Powlesland 1980). The lower survival of Robins in pairs 43.8% (7/16) compared with singles 71.4% (5/7) at Site B supports this assumption, although this difference was not statistically significant. Alternatively, radio-tagged birds may have been less likely to feed on pellets thrown to the ground because unlike banded birds they were not trained to appear for food (i.e. mealworms).

Aerial broadcasting of brodifacoum may pose less risk than hand broadcasting if trained birds associate people hand broadcasting pellets with food. However, banded Robin disappearances have been recorded elsewhere following rodent eradications using cereal baits containing brodifacoum at 20 ppm, aerially broadcast on islands (D. Brown, R. Empson and K. Owen pers. comms.).

Provided adequate funds are available, radio-telemetry is potentially the most reliable monitoring method for determining short- to medium-term poison impacts. It avoids the bias associated with repeatedly feeding birds and bodies can be recovered so that direct measures of poisoning can be obtained. However, loss of aerials and battery failure can reduce the value of this technique and biased samples towards single males should be avoided. Accordingly, I suggest further research is performed using a combination of radio-telemetry and roll-calling to test the reliability of roll-calling as a technique and assess the most cost-effective means of determining poison impacts on bird populations.

Comparison of poison impacts between sites

At least two Chaffinch, one Blackbird and one Silvereye were probably poisoned at Site B. However, death could not be attributed to poisoning because brodifacoum levels in maggot samples were considerably lower than the published LD_{50} for Blackbirds and Silvereyes (Godfrey 1985). Robins were also probably poisoned at Site B but due to the variation in results obtained between survey methods it is not possible to give an absolute percentage of Robins poisoned at Site B. If the disappearance rate recorded at the non-treated site is subtracted from the total disappearance at Site B then a minimum of 66% of Robins survived. However, the confidence intervals were extremely wide and this estimate could be anywhere between 43% and 84%. Therefore, more studies using radio-transmitters on Robins and other bird species are needed to increase sample sizes so as to accurately access the impacts of poisoning.

The use of bait feeders at Site A increased Robin survival compared with Site B where pellets were hand broadcast and left exposed on the forest floor. Robins may not have been able to gain direct access to pellets in bait feeders because of the modified entrances. Elsewhere, Robins have been observed pecking at Talon 20 P baits when hand broadcast onto the forest floor (Alterio *et al.* 1996) and research by Morgan and Wright (1996) suggests that insectivorous birds are more likely to be killed by eating poison baits than poisoned invertebrates. Replication of experiments that test the impacts of different predator control operations are much needed to determine more accurately the risks to non-target bird species.

Predator control and implications for restoration

Brodifacoum poisoning operations provide a multi-predator control technique which is effective against a variety of important mammalian predators (Henderson *et al.* 1994, Alterio 1996, Alterio *et al.* in press, Brown *et al.* 1997). Sustained use of this technique offers a valuable means of restoring native bird communities that are presently limited by predation. The relative threat of the different predators to indigenous species has not been clearly identified (Brown 1997) so targeting the most important predator species is not yet possible. The removal of one predator species could result in increased densities of other predators (Fitzgerald 1990) or diet switching (Murphy and Bradfield 1992) that could result in increased predation pressure. Therefore, measures of the ecological costs as well as benefits to native bird communities are required before net conservation benefit or harm can be assessed.

Did Robin populations in this study receive a net gain or loss from poisoning? The poisoning operations at Sites A and B killed stoats, ship rats and possums (Brown *et al.* 1997) which possibly resulted in reduced predation of adults and almost certainly of eggs, chicks and newly fledged Robins. However, the net gain of predator control could not be determined by this study because productivity (intensive monitoring of nesting attempts) was not measured. Studies that scale productivity with and without predator control against mortality from predation, poisoning and old age are necessary to determine net benefit to Robin populations.

Application of brodifacoum in feeders reduced the risk of poisoning Robins in this study. However, identifying the risks to birds from brodifacoum in bait feeders placed above ground to poison possums is also needed because bait feeders have become important tools for mainland restoration projects in New Zealand (Clout and Saunders 1995, Bradfield and Flux 1996). Bait feeders used to target possums could potentially increase the risk of poisoning inquisitive non-target species such as Weka *Gallirallus australis* and Kea *Nestor notabilis* by providing a large quantity of easily accessible toxin.

Effective and safe predator control techniques are needed to combat alien predators that threaten biodiversity in New Zealand and elsewhere. However, risks must be clearly identified before brodifacoum poison can be used widely. Knowledge of the route of poisoning would allow a preliminary risk assessment for different birds to rank their vulnerability and so prioritize the research on non-target impacts. Radio transmitters could be used to obtain more accurate measures of poisoning which could then be scaled against gains to determine the overall worth of brodifacoum as a multi-predator control tool for the restoration of New Zealand's native bird communities.

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