R.G. POWLESLAND[1], J.W. KNEGTMANS[1] and I.S.J. MARSHALL[2]

[1]Science and Research Unit, Department of Conservation, P.O. Box 10420, Wellington, New Zealand.
[2]Pureora Field Centre, Department of Conservation, R.D. 7, Te Kuiti, New Zealand.

COSTS AND BENEFITS OF AERIAL 1080 POSSUM CONTROL OPERATIONS USING CARROT BAITS TO NORTH ISLAND ROBINS (*PETROICA AUSTRALIS LONGIPES*), PUREORA FOREST PARK

Summary: Large scale aerial poison operations with 1080-carrot baits are used extensively to control possum (*Trichosurus vulpecula*) populations in New Zealand forests for ecosystem conservation purposes and to stop the spread of bovine tuberculosis. Although various procedures have been implemented to reduce the incidence of bird kills, dead birds continue to be found after poison operations. Colour-banded North Island robins (*Petroica australis longipes*) were monitored in treatment and non-treatment areas to determine the costs and benefits of aerial 1080-carrot bait operations to robin populations. An August 1996 operation, that included much chaff or fine particles of bait, resulted in 43% mortality of territorial birds (banded and unbanded) or 55% mortality of colour-banded birds. During the same period there was no robin mortality in the non-treatment area. By comparison, the September 1997 operation, that included minimal amounts of chaff, resulted in just 8.6% and 9.7% robin mortality as determined by territory mapping and of banded birds, respectively. These levels of mortality did not differ significantly from that evident in the non-treatment area. Monitoring of possums and rats indicated that both populations were at very low densities and remained so during the robin nesting seasons (September-February) following the operations. Robin breeding was particularly successful in the treatment areas following the two poison operations (mean of 3.7 and 3.8 fledglings per pair) compared with that in the non-treatment area in 1996-97 (0.4 fledglings per pair) and in the post-treatment area in 1997-98 (1.5 fledglings per pair). Through recruitment of the fledglings, both populations had more robins and a greater proportion of females one year after the possum control operations than immediately before. Thus the results suggest that as long as carrot bait protocols are strictly adhered to and baits are distributed over large blocks of forest so that mammalian predator populations remain low during the next robin nesting season, the robin populations will benefit from aerial 1080-carrot possum control operations.

Keywords: North Island robin; 1080; sodium monofluoroacetate; carrot baits; colour-bands; mortality; nesting success; population recovery.

Introduction

Over the past 30 years there have been increasing attempts to reduce brushtail possum (*Trichosurus vulpecula* Kerr) populations in New Zealand because of the damage they cause to indigenous forest ecosystems (Atkinson *et al.*, 1995), and because they are a vector of bovine tuberculosis to cattle and deer (Livingstone, 1994), particularly on farms bordering forests. Currently, the most common method of control involves aerial broadcasting of carrot or cereal baits containing sodium monofluoroacetate (Compound 1080), which achieves a population reduction, on average, of about 70% (Morgan, Batcheler and Peters, 1986), but can exceed 90% (Eason *et al.*, 1993).

Birds, including native and endemic species, have been found dead after aerial possum control operations (Spurr and Powlesland, 1997). Various procedures have been implemented to reduce the number of birds killed during aerial 1080 operations. This includes the sieving out of small fragments of bait that birds are more capable of swallowing, dying baits green so that they are less attractive to birds, adding cinnamon which acts as a repellent to birds but not possums, and reducing application rates on the assumption that it would reduce bird-bait encounters (Harrison, 1978a,b; Morgan *et al.*, 1986; Spurr, 1991).

The finding of dead poisoned birds gives no indication of the effect of possum control operations on bird populations. Poisoning may replace other causes of mortality, such as winter starvation, or may be additional to them (Spurr, 1991). If poisoning represents an additional source of mortality, it may have considerable impact on the species' population dynamics, and hence its long-term probability of local survival. This would be particularly true in forests where bovine tuberculosis is endemic in possums, since control operations will be carried out regularly, often at two- to five-year intervals.

The 5-minute count technique (Dawson and Bull, 1975) has been used to monitor the impact possum control operations have on populations of small passerines in indigenous forests (Spurr, 1991, 1994). This technique involves monitoring bird communities before and after poison operations in treatment and non-treatment study areas. Since most bird species are recorded from calls during these counts, the results reflect species conspicuousness as well as numbers. Thus, measures of (mainly vocal) conspicuousness have been used as indices of bird abundance, and by comparing before and after results, the level of mortality associated with poisoning programmes can be estimated. One problem with this method is that species conspicuousness varies considerably during the year, and for some species during late winter-early spring it can vary dramatically from month to month, and from day to day depending on the weather, and the status of the individual (e.g., paired versus unpaired male (Powlesland, 1983)). Thus, as might be expected, the 5-minute count method has provided some anomalous results. For example, the index for a North Island robin (*Petroica australis longipes* Garnot) population monitored in one of eight trials in winter "increased" in a treatment block following a toxic carrot operation (Spurr, 1991). It is very unlikely that this result reflected an increase in robin numbers, since the species does not breed in winter and individuals are particularly sedentary and territorial at this time (R.G. Powlesland, *pers. obs.*).

Two reviews of the impacts of 1080 operations on forest birds have concluded that the 5-minute count technique is not a reliable method of assessing the effects of possum control operations on forest birds, except where there is very substantial mortality (Norton, 1992; Atkinson *et al.*, 1995). The method that both of these reviews recommended for monitoring the mortality of forest birds was to mark the birds so that they could be individually monitored.

Using such methods, the objective of this work was to determine the costs (mortality during poison operations) and benefits (improved nesting success and recruitment following poisoning of introduced mammalian predators) of aerial possum control operations using 1080 carrot baits to North Island robins in Pureora Forest Park. The North Island robin was chosen for the study because individuals have been found dead after aerial possum control operations (Spurr, 1991) and are territorial throughout the year. In addition, they can be trained to approach observers for a reward of food, thus enabling the efficient monitoring of sufficient numbers of robins in both treatment and non-treatment study areas.

Methods

Study areas

The two study areas used were selected because they contained sufficient numbers of robins, were reasonably close to Pureora village, and were within the boundaries of forest blocks that were to receive aerial possum poisoning operations carried out by Environment Waikato under contract to the Animal Health Board. The Tahae study area, part of the Waipapa Ecological Area, is bounded by Fletcher's Road, the Waipapa River and an extensive area of scrub known as Taparoa Clearing (Leathwick, 1987)(Fig. 1). The site comprises about 100 ha, is relatively flat at 520-540 m a.s.l., and has not been logged. The forest cover consists of scattered podocarps, particularly rimu (*Dacrydium cupressinum* Lamb.), kahikatea (*Dacrycarpus dacrydioides* A. Rich) and matai (*Prumnopitys taxifolia* Laubenf.) emergent over a mainly tawa (*Beilschmiedia tawa* A. Cunn.) canopy. Other common canopy and understorey species include hinau (*Elaeocarpus dentatus* J.R. and G. Forst.), kamahi (*Weinmannia racemosa* Linn. f.), mahoe (*Melicytus ramiflorus* J.R. and G. Forst.), miro (*Prumnopitys ferruginea* Laubenf.), totara (*Podocarpus totara* G. Benn. ex Don), maire species (*Nestegis* spp.), wheki (*Dicksonia squarrosa* Forst. f.), soft tree fern (*Cyathea smithii* Hook. f.) and supplejack (*Ripogonum scandens* J.R. and G. Forst.). Over the eastern third of the study area, emergents are less frequent and rewarewa (*Knightia excelsa* R. Br.), fivefinger (*Pseudopanax arboreus* Philipson) and tree ferns occur more frequently in the canopy and understorey. While generally sparse under the dense canopy, ground species often present include filmy ferns (*Hymenophyllum* spp.), hen and chickens fern (*Asplenium bulbiferum* Forst. f.), bush rice grass (*Ehrharta diplex* F. Muell.), *Blechnum fluviatile* Salom., hookgrass (*Uncinia* spp.) and *Leptopteris hymenophylloides* Presl (Leathwick, 1987). Possum and rat control in this study area was carried out using 1080 poison (0.15% w/w) in cereal baits (Wanganui RS5 pellets) in stations at 150 m

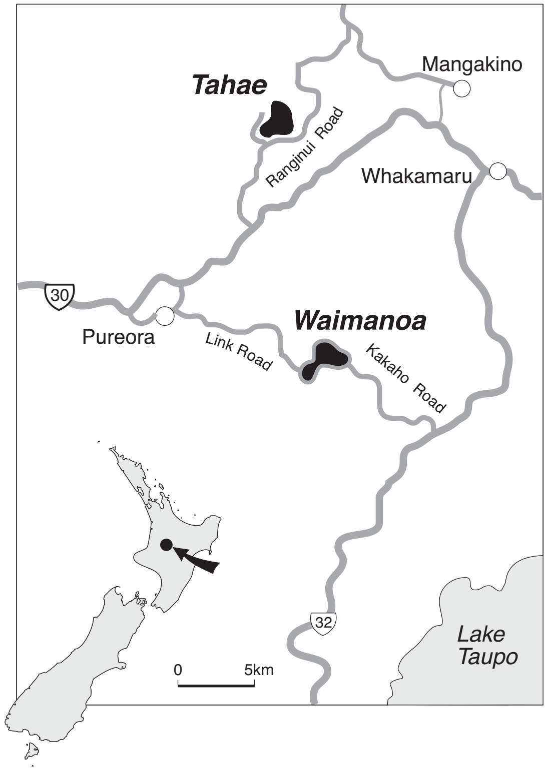

Figure 1: *Location of the Tahae and Waimanoa study areas, Pureora Forest Park*

intervals. It is not known when this control programme began or the frequency at which the stations were refilled, but the programme ended in March 1994.

The Waimanoa study area is bordered mainly by Waimanoa and Link Roads (Fig. 1). Although the study area comprises about 300 ha, some of it was not inhabited by robins and only about 100 ha was regularly searched for them. The topography is of rolling country, with the altitude varying from 700 to 740 m a.s.l. Logging of mainly emergent podocarps occurred over some of the study area during the 1970s and the density of emergent trees is less than at Tahae. Toetoe (*Cortaderia fulvida* Zotov) and wineberry (*Aristotelia serrata* W.R.B. Oliver) are common on former skid sites and logging tracks through the forest. There had been no possum control in the study area during the past 10 years, but 1080 carrot baits were spread over the forest to the north of Waimanoa Road in winter 1993, and south of Link Road in winter 1994.

Capture and marking robins

North Island robins were captured using electronically operated clap traps or mist nets. Prior to capture attempts, robins were fed mealworm (*Tenebrio* sp.) larvae in conjunction with tapping the lid against the mealworm container. This noise was made so that the robins associated it with being fed, such that they would be encouraged to approach us for food, rather than us having to search for them. Each robin was captured only after it regularly approached us for mealworms. While fledgling and juvenile robins could often be fed beside the trap the first time it was presented, adults were initially wary of the trap and so had to be fed near it several times before they could be safely trapped. Those robins that would not feed at the clap trap were fed near a mist net and then startled into it or attracted into it using taped song. Once captured, each robin was fitted with an individual combination of a numbered metal leg band and two or three colour bands (size B, butt bands).

Monitoring robins

The survival of each banded robin was monitored at least once a week, and every day or second day for a fortnight immediately after each poison operation. To find nests to monitor breeding success, if the female of a pair was attracted she was subsequently followed back to the nest. If the male was attracted, often he would go to the vicinity of the nest with mealworms to feed his mate, and we could then follow her back to the nest. Once found, the nest location was marked nearby with track tape, and the nest visited at least every third day to monitor its fate.

Rat population indices

The proportion of baited tracking tunnels containing rat foot-prints was used to provide an index of rat abundance (King and Edgar, 1977; Innes *et al.*, 1995). We assumed that these indices directly reflected actual population densities (Innes *et al.*, 1995; Brown *et al.*, 1996). One hundred tracking tunnels were placed at 50 m spacings along a circuit route through the Tahae study area, and along three lines spaced 150 m apart at the Waimanoa study area. Each tunnel was baited with about 5 mm^3 of peanut butter at both ends and ‘set’ for one night. Data are expressed as percent ‘available’ tunnels with rat tracks; those tipped over were deleted from analyses. Foot-print tracking indices in the two study areas were taken on the same night to account for differences due to weather and other variables on rat activity.

Possum population indices

The capture rate of possums in leg-hold traps was used to provide an index of possum abundance. The method used differed for the two poison operations. In 1995-96, at each study area 34 soft-catch traps (Victor No. 1) were set at 20 m spacings along a tape line. Lure (a mixture of 5.5 kg of white flour, 1.5 kg of icing sugar and 10 ml of orange essence) was smeared on the tree above each trap. The trap-line was operated for three dry nights and checked daily, fresh lure being re-applied daily if necessary. Each captured possum was marked by clipping the fur from its tail tip (to detect recaptures) and then released (none had obviously broken bones as a result of the trapping). The index of abundance (captures/100 trap-nights) is corrected for traps sprung but without a captive, and non-target captures (rats)(Cunningham and Moors, 1996).

In 1997, the method used involved setting two trap lines in each study area, each line consisting of 20 traps spaced at 20 m intervals along a tape line. Lure (a mixture of 5 kg of white flour and 1 kg of icing sugar, no essence), was smeared on the tree above each trap, and re-applied daily if necessary. The trap lines at both study areas were operated simultaneously for three dry nights. All trapped possums were killed and disposed of at least 10 m from the traps.

1080 analysis

A muscle sample from each of three robins found dead was submitted to the National Chemical Residue Laboratory (Ministry of Agriculture and Fisheries, Wallaceville Animal Research Centre, Upper Hutt, New Zealand) for 1080 residue analysis. The determination of 1080 presence in the samples was by gas chromatography (1080ToxV2.GC FID) (Hoogenboon and Rammell, 1987), with a detection limit of 0.1 mg/kg.

Results

Poison operation - September 1996

The poison operation that included the Tahae study area encompassed 37 525 ha over the Rangitoto Range and North Block of Pureora Forest Park. The Tahae study area was part of the second stage of the operation (16 587 ha). Pre-feed carrot baits (non-toxic) were spread during 12-14 August 1996 at a rate of 7 kg ha^{-1}. Because of rain, the spreading of the toxic baits (1080-carrot baits, the toxin at 0.08% w/w at a rate of 15 kg ha^{-1}) was delayed until 17-18 September 1996 (Lorigan, 1996). No rain was recorded at Pureora until the ninth day after the poison operation.

Carrots were processed into baits using a Reliance cutter and screener. The chaff or small pieces of carrot were removed through a 16 mm screen. The amount of chaff or wastage that these machines produce is generally about 20% by weight. The wastage for the first stage of the operation was calculated to be 23.1%, but it was only 9.9% for the second stage (Lorigan, 1996). This suggests that the rest of the expected wastage (10-12%) was not sieved out, but was made toxic and distributed with the baits.

Impact of the poison operation on possums and rats

Possum trapping in the treatment area (Tahae) during October 1995 gave an index of abundance of 6.2 possums/100 corrected trap-nights, and 3.2 possums during July 1996 when the monitoring was disrupted by rain. No possums were trapped in the treatment area during the October and December 1996 monitoring sessions following the poison operation.

By comparison, in the non-treatment area (Waimanoa), monitoring during December 1995 resulted in 8.9 possums/100 corrected trap-nights and 3.1 possums in July 1996. During the October and December 1996 monitoring sessions in the non-treatment area, 14.1 and a minimum of 14.7 possums/100 corrected trap-nights, respectively, were captured.

The rat population index during the robin breeding season (September 1996 to February 1997) was reduced by 89-95% in the treatment area, but remained similar to the pre-poison level in the non-treatment area (Fig. 2a).

Robin mortality during the 1996 poison operation

None of 32 robins disappeared from the non-treatment area during the fortnight following the poison operation (18 September - 2 October 1996), but 42.9% of 28 disappeaed from the treatment area (Table 1). The proportion of males that disappeared (44.4% of 18) was not significantly different to that for females (40.0% of 10) (χ^2=0.029 with Yates correction, d.f.=1, P=0.86; Table 1).

Mortality of colour-banded birds that would readily approach us for mealworms was zero in the non-treatment area (Table 2). In comparison, 12 of 22 (54.5%) colour-banded robins in the treatment area disappeared. As for the territory mapping result, there was no significant difference in the proportion

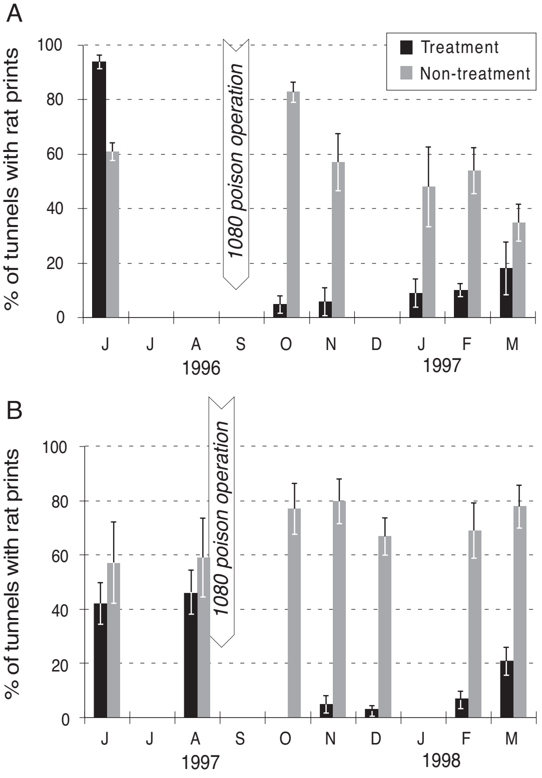

Figure 2: *Tracking indices for rat abundance (% of tunnels with foot-prints) in the treatment and non-treatment study areas before and after 1080 possum poison operations, Pureora Forest Park. Bars are standard errors.*
A - poison operation in September 1996; treatment area was Tahae and non-treatment was Waimanoa
B - poison operation in August 1997; treatment area was Waimanoa and post-treatment was Tahae

Table 1: *Number of robins present in treatment (Tahae) and non-treatment (Waimanoa) study areas before and after an aerial 1080 possum poison operation in September 1996 as determined by territory mapping (banded plus unbanded robins in a defined area), Pureora Forest Park.*

	Total number robins	Male	Female
Non-treatment area			
Pre-operation	32	21	11
Post-operation	32	21	11
Treatment area			
Pre-operation	28	18	10
Post-operation	16	10	6
Number disappeared	12	8	4

Table 2: *Number of robins present in treatment (Tahae) and non-treatment (Waimanoa) study areas before and after an aerial 1080 possum poisoning operation in September 1996 as determined by monitoring banded robins that would approach for a food reward (mealworms), Pureora Forest Park.*

	Number of robins	Male	Female
Non-treatment area			
Pre-operation	24	15	9
Post-operation	24	15	9
Treatment area			
Pre-operation	22	14	8
Post-operation	10	7	3
Number disappeared	12	7	5

of colour-banded males that disappeared (50% of 14) as compared with that of colour-banded females (62.5% of 8) (χ^2=0.015 with Yates correction, d.f.=1, *P*=0.903; Table 2).

Of the 12 banded robins that disappeared, the majority did so within three days of the poison baits being distributed. All were present on 18 September when the poison operation was completed. However, the next day five birds could not be found, and on 20 September, a further four robins could not be found. Two robins present on 20 September were not located when next searched for on 23 and 26 September. The 12th robin was a female whose mate had disappeared on 19 September. She was seen in the territory on the 26 September but not subsequently. Since she survived at least eight days after the poison operation and had lost her mate it is possible that she was not poisoned but emigrated out of the study block to find a new mate.

Two (B-42125 and B-78665) of the 12 banded birds that disappeared were eventually found, both dead in their territories. B-78665 was found 21 days after it disappeared and the other 27 days afterwards. Because the weather conditions were relatively cold and dry following the poison operation, neither bird had decomposed much. Muscle samples were submitted for 1080 analyses and both were positive; B-78665 had 0.37 mg kg^{-1} of 1080, and B-42125 had 0.83 mg kg^{-1}. A freshly dead unbanded robin found in the study area on 19 September, the day after the poison operation, had 3.80 mg kg^{-1} of 1080.

Autopsy of the unbanded, freshly dead robin revealed that the gizzard contained fragments of invertebrate exoskeletons. Nothing was found in the alimentary tract from the beak to the gizzard.

Robin nesting success in the 1996-97 season

Just four (11%) of the 35 nests found in the non-treatment area successfully fledged chicks (Table 3). A nesting attempt was considered successful if at least one fledgling survived beyond the first week after leaving the nest. In contrast, in the treatment area, of the 18 nests found during the 1996-97 season, 13 (72%) were successful. The mean number of fledglings reared per pair was 3.7 in the treatment area and 0.4 in the non-treatment area. All seven females survived the entire nesting season in the treatment area. In the non-treatment area, of the 14 females, one was killed on the nest, and another was seen with a badly injured leg immediately after her clutch was preyed upon. She did not re-nest and later disappeared. In addition, two other females disappeared from this study area late in the nesting season. They may have been killed during nest predations or have moved out of the study area following the failure of their last nesting attempts.

Status of the populations a year after the 1996 poison operation

In the non-treatment area prior to the poison operation (September 1996) there were 32 robins present as determined by territory mapping (Table 4), 11 (34.4%) being females. There was little change in the status of this population by August 1997, with 33 robins present of which 12 (36.4%) were females. In contrast, in the treatment area the population grew from 28 before the poison operation to 36 in August 1997, a 28.6% increase (Table 4). The population increased by 125% since October 1996 if the 12 robins that died during the poison operation are taken into account.

Table 3: *Robin nesting success in the 1996-97 season following the September 1996 aerial 1080 possum poisoning operation, Pureora Forest Park.*

	Non-treatment area	Treatment area
Number of pairs monitored	14[1]	7
Number of nests monitored	35	18
Nesting success[2]	4 (11%)	13 (72%)
Number of fledglings	6	26
Mean no. of fledglings/pair	0.4	3.7
Loss of adult females	4 (28%)	0

[1]Two females appeared mid-season and paired with bachelors.
[2]Number of nests that resulted in at least one fledgling surviving beyond the first week after leaving the nest.

Table 4: *Impact of recruitment by August 1997, following the September 1996 1080 possum poison operation, on the number of robins in each study area as determined by territory mapping, Pureora Forest Park.*

	Non-treatment area	Treatment area
Pre-operation (Sept 1996)	32 (21,11)[1]	28 (18,10)
Post-operation (Oct 1996)	32 (21,11)	16 (10,6)
Recruitment (Aug 1997)	33 (21,12)	36 (20,16)

[1]Figures in brackets are the number of males, females

Poison operation - August 1997

The August 1997 poison operation that included the Waimanoa study area encompassed 8577 ha. The Waimanoa study area was part of the second stage of the operation (5077 ha). Pre-feed carrot baits were spread during 5-7 August 1997 at a rate of 5 kg ha^{-1}. The toxic baits (1080-carrot baits, the toxin at 0.08% w/w) were distributed at 10 kg ha^{-1} on 29-30 August. There was 9.5 mm of rain during 2-3 September and a further 22 mm on 11-12 September. By the 23 September over 100 mm of rain had fallen since the poison operation.

The bait quality was checked by Department of Conservation staff. Chaff was considered to include any particle able to pass through a sieve of 5-mm square mesh. All 10 samples of bait checked contained less than 0.2% of chaff by weight of the processed carrots, and so was well within the guideline of 2.5%.

Impact of the poison operation on possums and rats

Possum trapping was carried out during July 1977 simultaneously in the treatment (Waimanoa) and post-treatment (Tahae) study areas to determine possum abundance prior to the aerial poison operation. The two trap lines in the treatment area resulted in 18.5 and 28.8 possums captured/100 trap-nights, with a mean of 23.7. By comparison, the two lines in the post-treatment area, which had been subjected to an aerial 1080 poison operation in September 1996, caught one possum; a mean of 0.8 possums captured/100 trap-nights.

The impact of the August 1997 poison operation on possums was determined by MAF Quality Management staff throughout the 8577 ha block that baits were distributed over. Fifteen lines were operated in the standard Department of Conservation manner, and two possums were caught, giving a mean of 0.22 captures/100 trap-nights (G. Cochrane, *pers. comm*). No post-poison operation monitoring for possums was carried out in the post-treatment area.

Rat tracking indices for the treatment area (Waimanoa) were at about 44% during June-August 1997, and at about 58% for the post-treatment area (Tahae) during the same period (Figure 2b). Following the poison operation, no rats were detected in the treatment area during September and October, and the indices rose to 7% by February 1998, late in the robin nesting season. By comparison, rat tracking indices for the post-treatment area during October 1997 to February 1998 remained high (67 - 80%).

Robin mortality during the 1997 poison operation

In the post-treatment area (Tahae), just one robin disappeared during the fortnight following the poison operation as determined by territory mapping (banded and unbanded birds; Table 5). This represented 2.0% of the 49 birds monitored. By comparison, in the treatment area (Waimanoa), three (8.6%) of 35 robins disappeared. There was no significant difference in the proportion of robins that disappeared from the two study areas (χ^2=0.750 with Yates correction, d.f.=1, P=0.386). The proportion of males that disappeared in the post-treatment area (8.7% of 23) was not significantly different to that of females (8.3% of 12) (χ^2=0.360 with Yates correction, d.f.=1, P=0.549).

If the mortality is determined for just those birds that were colour-banded and that would readily approach us for mealworms, then the percentage mortality was similar: 2.4% in the post-treatment area and 9.7% in the treatment area (Table 6). No dead robins were found.

Table 5: *Number of adult robins present in treatment (Waimanoa) and post-treatment (Tahae) study areas before and after an aerial 1080 possum poison operation in August 1997 as determined by territory mapping (banded plus unbanded robins in a defined area), Pureora Forest Park.*

	Total	Male	Female
Post-treatment area			
Pre-operation	49	27	22
Post-operation	48	26	22
Number disappeared	1	1	0
Treatment area			
Pre-operation	35	23	12
Post-operation	32	21	11
Number disappeared	3	2	1

Table 6: *Number of adult robins present in treatment (Waimanoa) and post-treatment study areas before and after an aerial 1080 possum poison operation in August 1997 as determined by monitoring banded robins that would approach for a food reward (mealworms), Pureora Forest Park.*

	Total	Male	Female
Post-treatment area			
Pre-operation	42	24	18
Post-operation	41	23	18
Number disappeared	1	1	0
Treatment area			
Pre-operation	31	20	11
Post-operation	28	18	10
Number disappeared	3	2	1

Robin nesting success in the 1997-98 season

Almost all nests of robin pairs in the treatment and post-treatment areas were found, and it is likely that only one or two were not detected. In the post-treatment area, 67 robin nests were found or known of. Twenty (29.9%) of the nests were successful (Table 7). At least 34 fledglings were reared by the 23 pairs (1.5 fledglings per pair) present at the start of the season. Five males and two females disappeared during the season. This represents 14.9% of the 47 birds present at the start of the season.

In contrast, in the treatment area, 30 nests were found or known of, of which 20 (66.7%) were successful (Table 7). At least 38 fledglings were reared by the 10 pairs, an average of 3.8 fledglings per pair. One male and one female disappeared during the breeding season, 6.3% of the 32 robins initially present. The proportion of robins that disappeared from the two study areas during the breeding season did not differ statistically (χ^2=0.0315 with Yates correction, d.f.=1, P=0.859).

Table 7: *Robin nesting success in the 1997-98 season following the August 1997 aerial 1080 possum poisoning operation, Pureora Forest Park.*

	Post-treatment area	Treatment area
Number of pairs monitored	23	10
Number of nests monitored	67	30
Nesting success[1]	20 (30%)	20 (67%)
Number of fledglings	34	38
Mean no. of fledglings/pair	1.5	3.8
Loss of adults	7 (15%)	2 (6%)

[1]Number of nests that resulted in at least one fledgling surviving beyond the first week after leaving the nest.

Table 8: *Impact of recruitment by June 1998, following the August 1997 1080 possum poisoning operation, on the number of robins within each study area as determined by territory mapping, Pureora Forest Park.*

	Post-treatment area	Treatment area
Pre-operation (Aug 1997)	49 (27,22)[1]	35 (23,12)
Post-operation (Oct 1997)	48 (26,22)	32 (21,11)
Recruitment (June 1998)	65 (32,27,6)	46 (23,20,3)

[1]Figures in brackets are the number of males, females, and unknowns

Status of the populations nearly a year after the 1997 poison operation

In the post-treatment area prior to the poison operation (August 1997) there were 49 robins present as determined by territory mapping (Table 8), 22 (44.9%) being females. By June 1998, there were 65 robins present (32.6% increase) in the same area of forest, of which at least 41.5% were female. By comparison, in the treatment area the population had increased from 35 before the poison operation to 46 in June 1998, a 31.2% increase (Table 8).

Discussion

Robins are known to eat carrot and cereal-based baits, and have been found dead after aerial 1080 possum control operations, especially in the 1970s when the toxin was distributed on unscreened carrot baits (Harrison, 1978a, b; Spurr, 1991; Spurr and Powlesland, 1997). Therefore, it was not unexpected that some robins in this study would disappear immediately after the toxic carrot baits had been distributed. However, the magnitude of the mortality (43-55% loss of birds) in September 1996 was a surprise. Six studies by Spurr (1991), using the 5-minute count technique to compare robin conspicuousness before and after poison operations of treatment and non-treatment areas, indicated that there was no significant mortality of North Island robin populations exposed to screened carrot 1080 baits. The much lower robin mortality (8-10% of birds) during the second experiment (August 1997) was closer to the level expected.

The level of mortality of colour-banded robins exposed to cereal baits containing brodifacoum has been at a similar magnitude to the September 1996 losses at Pureora. The mortality of robins following the aerial distribution of Talon 7-20 in two study areas on Kapiti Island (one coastal and one near the summit) during September (first application) and October 1996 (second application) was monitored. Observations indicate that 26% of the coastal (n=38) and 66% of the ridge-top robins (n=50) disappeared (R.A. Empson, *pers. comm.*). At Maruia, South Island robins (*Petroica australis australis* Sparrman) were monitored following the broadcast of Talon 20P by hand in October 1996. At the non-treatment site, 86% of 21 robins definitely survived, but only 52% of 23 robins at the treatment site definitely survived (Brown, 1997a).

It is plausible that the difference in robin mortality between the two 1080 operations in Pureora Forest Park was caused by the different amount of chaff or small fragments distributed with the baits. The hazard to birds of spreading chaff with baits was determined during poison operations in the 1970s; removal of chaff reduced bird deaths by about 50% (Harrison, 1978b).

Whether the robins that die during aerial 1080 poison operations do so as a result of eating bits of bait (primary poisoning) or invertebrates that have fed on baits (secondary poisoning) is not known. None of three robins autopsied after being found dead following the 1996 operation had carrot fragments in their digestive systems. This does not necessarily mean that they did not die of primary poisoning, because robins regularly regurgitate pellets of indigestible portions of food, such as insect exoskeletons and seeds (Powlesland, 1979). Therefore robins may regurgitate toxic foods from the crop and/or gizzard during the period between eating them and dying. Two of 13 robins at Pureora that ate mealworms coated with cinnamon, which is applied to 1080 baits partly to act as a repellent to birds (Spurr, 1993), almost immediately regurgitated them (R.G. Powlesland, *pers. obs.*). Other species of non-target insectivorous birds found dead after aerial 1080 possum control operations in Pureora Forest Park have been the tomtit (*Petroica macrocephala* Gmelin)(Nugent, Sweetapple and Whitford, 1996; Powlesland, Knegtmans and Marshall, 1998), grey warbler (*Gerygone igata* Quoy and Gaimard) (R.G. Powlesland, *pers. obs.*) and rifleman (*Acanthisitta chloris* Sparrman)(Nugent, *et al.*, 1996; Spurr and Powlesland, 1997). None of the crops and gizzards of three tomtits, two grey warblers and five riflemen contained bits of carrot. Further research is required to determine whether these species die from primary or secondary poisoning during aerial 1080 possum control operations.

Where nests could be checked, predators were responsible for at least 92% of 25 failed robin nesting attempts in 1996-97 and at least 94% of 36 in 1997-98 in the non-treatment areas at Pureora. Predators were responsible for a greater proportion of failed nesting attempts at Pureora than at

Kaharoa. Of 38 failed North Island robin nesting attempts found at Kaharoa during the 1993-94 season, at least 68% failed as a result of predation (Brown, 1997b). At Kowhai Bush, Kaikoura, of 589 South Island robin nesting attempts monitored during 1971-76, 61% were preyed upon (44-66% per year)(Moors and Flack, 1979). As well as predation, other factors result in nest failures, such as desertion for various reasons (weather related, death of an adult) and the occasional nest falling from its site. Taking all failures into account, nesting success evident in the three studies was 11% at Pureora in the non-treatment study area during the 1996-97 season, 18% at Kaharoa (Brown, 1997b) and 32% at Kowhai Bush (Flack, 1979). Therefore, the continued presence of robin populations on the North and South Islands, albeit as a disjunct distribution, seems to be due to the good survival of adults outside the nesting season and their ability to renest repeatedly during the nesting season. One pair at Kaharoa was recorded nesting 10 times without success in one season (Brown, 1997b). Nesting success of robins on two islands in the Marlborough Sounds without mammalian predators was much greater than for the three sites described above. On Allports Island just two (12.5%) of 16 nests found during 1973-76 failed, and on Outer Chetwode Island the failure rate was estimated to be less than 10% (Flack and Lloyd, 1978).

The greater nesting success of robins in the treatment areas at Pureora directly after the poison operations than occurred concurrently in the non-treatment areas (Tables 3 and 7) can largely be attributed to the success of the poison operations in killing most possums and rats (Figs. 2 and 3). Ship rats are known predators of robin eggs and nestlings (Brown *et al.*, 1998), and nest predation signs consistent with that described by Brown *et al.* (1996a) for ship rats were evident at Pureora. Possums are also known to take eggs and nestlings of forest birds (Brown, Moller and Innes, 1996). The removal of these two species by the 1080 poison operations probably contributed most to the improved robin nesting success. Stoats (*Mustela erminea* L.) are also killed during 1080 poison operations from secondary poisoning (Murphy *et al.*, 1999). Whether stoats are a significant predator of robin eggs and chicks is unknown. It is evident that possum and rat populations in the treatment areas remained sparse throughout the robin nesting season (September-February) following poison operations. These results were probably dependent on the large areas over which baits were distributed during both operations, so that little, if any, emigration of these mammals into the treatment areas occurred during the six months immediately after the operations.

The moderate nesting success (30%) of robins in the post-treatment area during the 1997-98 season suggests that the beneficial effect of aerial 1080 possum control operations on robin nesting can continue into the second nesting season. This result may have occurred because the study area was part of a large block over which poison baits were spread (37 525 ha) which bordered on to a block (2900 ha) where control of possums and rats was being carried out using bait stations (H. Matthew, *pers. comm.*). Thus the increase in predator numbers was probably the result of reproduction of the few remaining survivors, rather than immigration from outside the treated area.

The high robin nesting success in the treatment areas during 1996-97 (3.7 fledglings per pair) and 1997-98 (3.8 fledglings per pair) resulted in the status of the two populations being better one year after the 1080 operations than prior to the operations. This improvement was not just in robin density but also in the sex ratio. Before the possum control operations, both robin populations had about one female to two males, but one year later the ratio was almost one to one. It is not known how long this improved population status, both density and sex ratio, will remain. However, the nesting success of robins in the Tahae study area during the second breeding season (1.5 fledglings per pair) following the poison operation in 1996 and a subsequent further increase in density to June 1998 (Table 8), with the sex ratio remaining at almost 1:1, suggests that a decline in status will not occur until at least the third spring after the poison operation.

In areas at Pureora with no mammal predator control, the sex ratio was 1.5-2.0:1.0 (male:female) and the nesting success was low. Thus, the long-term viability of this population depends on no further mortality factors impacting on the adults unless they coincide with increased nesting success and recruitment. Such a scenario is possible after an aerial 1080-carrot possum control operation. Even if a few robins are killed by such operations, if both the rat and possum populations are substantially reduced just before the start of the robin breeding season, and a large area is involved (so that reinvasion of mammalian predators from neighbouring habitat is slow), the remaining robins can be expected to nest more successfully than they are able to when these predators are present at moderate densities. This enables the robin population to increase to above pre-poison levels within one year, and for the sex ratio to improve almost to 1:1.

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