Impacts of aerial 1080 possum control operations on North Island robins and moreporks at Pureora in 1997 and 1998

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Contents

Impacts of aerial 1080 possum control operations on North Island robins and moreporks at Pureora in 1997 and 1998

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ABSTRACT

This is the final report describing the results from the second and third years of a three-year programme to determine the costs and benefits of aerial 1080 possum control operations to North Island robins (*Petroica australis longipes*) and moreporks (*Ninox novaeseelandiae*) in Pureora Forest Park, North Island, New Zealand. During this study robins were individually colour-banded, and moreporks radio-tagged in both treatment and non-treatment study areas. A poison operation using carrot baits in August 1997 covered 8577 ha and incorporated the 300 ha Waimanoa study area. A poison operation using cereal baits in August 1998 covered just the 200 ha Long Ridge study area. After the 1997 operation, very few possums remained alive and rat foot-print tracking indices remained very low during the robin nesting season (September 1997–February 1998). Similarly, possum and rat population indices were much reduced after the 1998 operation, but rats and possums were found in a small portion of the study area, presumably because it did not receive baits.

Following both the 1997 and 1998 poison operations, there was no significant difference in the proportion of banded robins that disappeared from the non-treatment and treatment study areas. During the 1997/98 nesting season, the nesting success of robins was significantly better in the treatment area than in the non-treatment area. One year after the poison operation (spring 1998), the robin population in the treatment area had increased by 37% on the number present just prior to the poison operation, compared with 16.3% in the non-treatment area.

No radio-tagged moreporks were available in the treatment area during the 1997 poison operation, and all three radio-tagged in each of treatment and non-treatment areas were still alive two months after the poison operation in 1998.

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1. Introduction

Over the past 30 years there have been increasing attempts to reduce brushtail possum (*Trichosurus vulpecula*) populations in New Zealand because of the damage they do 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. One method of control involves the aerial distribution of carrot or cereal baits containing Compound 1080 (sodium monofluoroacetate), which achieves an average reduction in density of about 70% of populations near carrying capacity (Morgan et al. 1986) and can exceed 90% (Eason et al. 1994). Most operations are carried out in autumn and winter, but with a few in spring.

As well as possums, rodent populations, particularly those of the ship rat (*Rattus rattus* L.), are known to suffer high mortality (87–100%) during aerial 1080 possum poisoning operations (Innes et al., 1995). Since ship rats eat seeds, invertebrates, lizards, and birds and their eggs (Innes, 1990), including the eggs and young of North Island robins (Brown, 1997b), the major reduction in rat densities, albeit temporary, is a beneficial by-product of aerial possum control operations for forest ecosystem conservation.

Both native and endemic bird species have been found dead after aerial possum control operations (Spurr 1991, Spurr & Powlesland 1997). Various procedures have been implemented to reduce the number of birds killed, including screening out small fragments of bait, called 'chaff' that are created during production, that birds are more capable of swallowing, dyeing the 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 will reduce bird-bait encounters and so reduce bird mortality (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 of birds may be replacing other causes of mortality, such as winter starvation, or it may be additional to it. If it is additional to usual mortality then it may have considerable impact on the species' population dynamics, and therefore on its long term survival. This would be particularly relevant in forests where bovine tuberculosis is endemic in the possum population since control operations are carried out at 3–5 year intervals to prevent the spread of the disease.

Birds can be marked using colour bands or transmitters so that they can be individually monitored (Powlesland et al. 1998). Using such methods, the objective of the project was to determine the costs and benefits of aerial possum control operations to the North Island robin (*Petroica australis longipes*) and morepork (*Ninox novaeseelandiae*) in Pureora Forest Park. These species were chosen for the study because they have been found dead after aerial 1080 possum control operations (Spurr & Powlesland 1997) and are territorial throughout the year. Robins can be trained to approach observers for a reward of food, thus enabling the monitoring of sufficient numbers of this relatively small species (29 g) for comparison of results from treatment and non-treatment study areas. By comparison, moreporks (185 g) can carry transmitters and so can be relocated by radio-telemetry at regular intervals for several months to determine mortality. The results from the 1996 poison operation were presented in Powlesland et al. (1998). This report describes the results from the 1997 and 1998 poison operations.

2. Methods

2.1 STUDY AREAS

2.1.1 Names of treatment and non-treatment study areas in each year

The treatment and non-treatment areas for each year of the study are indicated in Table 1.

TABLE 1. NAMES OF THE STUDY AREAS THAT WERE USED AS TREATMENT AND NON-TREATMENT AREAS IN EACH YEAR.

YEAR	TAHAE	WAIMANOA	LONG RIDGE
1996	Treatment	Non-treatment	
1997	Non-treatment	Treatment	
1998		Non-treatment	Treatment

2.1.2 Tahae

This forest block (Fig. 1), part of the Waipapa Ecological Area, is bordered by Fletcher's and Ranginui Roads (Leathwick 1987). The study area consists of 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*), kahikatea (*Dacrycarpus dacrydioides*) and matai (*Prumnopitys taxifolia*), emergent over a mainly tawa (*Beilschmiedia tawa*) canopy. Other fairly common canopy and understorey species include hinau (*Elaeocarpus dentatus*), kamahi (*Weinmannia racemosa*), mahoe (*Melicytus ramiflorus*), miro (*Prumnopitys ferruginea*), totara (*Podocarpus totara*), maire species (*Nestegis* spp.), wheki (*Dicksonia squarrosa*), soft tree fern (*Cyathea smithii*) and supplejack (*Ripogonum scandens*). While generally sparse under the dense canopy, ground species often present include filmy ferns (*Hymenophyllum* spp.), hen and chicken fern (*Asplenium bulbiferum*), bush rice grass (*Microlaena avenacea*), *Blechnum fluviatile*, hookgrass (*Uncinia* spp.) and *Leptopteris hymenophylloides* (Leathwick 1987). Prior to this study, possum and rat control in the study area was carried out until March 1994 using 1080 poison (0.15% w/w) in cereal baits (Wanganui RS 5 pellets) in stations at 150 m intervals along lines separated by 150 m. It is not known when this control programme began or the frequency with which the stations were refilled.

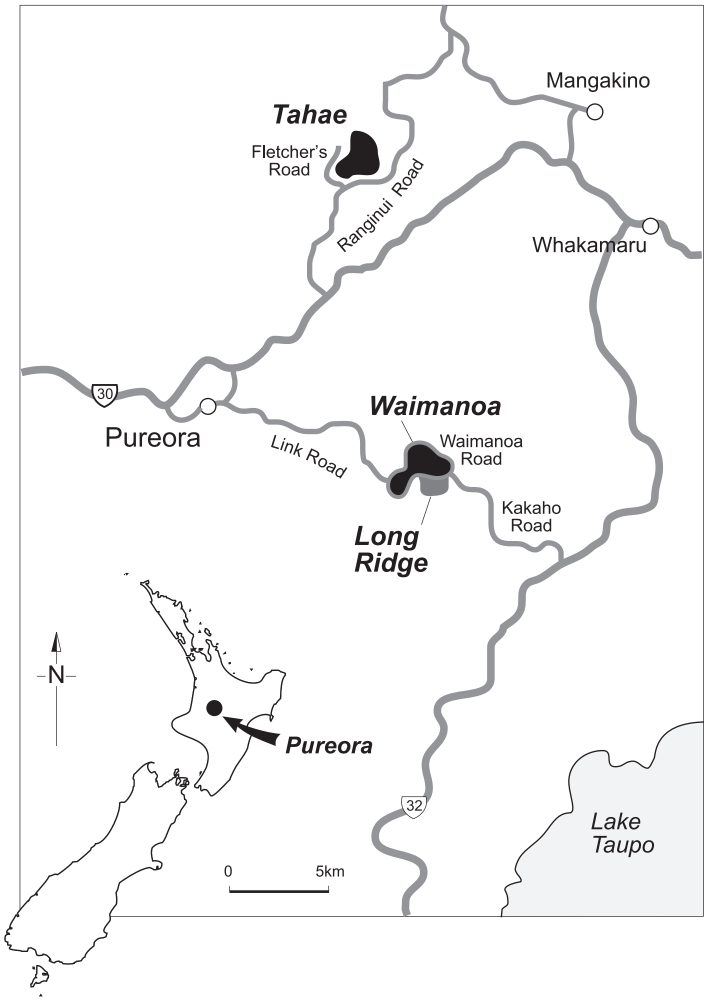

Figure 1. Locations of the three study areas at Pureora Forest Park.

2.1.3 Waimanoa

The Waimanoa study area is bordered by Waimanoa and Link Roads (Fig. 1). Although it comprises about 300 ha, some of it was not inhabited by robins and so only about 100 ha was regularly visited. It is rolling country, with altitude varying from 700 to 740 m a.s.l. Logging of mainly emergent podocarps occurred over some of the block during the 1970s, so the density of emergents is less in parts of the block than at Tahae. Toetoe (*Cortaderia fulvida*) and wineberry (*Aristotelia serrata*) are common on the former skid sites and logging tracks. There had been no possum control in the block in the previous ten years, but the forest to the north of Waimanoa Road was poisoned with 1080 carrot baits in winter 1993, and that to the south of Link-Kakaho Road with 1080 carrot baits in winter 1994 (J. Mason, pers. comm.).

2.1.4 Long Ridge

This study area, adjacent to Waimanoa (Fig. 1), is bordered by Long Ridge and Link Roads. It is 200 ha in area, but only about 100 ha was regularly visited to monitor robins and tomtits. It is rolling country, with altitude varying from 650 to 730 m a.s.l. The vegetation of this study area is much the same as that in Waimanoa, with logging in the 1970s having removed some emergent podocarps and created open areas now covered mainly by toetoe, wineberry, bush lawyer (*Rubus* spp.) and tree ferns, such as *Dicksonia squarrosa* and *Cyathea smithii.* 1080-carrot baits were distributed over the area in winter 1994.

2.2 CAPTURE AND MARKING OF BIRDS

Prior to capture attempts, most robins were fed mealworm (*Tenebrio molitor*) larvae in conjunction with tapping the lid against the mealworm container. This noise was made so that the robins associated the noise with being fed to encourage them to approach us for food, rather than us having to search for them. It is possible that robins trained to accept food rewards may be more likely to sample or eat novel food items. However, we consider this to be of low risk during our study because the offered food was alive and looked much the same as larvae of some native beetles in the forest, such as that of wireworms (*Conoderus exsul* or *Agryprus variabilis*), and quite different to a 1080 carrot or cereal bait, or a fragment of either.

Robins were captured using two methods—an electronically operated clap trap or a mist net. 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 colour bands obtained from the Banding Office, Department of Conservation.

Moreporks were caught in mist net rigs consisting of two 3 × 12 m nets (60 mm mesh size) erected one above the other using telescopic aluminium poles (Dilks et al. 1995). The top of the net was 7–8 m high. Owls were attracted to the rig by broadcasting various morepork calls or squeaky noises from an Aubudon bird caller through speakers, one on either side of the middle of the net about 20 m distant and 1–2 m above the ground. Most attempts to capture moreporks were made at dusk so that any owl could be seen when it arrived nearby, and caught in the net by switching the calls from one speaker to the other so that the bird flew into the net when flying from speaker to speaker. A numbered metal leg band was fitted to each morepork. A single stage transmitter (Sirtrack Ltd, Havelock North) was fitted using a back-pack harness design (Flux 1994, Karl & Clout 1987). The transmitters were 4–5 g in weight, signalled at 30 pulses per minute and had a transmission life of about nine months. The birds were then weighed and released.

2.3 MONITORING MARKED BIRDS

The survival of each banded robin was monitored by attracting and feeding it a few mealworms at least once a week from January 1997 to September 1998. To monitor nesting success we needed to locate nests. If the female was attracted she was 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 then we would follow her back to the nest. Once found, the nest location was marked nearby with track tape, and the nest visited about every third day to monitor the fate of its contents.

Each radio-tagged morepork was located during the day about once a week after it had been radio-tagged and until September 1998 to determine whether it was alive and its roost location.

2.4 RAT POPULATION INDICES

The proportion of baited tracking tunnels containing rat foot-prints was used to provide an index of rat abundance (King & Edgar 1977, Innes et al. 1995). We assumed that these indices directly reflected actual population densities (Innes et al. 1995, Brown et al. 1996a). One hundred tracking tunnels were placed at 50 m intervals along a circuit (Tahae) or three lines (Waimanoa and Long Ridge) through the study areas. Each tunnel was baited with peanut butter at both ends and left for one night. Data are expressed as percent 'available' tunnels with rat tracks; those tipped over, probably by possums, were deleted from analyses. Foot-print tracking indices in treatment and non-treatment study areas were taken on the same night to account for differences due to weather and the impact of other variables on rat activity.

2.5 POSSUM POPULATION INDICES

The capture rate of possums in leg-hold traps (Victor No. 1) was used to provide an index of possum abundance (Warburton 1996). Two trap lines were set up in both treatment and non-treatment areas, each line consisting of 20 traps spaced at 20 m intervals along a taped line. Lure, a mixture of 5 kg of white flour and 1 kg of icing sugar, was smeared on the tree just above each trap, and re-applied daily if necessary. The trap lines in 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. Each post-operation trap line was 200 m from a pre-operation line.

3. Results

3.1 1997 POISON OPERATION

3.1.1 Poison drop

The August 1997 poison operation that included the Waimanoa study area encompassed 8577 ha, and was carried out by Environment Waikato. 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 sowing rate of 5 kg/ha. The toxic baits (1080 carrot baits, the toxin at 0.08% w/w) were distributed at 10 kg/ha on 29–30 August from a hopper slung under a helicopter. Bait toxin analyses are available for 10 samples from the first stage of the operation when the toxin concentration was expected to be 0.15% w/w. The determinations at the Toxicology Laboratory, Landcare Research, Lincoln gave a mean toxicity level of 0.141% (range = 0.12–0.17, S.D. = ±0.0137). No bait samples were available from the second stage of the operation (0.08% w/w 1080), which included the Waimanoa study area, for toxin level analyses.

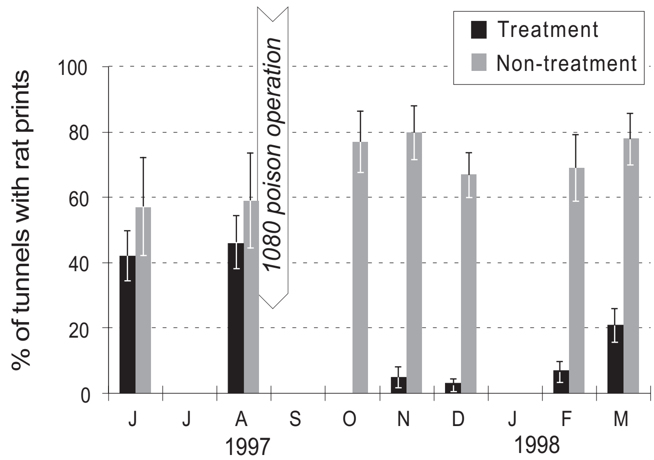

Figure 2. Tracking indices of rat abundance (percentage of tunnels with foot-prints) in treatment and non-treatment study areas before and after an aerial 1080 possum poisoning operation on 29–30 August 1997 at Pureora. Bars are standard errors from dividing the 100 tunnels into groups of 25.

Chaff content of samples of bait was checked by Department of Conservation staff. Chaff or fine fragments 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 were well within the guideline of 2.5%. There was 9.5 mm of rain during 2–3 September and a further 22 mm on 11–12 September. By 23 September over 100 mm of rain had fallen since the poison baits had been distributed.

3.1.2 Impact on rats and possums

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

Possum indices prior to the poison operation were determined during July 1997, in both the treatment and non-treatment study areas. 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 non-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 over which baits were distributed. Fifteen lines were operated using Department of Conservation protocols (Warburton 1996), 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 non-treatment area.

3.2 1998 POISON OPERATION

3.2.1 Poison drop

The August 1998 poison operation encompassing just the Long Ridge study area (c. 200 ha), was contracted to Epro Ltd, Taupo. There was no pre-feeding with non-toxic baits; the toxic baits (1080 Wanganui No. 7 baits, toxin at 0.08% w/w) being distributed at 5 kg/ha on 4 August. Two samples of bait were submitted to the National Chemical Residue Laboratory (Ministry of Agriculture & Forestry, Wallaceville Animal Research Centre, Upper Hutt), with the analyses indicating the toxin level at 0.095 and 0.106%. JWK assisted with the loading of the baits into the hopper slung under the helicopter. He observed that the baits were in excellent condition, appearing to be freshly made, and the bags of baits contained little dust and few fragments.

The first two nights after the baits were spread were frosty, followed by a few showers during 7–9 August. On 10 August, 58 mm of rain fell, and by 16 August, 200 mm had fallen and baits on the ground were saturated and disintegrating.

3.2.2 Impact on rats and possums

The rat tracking index for the treatment area (Long Ridge) was 46% on 21 July 1998, and 45% for the non-treatment area (Waimanoa) on the same date. On 16 August, when the post-operation rat monitoring was carried out, the index for the treatment area was 9%, and 41% for the non-treatment area (% of 100 tunnels in each case). At Long Ridge, rat foot-prints were present in tracking tunnels about 500 m from the edge of the poison area, and in a few tunnels at the edge of the study area about 50 from Link Road.

Possum indices prior to the poison operation were determined during 16–19 July (traps closed because of rain for one night) in both treatment and non-treatment (beyond the boundaries of the Long Ridge study area) study areas. The trap lines in the treatment and non-treatment areas resulted in a mean of 9.7 and 13.2 possums captured/100 trap-nights respectively (Table 2). The possum indices after the poison operation were determined during 18–20 August. The trap lines in the treatment and non-treatment areas resulted in a mean of 2.5 and 8.6 possums/100 trap-nights.

TABLE 2. POSSUM MONITORING (POSSUMS PER 100 TRAP-NIGHTS) RESULTS FOR BEFORE AND AFTER THE AUGUST 1998 POISON OPERATION AT LONG RIDGE STUDY AREA, PUREORA FOREST PARK.

	NON-TREATMENT AREA			TREATMENT AREA		
	Line 1	Line 2	Mean	Line 1	Line 2	Mean
Pre-operation	13.9	12.4	13.2	8.8	10.7	9.7
Post-operation	3.5	13.7	8.6	0.0	5.0	2.5

3.3 ROBINS

3.3.1 Impact of the 1997 poison operation

In the non-treatment area (Tahae), of the 42 colour-banded robins that would approach us for mealworms, just one (2.4%) disappeared during the fortnight following the poison operation. By comparison, in the treatment area (Waimanoa), three (9.7%) of 31 birds disappeared. There was no significant difference in the proportion of robins that disappeared from the two study areas ($c^2 = 0.695$ with Yates correction, d.f. = 1, P = 0.404). The proportion of males that disappeared in the treatment area (10.0%, 2 of 20) was not significantly different to that of females (9.1%, 1 of 11) ($c^2 = 0.306$ with Yates correction, d.f. = 1, P = 0.580). No dead robins were found incidentally while we worked in either of the study areas.

3.3.2 Impact of the 1998 poison operation

In the non-treatment area (Waimanoa), of the 42 colour-banded robins that would approach us for mealworms, two (4.8%) disappeared during the fortnight following the poison operation. None of 17 robins in the treatment area (Long Ridge) disappeared during the same period.

3.3.3 Nesting success in 1997/98

We believe we located most robin nests during the 1997/98 season. In the non-treatment area, 67 robin nests were found or known of. Twenty (29.9%) of nesting attempts were successful. At least 34 fledglings were reared by the 23 pairs (1.5 fledglings/pair) present at the start of the season. Five males and two females disappeared during the nesting season, 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. The difference in nesting success between the two study areas is significant ($c^2 = 10.1$ with Yates correction, d.f. = 1, $P < 0.01$). The proportion of robins that disappeared from the two study areas during the nesting season did not differ statistically ($c^2 = 0.032$ with Yates correction, d.f. = 1, P = 0.859).

3.3.4 Status of populations in September 1998

In the non-treatment area prior to the August 1997 poison operation there were 49 robins present as determined by territory mapping, 22 (44.9%) being females. In September 1998, there were 57 robins present in the same area, a 16.3% increase, and the proportion of females (45.6%) had not changed significantly ($c^2 = 0.015$ with Yates correction, d.f. = 1, P = 0.903).

By comparison, in the treatment area the population increased from 35 before the poison operation to 48 a year later, a 37% increase. In addition, the proportion of females in the population of the treatment study area increased from 34.3% to 41.7%, the increase not being significant ($c^2 = 0.206$ with Yates correction, d.f. = 1, P = 0.650).

3.4 MOREPORKS

3.4.1 Impact of the poison operations

No radio-tagged moreporks were present in the treatment area during the 1997 poison operation. Three radio-tagged moreporks were present in each of the non-treatment and treatment study areas during the 1998 poison operation. All six birds were alive two months after the distribution of the poison baits.

3.4.2. Mortality prior to poison operations

Of the 28 moreporks captured and tagged in the areas associated with the aerial 1080 possum poisoning study, 17 (61%) were alive and had functioning transmitters by the time the poison operations were carried out. The transmitters on five birds failed within six months, even though they had an expected field-life of nine months, and the fate of the birds wearing them could not be ascertained. Another six tagged birds died before the poison operations, one probably because its transmitter harness became loose and impeded its foraging. The other five birds died in winter.

In winter 1996, of 15 birds with functioning transmitters in Pureora Forest Park, including five in the Waipapa bait-station study area, three (20%) died in winter (none in the bait-station block). In winter 1997, three (43%) of seven birds died, but none of six birds died in winter 1998. Although the mean capture weight of the six birds that died during the 1996 and 1997 winters (170.7 g, S.D. = ±10.0) was less than that of the other 21 birds that survived these winters (185.9 g, S.D. = ±19.6), the difference was not significant (*t*-test = 1.81, d.f. = 25, P = 0.0817).

4. Discussion

4.1 POSSUM AND RAT MORTALITY DURING POISON OPERATIONS

There is no point in carrying out an aerial 1080 possum control operation designed to result in little or no robin mortality if it does not kill most possums. Ideally, for ecosystem conservation in areas inhabited by robins, the operation should result in a residual possum trap-catch rate of less than 3 possums per 100 trap-nights (see Saunders 1999) and insignificant robin mortality. Although minimal monitoring was carried out after the 1996 poison operation (Powlesland et al. 1998), the monitoring that was done indicated that both the 1996 and 1997 operation operations killed most possums. By comparison, three possums were caught along one of the trap lines operated in the treatment area following the 1998 operation, and none along the other. Based on observations made while monitoring robins through the study area, we suspect that these possums survived the poison operation because they occupied a small area that did not receive baits, rather than because there were too many possums for the density of baits or that the baits were unpalatable. Alternatively, the trapped possums could have migrated into the small poison area from contiguous habitat after the poison operation.

Indices of rat populations using foot-print tracking tunnels indicated that the aerial carrot 1080 possum poisoning operations at Pureora in 1996 (Powlesland et al. 1998) and 1997 (Fig. 2) reduced rat populations markedly. However, the 1998 poison operation resulted in the rat tracking index in the treatment area declined to only 9%. As for possums, rat foot-prints were present in tracking tunnels in an area over which baits apparently were not spread, and in a few tunnels at the edges of the study area because baits had to be a least 50 m from roads. Aerial 1080 cereal bait operations can be expected to reduce ship rat populations to an index of less that 5% (Innes et al. 1995).

The poison operations during this study at Pureora were planned to be carried out in July–August, just before the robins started nesting. The expectation was that ship rat populations would not recover to former levels before and during the following nesting season (September–February), thus allowing the birds to nest more successfully than if the poison operation was carried out in autumn (March–May), as is more usual (when suitable weather conditions for poison operations are more frequent). During both nesting seasons, rat tracking indices remained below 10%, much lower than pre-poison levels (94% in June 1996 (Powlesland et al. 1998) and 44% in August 1997 (Fig. 2)). While frequent rain in July–August can delay aerial poison operations, the use of toxic baits without pre-feeding with non-toxic baits reduces delays. The difference in nesting success of some forest bird species at 5% or less rat tracking index with that of 10–20% can be quite marked. For example, robins nesting in the Waipapa bait station area, Pureora, had 70.6% nesting success (n = 34) during the 1996/97 season when rat tracking indices averaged 6.5%, but only 47.6% success (n = 42) the following season when rat tracking indices averaged 12.5% (H.J. Speed, pers. comm.).

4.2 ROBIN MORTALITY DURING THE POISON OPERATIONS

Robins are known to eat both carrot and cereal-based baits, and have been found dead after aerial 1080 possum control operations, especially in the 1970s when unscreened carrot baits were distributed (Brown 1997a, Harrison 1978a, b, Spurr 1991, Spurr & Powlesland 1997). Therefore, it was not unexpected that some robins during this study would disappear immediately after toxic baits had been distributed. However, the magnitude of the mortality (43–55% loss of robins) after the first carrot operation in September 1996 was unexpected (Powlesland et al. 1998). The high level of mortality was considered to have been caused by much toxin-coated chaff being distributed with the baits (Lorigan 1996). 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).

The two differences in the baits used in the 1996 and 1997 carrot bait operations was the reduced sowing rate (15 kg/ha and 10 kg/ha respectively) and the lower incidence of chaff in the second operation. The result of 9.7% of monitored robins disappearing from the treatment area during the 1997 operation, compared with 54.5% in 1996 (Powlesland et al. 1998), suggests that reducing the sowing rate of toxic bait and the amount of chaff resulted in reduced robin mortality.

The further reduction in sowing rate to 5 kg/ha and a change from carrot to cereal bait for the 1998 experiment resulted in robin mortality being reduced to nil. This result was unexpected because dead robins had been found previously after aerial 1080 possum control operations using cereal baits. For example, an operation carried out at Waitotara, Wanganui Conservancy, in March 1998 using Wanganui No. 7 1080 baits (4 kg/ha, toxin at 0.15% w/w) resulted in 10 (26.3%) of 38 colour-banded robins that would readily approach for mealworms disappearing within three weeks (N. Marsh, pers. comm.). The level of mortality of colour-banded robins exposed to cereal baits containing brodifacoum was of a similar magnitude. At Maruia, South Island robins (*Petroica australis australis*) were monitored following the broadcasting of Talon 20P by hand in October 1996. At the non-treatment site, 14% of 21 robins disappeared, and at the treatment site 48% of 23 robins disappeared, the difference being significant (Fisher exact test, P = 0.0245) (Brown 1997).

Given that the 1998 Pureora aerial 1080 possum control operation was the first to result in no robin mortality and it encompassed a relatively small area, further monitoring of colour-banded robins is warranted when large scale possum control operations are being carried out using 1080 cereal baits. Even so, the results of the three operations at Pureora suggest that as long as bait production and quality protocols of the Department of Conservation are strictly adhered to, robin mortality is unlikely to differ significantly from that in non-treatment areas. Negligible or nil robin mortality may be the norm in future aerial 1080 possum poisoning operations as research leads to improvements in bait quality, reduced bait density and lower toxin levels while still achieving sufficient control of possum populations.

4.3 ROBIN NESTING SUCCESS

In the 1995/96 season, prior to any poison operation, nesting success was 22.2% of 18 nests found in the Tahae and Waimanoa study areas combined (Powlesland et al. 1998). Similarly, in 1996/97 in the non-treatment study area, nesting success was just 11% of 35 nests. Predators were responsible for most failed robin nesting attempts; at least 84.6% of 26 failed attempts in 1996–97 where the reason for the failure was determined (Powlesland et al. 1998). Two other studies have shown similar robin nesting success where introduced mammalian predators were not controlled. At Kaharoa, central North Island, 16% of 43 nesting attempts in the 1993/94 season were successful (Brown 1997a), and at Kowhai Bush, Kaikoura, 32% of 521 nesting attempts during 1971–77 were successful (Flack 1979).

In contrast, nesting success in the two Pureora study areas immediately after the poison operations was much greater. In 1996/97 at Tahae, nesting success was 72% (n = 18)(Powlesland et al. 1998), and in 1997/98 at Waimanoa it was 67% (n = 30). This improved nesting success can be attributed to the poison operations killing almost all possums and rats, both of which are predators of robin eggs and nestlings (Brown et al. 1996b, Brown 1997b, Brown et al. 1998).

The moderate nesting success (30%) of robins in the Tahae study area during the second season (1997/98) after the 1996 poison operation 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 (37 525 ha) over which poison baits were spread. Away from the margins of the block, the gradual increase in predator numbers was probably the result of reproduction of the few survivors, rather than immigration from outside the treatment area. In July 1997, the possum index was 0.8 possums/100 trap-nights, indicating that the possum population had recovered little in the previous 10 months. In August 1997, just before the robins started nesting, the rat index was 58%, compared with 85–95% during May–June 1996 (Powlesland et al. 1998). Thus, while the rat population index had increased from its low of 5% immediately after the poison operation, it had not recovered to its former level one year later when the robins started nesting in the second season after the poison operation.

4.4 STATUS OF ROBIN POPULATIONS A YEAR AFTER THE 1997 POISON OPERATION

The high nesting success in the treatment areas during 1996/97 (3.7 fledglings/pair) (Powlesland et al. 1998) and 1997/98 (3.8 fledglings/pair) resulted in there being greater numbers of robins in both study areas one year after each 1080 operation than before. By August 1997 in the Tahae study area, the population had increased from 28 to 36, a 28% increase (Powlesland et al. 1998). Similarly, by September 1998 in the Waimanoa study area, the number of robins had increased from 35 to 48, a 37% increase.

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 0.7–0.8:1 (Powlesland et al. 1998). It is not known how long this improved population status, in relation to both density and sex ratio, will continue. However, the nesting success of robins in the Tahae study area during the second breeding season following the poison operation in 1996 (1.5 fledglings/pair) and a subsequent further increase in density to September 1998 (16%), with a sex ratio of 0.8:1, suggests that if a decline does eventuate, it will not be evident until at least the third spring after the poison operation. With a more even sex ratio, the effective population size is still larger than before the operation.

4.5 MOREPORK MORTALITY

Too few radio-tagged moreporks were available during each of the three aerial possum control operations to state with any confidence what impact the operations had on the populations.

Overall, 18% of 28 radio-tagged moreporks died in winter before the poison operations. The deaths occurred in the first two winters when frosty weather was frequent, but none died during the very mild winter of 1998 when few frosts occurred. Almost the entire diet of Pureora moreporks, as determined from indigestible prey remains in regurgitated pellets, was of large nocturnal invertebrates, particularly adult beetles of the families Scarabaeidae and

Cerambycidae, stick insects (Phasmida), tree wetas (*Hemidiena* spp.) and spiders (Araneae) (Haw 1998). Frosty weather may dramatically reduce prey availability to moreporks presumably by reducing or preventing the movements of nocturnal invertebrates. We were unable to age the captured moreporks (adult or juvenile) and so it has not been possible to relate subsequent mortality to age and therefore possible foraging experience.

It is difficult to determine whether the carrying of transmitters by the five birds that died in winter was a factor in their deaths. The mean weight of the transmitters and harnesses was about 5 g, 2.2 to 3.2% of the heaviest and lightest morepork weights respectively. Therefore, even for the lightest bird, the transmitter and harness were less than the 4–6% guideline given for flighted birds greater than 50 g (Kenward 1987). The fact that moreporks died during the first two winters when frosts regularly occurred, but not during the very mild winter of 1998 when very few frosts were evident, suggests that prey availability may have been a contributing factor.

4.6 CONCLUSIONS

In areas at Pureora where no mammal predator control had been carried out, the robin sex ratio was 1.5–2.0:1.0 (male:female) and their nesting success was low (10–20% of nesting attempts fledged chicks). Thus, the long-term viability of such populations depends on no further mortality events impacting on the adults unless they coincide with increased nesting success and recruitment. Such a scenario is possible after an aerial 1080 possum control operation, whether carrot or cereal baits are used, from the results of our studies at Pureora. Even though a poisoning operation may lead to the death of some robins, if it is carried out just before the start of the robin nesting season (July–August), both the rat and possum populations are substantially reduced (rats to less than 5% tracking index, possums to less than 2 captures/100 trap nights), 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. In this case, it enables the robin population to increase to above pre-poison levels within one year, and for the sex ratio to improve to about 1:0.9 (male:female). However, because of the low level of replication during this study (each species monitored in just one treatment and non-treatment study area each year) it has limited power in predicting impacts of future aerial 1080 operations on robins.

Too few radio-tagged moreporks were monitored during this study to determine the impact of aerial 1080 possum poisoning operations on the species. A team of researchers could successfully carry out such a study in future if their objective is just to capture and monitor this species, and they are experienced in setting up and operating canopy-height mist-net rigs (Dilks et al. 1995), rather than nets set up on telescopic poles.

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