Evaluating the impacts of 1080 possum control operations on North Island robins, North Island tomtits and moreporks at Pureora—preliminary results

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CONTENTS

Abstract

This report describes the results from the first two 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*), North Island tomtits (*Petroica macrocephala toitoi*) and moreporks (*Ninox novaeseelandiae*) in Pureora Forest Park. Prior to this study, the five-minute count technique had been used to quantify mortality of forest passerines during aerial possum control operations. During this study robins were individually colour-banded, and the moreporks radio-tagged at both treatment and non-treatment study areas. The poison operation took place in mid September 1996 (carrot baits, 15 kg/ha, 1080 0.08% ww). An audit after the operation indicated that only 9.9% wastage (chaff) by weight was produced, rather than the expected c. 20%. This suggests that the other 50% of the expected chaff was not screened out and so was made toxic and distributed with the baits. No possums were trapped in the treatment area during October and December 1996. Rodent population indices from foot-print tracking tunnels indicated the rat population (known to be mainly ship rats (*Rattus rattus*)) had declined markedly in the treatment area (94% in June 1996 to 5% in October 1996) following the poison operation, and indices remained low (5–10%) during the robin nesting season (October-February). Twelve (54.5%) of the 22 banded robins in the treatment area disappeared during the fortnight immediately following the poison operation, but none of 24 in the non-treatment area. If the mortality is considered with regard to the number of banded and unbanded robins in a defined area, 12 (42.8%) of 28 robins disappeared from the treatment area, but none of 32 in the non-treatment area. All three robins found dead following the operation tested positive for 1080. In the treatment area, nesting success (72%, n=18 nests) and mean number of fledglings produced per pair (3.7, n=7 pairs) was much greater than in the non-treatment area (11%, n=35 nests; 0.4, n=14 pairs). The high nesting success in the treatment area resulted in the number of robins present just before the start of the next nesting season (August 1997) being 36, a 28.6% increase in the number present prior to the poison operation. In contrast, the numbers present in the non-treatment area remained much the same, 32 in September 1996 as compared with 33 in August 1997. All five tomtits, including two banded birds, that were regularly fed in the treatment area disappeared immediately after the poison operation. No tomtits were monitored in the non-treatment area. One of six radio-tagged moreporks (16.7%) in the treatment area was found dead during the poison operation and tested positive for 1080. The single radio-tagged morepork in the non-treatment area was alive several months afterwards.

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. Currently, the common method of control involves the aerial broadcasting of carrot or pollard baits containing Compound 1080 (sodium monofluoroacetate), which can achieve a reduction, on average, 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.

Birds have been found dead after aerial possum control operations, including native and endemic species (Spurr 1991). Various procedures have been implemented to reduce the number of birds killed, including screening out small fragments of bait that birds are more capable of swallowing, dying 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 would 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 regularly there, often annually or biennially (Livingstone 1991), to prevent the spread of the disease.

In order to monitor the impact of possum control operations on populations of small passerines in indigenous forests the 5-minute count technique (Dawson & Bull 1975) has been used (Spurr 1991, 1994). This has involved monitoring the bird communities before and after poison operations in treatment and non-treatment study areas. Since most bird species are recorded as calling during the counts, the results reflect species conspicuousness, rather than numbers. Thus, measures of mainly vocal conspicuousness are used as indices of bird numbers, and by comparison of before and after results, the level of mortality. One problem with this method is that a 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 (paired versus unpaired male, Powlesland 1983). Thus, as might be expected, the 5-minute count method has provided some anomalous results. For example, the indice for a North Island robin (*Petroica australis longipes*) population monitored in one of eight trials in winter 'increased' in the treatment block following a toxic carrot operation (Spurr 1991). This is very unlikely to reflect an increase in

robin numbers since the species does not breed in winter and individuals are particularly sedentary and territorial (RGP pers. obs.).

Thus, reviewers of the impacts of 1080 operations on forest birds concluded that the 5-minute count technique was 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 reviewers 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 the present project is to determine the **costs and benefits** of aerial possum control operations to North Island robins and moreporks (*Ninox novaeseelandiae*) in Pureora Forest Park. These were chosen for the study because individuals of both species have been found dead after 1080 possum control operations (Spurr 1991) and are territorial throughout the year. In addition, robins can be trained to approach observers for a reward of food, thus enabling the monitoring of sufficient numbers of this relatively small species (180 mm length, 28 g) for the comparison of results from treatment and non-treatment study areas. By comparison, moreporks (290 mm length, 185 g) can carry transmitters and so can be relocated by radio-telemetry at regular intervals for several months to determine mortality. This report describes the results of the first year's field programme, jointly funded by the Department of Conservation and the Animal Health Board, to meet the objective.

2. Methods

2.1 STUDY AREAS

2.1.1 Climate

The two study areas referred to in this report are part of the Pureora Forest Park situated in the central North Island on the western side of Lake Taupo (Fig. 1). The climate at Pureora (Fig. 1) is cool, moist and calm. The mean annual temperature at Pureora Village, from records for 1947 to 1980, is 10.5°C, with monthly means ranging from 5.4°C in July to 15.6°C in February (New Zealand Meteorological Service 1983). Frosts are common, averaging 87 per year. The annual rainfall averages 1804 mm, with monthly averages ranging from 106 mm in January to 197 mm in July (New Zealand Meteorological Service 1983).

2.1.2 Tahae

The treatment study area is known locally as Tahae (Fig. 1). This forest block, 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). 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

FIGURE 1. LOCATIONS OF TREATMENT (TAHAE) AND NON-TREATMENT (WAIMANOA) STUDY AREAS AT PUREORA.

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*). Over the eastern third of the study area, emergents are less frequent and rewarewa (*Knightia excelsa*), fivefinger (*Pseudopanax arboreus*) 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*), bush rice grass (*Microlaena avenacea*), *Blechnum fluviatile*, hookgrass (*Uncinia* spp.) and *Leptopteris hymenophylloides* (Leathwick 1987). Possum and rat control in this study area was carried out until March 1994 using 1080 poison (0.15%) in cereal baits (Wanganui RS 5 pellets) in stations at 150 m intervals.

2.1.3 Waimanoa

The non-treatment study area is called Waimanoa, being bordered mainly by Waimanoa Road, and Link Road (Fig. 1). Although the block comprises about 300 ha, some of it is not inhabited by robins and so, to date, only about 100 ha is regularly visited for field work. 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 block during the 1970s and 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 through the forest. There has been no possum control in the block recently, 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.

2.2 CAPTURE AND MARKING OF BIRDS

North Island robins were captured using two methods—an electronically operated clap trap or a mist net. Prior to capture attempts, most 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 the noise with being fed to encourage them to approach us in future for food, rather than us having to search for them. While fledgling and juvenile robins could often be fed beside the trap the first time it was presented, adults were wary of the trap and so had to be fed near it for a few visits before they would take mealworms right beside the trap and not dart away immediately. 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 a numbered metal leg band and an individual combination of colour bands (size B, butt bands) obtained from the Banding Officer, Department of Conservation.

North Island tomtits were captured using a mist net. Prior to capture, each tomtit was trained to approach us for mealworms in the same manner as robins. Once captured, each tomtit was fitted with a numbered metal leg band and an individual combination of colour bands (size A, butt bands) obtained from the Banding Officer, Department of Conservation.

Moreporks were caught in mist net rigs consisting of two 3 m by 12 m nets (60 mm mesh size) erected one above the other using telescopic aluminium poles. The top of the top net was at 7–8 m high. The owls were attracted into the net by broadcasting the territorial 'morepork' call through speakers, one on either side of the middle of the net about 20 m distant and 1–2 m above the ground. Usually a bird was attracted at dusk so that it 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 band (size E) was fitted to the captured bird's leg, and wing length (flatten wing from tip of longest primary to carpal flexure) and tail length (base of central feathers to the tip of the longest feather) recorded. Then a single stage transmitter (from Sirtrack Ltd, Havelock North, New Zealand or Holohil Systems Ltd, Ontario, Canada) was fitted using a back-pack harness

design (Karl & Clout 1987, Flux 1994). The transmitters were 4–5 g in weight, signalled at 30 pulses per minute and had a transmission life of about nine months. Afterwards the bird was 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. To find nests to monitor breeding success, if the female of a pair 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. Finding nests often took several attempts because the robins could fly through the undergrowth much quicker than we could scramble through it, especially the supplejack thickets! Once found, the nest location was marked nearby with track tape, and the nest visited at least every third day to monitor the fate of its contents. If the eggs or nestlings were preyed upon, the nest and area nearby were inspected closely for clues to the identity of the predator.

Each radio-tagged morepork was located during the day about once a week to determine whether it was alive and its roost location. Roost sites used more than once were marked and, if possible, the ground beneath cleared of litter and ground plants so that any regurgitated pellets could be more readily seen. The pellets of indigestible prey fragments were dried and stored individually for subsequent prey identification.

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). 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.

2.5 POSSUM POPULATION INDICES

The capture rate of possums in leg-hold traps was used to provide an index of possum abundance. Thirty-four leg-hold traps were set at 20 m spacings along a track in the study area. 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. Each captured possum was marked by clipping the fur from its tail tip (to detect recaptures) and then released (none had 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 & Moors 1996).

3. Results

3.1 ROBINS

3.1.1 Numbers banded

Banding of robins in the Tahae study area began in September 1995. As at 15 September 1996 (just prior to the poison operation), 43 robins had been banded; nine nestlings, two fledglings (young that have left the nest but were being fed by their parents), five juveniles (young recently independent of parental care and with no or very little white feathering on breast) and 27 adults. Of the nestlings and fledglings banded during the 1995–96 season, only one established on a territory within the study areas. It is possible that one or more of the others established territories beyond the study areas.

In the Waimanoa study area banding of robins began in March 1996. As at 15 September 1996, 27 had been banded, one juvenile and the rest adults.

3.1.2 Proportion of bachelors

In October 1995, of 18 male robins in the Tahae study block, nine (50%) were bachelors. By comparison, of the 19 males evident there in September 1996 (start of the nesting season), six (31.6%) were bachelors. At Waimanoa in September 1996, eight (40.0%) of the 20 males in the study block were bachelors.

3.1.3 Nesting success in the 1995–96 season

In total, 18 robin nests were found during the 1995–96 nesting season, 15 at Tahae and three at Waimanoa. Only five (27.7%) nests produced fledglings. Of the 13 unsuccessful nests, five failed due to egg predations, four due to chick predations, two were abandoned (not observer induced) and two failed for unknown reasons. At least a further six nests, and probably up to 11, were not found but were evident by the appearance of fledglings or the behaviour of the pair. Four of these resulted in fledglings.

Pairs that start nesting early in the breeding season (by mid September) have the potential to raise three broods. None of the four pairs monitored throughout the season raised three broods, although one pair had fledged two broods and the female was incubating her third clutch when it was preyed upon. Two pairs raised two broods, one raised one and the fourth pair raised none.

Of 12 pairs present at the start of the 1995–96 breeding season, all males were present at the end, but two females (16.7%) disappeared at the time their nests were preyed upon. In addition, one other female disappeared in late December-January when she may have been nesting. Assuming this was the case, a total of 25% of females disappeared during the breeding season.

3.1.4 Poison operation

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 operation was carried out by Environment Waikato under contract to the Animal Health Board. The main objective was to lower the possum population in this bovine tuberculosis area so as to significantly reduce the number of reactor cattle on farms adjacent to the forest block (Lorigan 1996). The Tahae treatment site was part of the second stage of the operation (16 587 ha). Pre-feed carrot baits were spread during 12–14 August 1996 at a rate of 7 kg/ha. 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) 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%. The wastage for the first stage of the operation was calculated to be 23.1%, but only 9.9% for the second stage (Lorigan 1996). This suggests that the other approximately 50% of the expected wastage was not screened out, and was made toxic and distributed with the baits.

3.1.5 Impact of the poison operation on possums and rats

Possum trapping in the treatment area during October 1995 gave an index of abundance of 6.2 possums/100 corrected trap nights, but 3.2 possums during July 1996 when the monitoring was disrupted by rain. No possums were trapped in the treatment area during October and December 1996 following the poison operation. By comparison, in the non-treatment area monitoring during December 1995 resulted in 8.9 possums/100 corrrected 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.

Monitoring rat populations in June 1996 resulted in 94% of tracking tunnels having foot-prints in the treatment area, and 61% in the non-treatment area (Fig. 2). Rat population indices for the non-treatment area after the poison operation and during the robin nesting season (September-February) declined from 83% in October 1996 to 48% in January 1997 (Fig. 2). During autumn and winter, the rat index in the non-treatment area varied between 35% and 48%, suggesting that there was little change in rat abundance. In contrast, in the treatment area, the low tracking tunnel index indicated that few rats remained immediately after the poison operation, and it increased only marginally during the nesting season (5 to 10%)(Fig. 2). However, during autumn and winter, the rat population index increased to 58%.

3.1.6 Mortality during the poison operation

In the non-treatment area, no robins disappeared during the fortnight following the poison operation (18 September to 2 October 1996) as determined by territory mapping (all robins whether banded or not)(Table 1). However, in the

FIGURE 2. TRACKING INDICES OF RAT ABUNDANCE (% OF TUNNELS WITH FOOTPRINTS) IN TREATMENT AND NON-TREATMENT STUDY AREAS BEFORE AND AFTER AN AERIAL 1080 POSSUM POISONING OPERATION AT PUREORA, 1996–97.

TABLE 1. NUMBER OF ADULT ROBINS PRESENT IN TREATMENT AND NON-TREATMENT BLOCKS BEFORE ANDAFTER AN AERIAL 1080 POSSUM POISONING OPERATION IN SEPTEMBER 1996 AS DETERMINED BY TERRITORY MAPPING (BANDED PLUS UNBANDED ROBINS IN A DEFINED AREA).

	TOTAL	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 ADULT ROBINS PRESENT IN TREATMENT AND NON-TREATMENT BLOCKS BEFORE AND AFTER AN AERIAL 1080 POSSUM POISONING OPERTION IN SEPTEMBER 1996 AS DETERMINED BY MONITORING BANDED ROBINS THAT WOULD APPROACH FOR A FOOD REWARD (MEALWORMS).

	TOTAL	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

treatment area, 12 of the 28 robins disappeared (42.8%). The proportion of males that disappeared (44.4% of 18) was not significantly different to that for females (40.0% of 10)(Chi-square test, P=0.39)(Table 1).

If the mortality is determined for just those birds that were colour-banded and that would readily approach us for mealworms then, again, none of the robins in the non-treatment area disappeared (Table 2). In comparison, 12 of 22 (54.5%) robins in the treatment area disappeared. As for the territory mapping result, there was no significant difference in the proportion of colour-banded males that disappeared (50% of 14) as compared with that of colour-banded females (62.5% of 8)(Chi-square test, P=1.02)(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 the 18 September when the poison operation was completed. However, the next day five birds could not be found, and on the 20th a further four robins could not be found. Two robins present on the 20th were not located when next searched for on the 23rd and 26th. The twelfth robin was a female whose mate had disappeared on the 19th. She was seen in the territory on the 26th 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 & 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 of 1080, and B-42125 had 0.83 mg/kg. A freshly dead unbanded robin found in the study area on 19 September, the day after the poison operation, had 3.8 mg/kg 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.

3.1.7 Nesting success in the 1996–97 season

Just four (11%) of the 35 nests found in the non-treatment area each fledged at least one chick that survived beyond the first week after nest leaving (Table 3). This is much lower than the 28% success rate for the combined tally of 18 nests found in the two study sites during the previous nesting season. 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 disappeared in autumn. 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 followed the failure of their last nesting attempts.

TABLE 3. ROBIN NESTING SUCCESS IN THE 1996/97 SEASON FOLLOWING THE SEPTEMBER 1996 AERIAL 1080 POSSUM POISONING OPERATION.

	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 number of fledglings/pair	0.4	3.7
Loss of adult females	2 (14%)	0

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

TABLE 4. IMPACT OF RECRUITMENT BY AUGUST 1997 ON THE NUMBER OF ROBINS WITHIN EACH STUDY AREA AS DETERMINED BY TERRITORY MAPPING.

	NON-TREATMENT AREA	TREATMENT AREA
Pre-operation (September 1996)	32 (21,11)[1]	28 (18,10)
Post-operation (October 1996	32 (21,11)	16 (10,6)
Recruitment (August 1997)	33 (21,12)	36 (20,16)

[1]Figures in brackets indicate the number of males and females.

Of the 36 nesting attempts that failed during the 1996–97 nesting season (5 in the treatment area and 31 in the non-treatment area), 28 failed because of a predation event. Ten of the 28 (35.7%) failed at the egg stage, and the rest (64.3%) at the chick stage.

3.1.8 Status of the populations a year after the 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, at the treatment site the population had increased from 28 before the poison operation to 36 in August 1997, a 28.6% increase (Table 4). The proportion of females in this population had increased from 35.7% to 44.4%.

3.2 TOMTITS

No tomtits in the non-treatment area were colour-banded or regularly fed. In the treatment area, five individuals, two of which were colour-banded, were regularly fed. None of these five birds approached us for mealworms after the poison operation. Between the 19 and 26 September we neither saw nor heard any tomtits in the treatment area, but tomtits were evident through the non-treatment area. During 10–24 October, up to four males were heard singing in the treatment area.

Two recently dead male tomtits were found following the poison operation. Both tested positive for 1080 in muscle samples; 0.52 and 0.31 mg 1080/kg of muscle.

3.3 MOREPORKS

3.3.1 Capture and monitoring prior to the poison operation

At Tahae (treatment study area) nine moreporks were radio-tagged between April and August 1996. Attempts to capture additional birds during August and September were unsuccessful. Of the radio-tagged moreporks, two died during August-September and the transmitter on another stopped functioning in August. This left six birds to monitor during the poison operation.

At Waimanoa (non-treatment study area) we captured and radio-tagged five moreporks during May and June. Further capture attempts during July to September were unsuccessful, even though birds called near the net sites in two cases. Of the five captured, one was found dead in August 1996 and the transmitters on three others failed within two months of attachment, leaving just one bird with a functioning transmitter prior to the poison operation. One of the birds with a defunct transmitter was seen at a roost with the transmitter still attached.

The remains of two of the dead moreporks consisted of feathers and a few major bones. The third bird was reasonably intact, except that its head was missing.

Of the six moreporks monitored after the poison operation in the treatment study area, one was found dead one month later, probably having died a week previously. Analysis of muscle tissue from this bird revealed 1080 was present (0.13 mg/kg). Of the remaining five moreporks, four were still alive two months after the operation, and the fifth had lost its transmitter. The one morepork with a functioning transmitter at the non-treatment site was also alive two months after poison operation.

3.3.2 Diet

From a cursory inspection, 20 regurgitated pellets or bits of pellets found under morepork roosts during December 1995 and October 1996, 16 contained just invertebrate exoskeleton fragments, and four contained invertebrate and bird remains. It is possible that one of the latter pellets also contained rodent hair.

4. Discussion

4.1 PROPORTION OF BACHELOR ROBINS

The proportion of bachelors compared with paired males in the Pureora study areas has varied from 32 to 50% (n=18-20 males/study area). This compares with a mean of 11.8% bachelor South Island robins (*Petroica australis*

australis) at Kowhai Bush, Kaikoura, during 1971–80 (0-25%/annum, n=12-50 males/year)(D. Flack & B.D. Lloyd pers. comm.). The usual suite of introduced mammalian predators was present at Kowhai Bush, with the most likely to kill robins being the ship rat, stoat (*Mustela erminea*), weasel (*M. nivalis*), feral cat (*Felis catus*), and brushtail possum (Flack & Lloyd 1978, Moors 1983, Brown *et al*. 1993). The reason for the marked bias towards males in these two populations is probably the increased vulnerability of females to predators during the breeding season (Flack & Lloyd 1978, Brown 1997, this study). Females alone incubate the eggs and brood the young, and so are more vulnerable to predators than males. Compared with the 33% loss of females and no losses of male robins at Pureora during the breeding season, at Kaharoa, Brown (1997) found that of 12 pairs of North Island robins, five (42%) lost females during the season, but only one (8%) lost a male. This bias in the sex ratio is not peculiar to robins, having been documented in the North Island kokako (*Callaeas cinerea wilsoni*)(Bradfield & Flux 1996, Innes *et al*. 1996), and both subspecies of the kaka (*Nestor meridionalis*) in mainland habitats (Beggs & Wilson 1991, Greene & Fraser 1995). As in the robin, the females of each of these species alone incubates the eggs and broods the young, and have been found dead at the nest after being killed by introduced mammalian predators.

4.2 ROBIN MORTALITY DURING THE POISON OPERATION

Robins are known to eat carrot and cereal-based baits, and have been found dead after 1080 possum control operations, especially in the 1970s when the toxin was distributed on unscreened carrot baits (Harrison 1978a, b, Spurr 1991, Spurr & Powlesland 1997). Therefore, it was not unexpected that a small proportion of the 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) was very surprising. This was because five studies by Spurr (1991), using the 5-minute count technique to compare 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 present study is the first attempt to monitor the mortality of individually colour-banded robins during a 1080 possum control operation.

The level of mortality of colour-banded robins exposed to cereal baits containing brodifacoum has been similar. 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 suggested that 30% of the coastal (n=37) and 64% of the summit robins (n=42) disappeared (R.A. Empson pers. comm.). At Maruia, South Island robins were monitored following the broadcast of Talon 20P by hand (3 kg/ha) 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 (K.P. Brown pers. comm.).

That the one freshly dead robin autopsied did not contain carrot fragments does not necessarily mean that it did not die of primary poisoning. 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. In support of this suggestion is the observation that two of 13 robins fed mealworms coated with cinnamon lure, which is mixed on carrot baits during 1080 operations to mask the smell of the toxin to possums, almost immediately regurgitated them (RGP pers. obs.). If it is essential to distinguish whether robins die of primary or secondary poisoning then perhaps experiments with captive birds will be required.

4.3 ROBIN NESTING SUCCESS

At Pureora, although only 18 robin nests were found during the 1995–96 breeding season, monitoring of these indicated a high level of losses to predators (at least 55.6%). During the 1996–97 breeding season in the non-treatment area, predators were responsible for the failure of at least 22 of 26 (84.6%) nesting attempts where the outcome was determined. Results from two other studies have shown similar outcomes. Of 43 North Island robin nests found at Kaharoa during the 1993–94 season, at least 58% failed as a result of predations (Brown 1997). At Kowhai Bush, Kaikoura, of 626 South Island robin nests found during 1971–76, 57% were preyed upon (44–66%/year)(Moors & Flack 1979). As well as predations, other factors result in nest failures, such as desertions 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 just 22.2% at Pureora, 17.8% at Kaharoa (Brown 1997) and 32% at Kowhai Bush (Flack 1979). The continued presence of robin populations on the main islands, albeit as a disjunct distribution, is 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 in one season (Brown 1997).

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 & Lloyd 1978).

At Pureora during the 1995–96 nesting season, of the nine nesting attempts that failed as a result of predatory activity, five (55.6%) failed during the egg stage. However, during the 1996-97 nesting season, of the 28 nests whose contents were taken by predators, 18 (64.3%) failed during the chick stage. The 1996–97 Pureora result differs from that of two other studies whereby most nests were found to have been preyed on during the egg stage. Of 98 preyed upon nests of 12 passerine species in Kowhai Bush found during 1975–77, 58.2% were plundered during the egg stage (Moors 1983). The proportion of 63 preyed upon robin and tomtit nests at Kaharoa that failed at the egg stage was even greater at 80.9% (Brown 1997). Why the 1996–97 Pureora result differs from the others is unknown, but may relate to the species of predators involved.

With a sex ratio of 1.5–2.0 males to 1.0 female and the low nesting success of robins at Pureora, mainly as a result of predation by introduced mammalian predators, the long-term viability of the population is dependent on no further mortality factors impacting on the adults unless it coincides with increased nesting success and recruitment. Such a scenario is possible as a result of an aerial possum control operation. Dead robins have been found after 1080-carrot operations (Spurr 1994), and robins are known to eat pollard baits (Lloyd & Hackwell 1993). However, even if a few robins are killed by such operations, if both the rat and possum populations are substantially reduced by the poison operation just before the start of the robin breeding season, then the remaining robins can be expected to nest more successfully than they can when these predators are present in high numbers. This enables the robin population to increase to above pre-poison levels within one year.

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

The continued monitoring of the robin populations in the treatment and non-treatment areas until August 1997, almost the first anniversary of the poison operation, indicated the dramatic recovery of the population in the treatment area and the static nature of that in the non-treatment area (Table 4). Not only had the Tahae population (treatment) replaced the 12 robins that died during the poison operation, but it had increased by 28% above its pre-poison number. In addition, and of much importance for the future of the population, the female component had increased from 36% to 44%. In comparison, the robin population in the non-treatment area had remained almost static, both in terms of total number and proportion of females.

The improvement in the status of the robin population in the treatment area (Tahae) is not quite as good as that for the population in the Waipapa bait station area at Pureora after one year of management (Speed & Bancroft 1997). The bait stations were set out on a 150 m grid and contained Talon 20P (brodifacoum) for possum and ship rat control from December 1995 to April 1996. For details of methods see Speed and Bancroft (1997). In May 1996, there were 30 adult robins (19 males and 11 females) along two kilometres of track. It is assumed that this number of birds closely matched the number present at the start of the nesting season in September 1995. By October 1996, early in the subsequent breeding season, the number of robins present along this track had increased by 63% to 49 (27 males and 22 females, H.J. Speed pers. comm.). The doubling in the number of females present was even more impressive (H.J. Speed pers. comm.). This improvement in the status of the Waipapa robin population within one year of predator control suggests that the Tahae population could have increased to a similar extent had fewer birds died during the poison operation.

4.5 TOMTIT MORTALITY DURING THE POISON OPERATION

The disappearance of all five tomtits that we regularly fed, including two banded birds, is the only quantitative information we obtained regarding the mortality of tomtits following the possum control operation. Almost all tomtits in the treatment block disappeared within two to three days of the poison operation, the two birds found dead both tested positive for 1080, and there was no obvious mortality of the species in the non-treatment block. These observations suggest that the sudden disappearance of tomtits in the treatment block was related to the poison operation.

High mortality of the tomtit has been noted during two other aerial possum control operations using 1080-carrot baits. In one operation using unscreened bait (30 kg/ha, 0.06% 1080 ww) in Cone State Forest, Southland, in September 1977, no tomtits were seen or heard two weeks after the operation (Spurr 1981). Monitoring using the five-minute count technique indicated that it took three years for the tomtit population to return to pre-poison levels. Although various measures have since been taken to reduce the attractiveness of carrot baits to birds (removal of chaff and addition of cinnamon in an attempt to repel birds), dead tomtits are still found after 1080-poisoning operations using carrot baits. For example, two dead tomtits were found incidentally following the aerial application of screened carrot bait (15 kg/ha, 0.08% 1080 ww) at Waihaha, Pureora Forest Park in August 1994, and both tested positive for 1080 (P. Sweetapple pers. comm.). Landcare Research staff working in the area immediately after the control operation did not see or hear any live tomtits (Nugent *et al*. 1996). In future, in order to better determine the impact of such possum control operations on tomtit populations, birds should be individually colour-banded in both treatment and non-treatment study areas and monitored to quantify the proportion that disappear and how long the population takes to recover.

4.6 MOREPORK MORTALITY DURING THE POISON OPERATION

One (16.7%) of the six radio-tagged moreporks in the treatment block at Pureora was found dead after the 1996 poison operation and tested positive for 1080. Moreporks had been found dead after 1080 possum control operations using carrot or cereal baits (Spurr & Powlesland 1997). However, none of seven birds monitored for the first time by radio-telemetry during an aerial 1080 possum control operation died (Walker 1997). The operation was carried out in August 1994 at Tennyson Inlet, Marlborough and Saxon River, Nelson, using RS 5 cereal baits (0.15% 1080 ww). All seven moreporks were alive five days after the operation. One month after the operation, a transmitter had fallen off one of the birds but the rest were still alive (Walker 1997). It is presumed that moreporks found dead following a 1080 operation and test positive to the toxin died from secondary poisoning because they are not known to eat vegetable matter or baits. The bulk of the morepork diet at Pureora is invertebrates, with a few regurgitated pellets containing bird remains, but no rodent remains (pers.

obs., J. Haw pers. comm.). This suggests that moreporks are poisoned after eating invertebrates that have eaten baits. It is also possible that the moreporks could have eaten poisoned birds, although whether moreporks would feed on dead invertebrates and birds is unknown.

4.7 FUTURE

The field work for this project is planned to continue for a further two years. It is planned to monitor the fate of individually colour-banded robins and tomtits, and radio-tagged moreporks during another aerial 1080-carrot possum control operation in winter 1997 that adheres to the standard protocols such that chaff (pieces of carrot less than 0.5 g) will make up less than 2.5% by weight of the bait sample. In addition, the nesting success and density of the robin and tomtit populations in both the non-treatment and treatment sites will be monitored to determine whether any benefits eventuate for these species as a result of the regular 3-year interval between aerial 1080 possum control operations carried out by Environment Waikato for the Animal Health Board in the Pureora area where bovine tuberculosis is endemic in the possum population. In winter 1998, the same monitoring procedure will be carried out, but the possum control will involve the aerial spreading of 1080 cereal baits.

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