SHORT COMMUNICATION

Bird species diversity and abundance before and after eradication of possums and wallabies on Rangitoto Island, Hauraki Gulf, New Zealand

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Abstract: Five-minute bird counts were made on Rangitoto Island in 1998 and 1999, 8 and 9 years after the start, and 1 and 2 years after the completion of a 7-year programme that resulted in eradication of the introduced brushtail possum (*Trichosurus vulpecula*) and brushtailed rock wallaby (*Petrogale penicillata*). These were compared with counts made in 1990 (immediately before the start of the programme), to assess whether bird species diversity and abundance had increased as a result of the eradications. The number of bird species detected in 1998/99 was similar to 1990. Five-minute counts of all species except silvereye (*Zosterops lateralis*) and tui (*Prosthemadera novaeseelandiae*) were also similar in 1998/99 to those in 1990. Silvereye and tui counts increased significantly. This is most likely a response to increased flowering of pohutukawa (*Metrosideros excelsa*) and rewarewa (*Knightia excelsa*) as a result of possum (and wallaby) eradication. The most likely reason for no apparent increase in the abundance of other bird species is the continued presence of predators, especially ship rats (*Rattus rattus*), cats (*Felis catus*), and stoats (*Mustela erminea*).

Keywords: bird abundance; bird species diversity; brushtail possums; brushtailed rock wallabies; eradication; habitat improvement; sodium monofluoroacetate; vertebrate pest control.

Introduction

The brushtail possum (*Trichosurus vulpecula*) and brushtailed rock wallaby (*Petrogale penicillata*) are two of a number of mammals that were introduced into New Zealand in the late 1800s (Cowan, 1990; Warburton and Sadleir, 1990; Clout and Ericksen, 2000). Possums now occur throughout most of New Zealand, including a number of offshore islands. Rock wallabies were only ever introduced to four offshore islands (Rangitoto, Motutapu, Kawau, and Great Barrier Islands). As a consequence of damage to vegetation from browsing, possum and wallaby numbers are controlled in areas of high conservation value, usually resulting in recovery of the vegetation (Norton, 2000).

A major gap in information about the benefits of controlling mammalian pests is whether the control results in increased bird populations (Spurr, 1994, 2000; Veltman, 2000). The best evidence of bird population increases is likely to come from offshore islands where the pests have been eradicated, rather than from the main islands (North, South, and Stewart Island) where they are only periodically reduced in abundance. Three islands where brushtail possums have been eradicated are Kapiti Island (2023 ha), off the south-west coast of the North Island, in 1986, and Rangitoto Island (2321 ha) and neighbouring Motutapu Island (1560 ha) in the Hauraki Gulf, off the north coast of the North Island, in 1997 (Clout and Ericksen, 2000; Brown and Sherley, 2002; Mowbray, 2002). Brushtailed rock wallabies have also been eradicated from Rangitoto and Motutapu Islands (Sadleir and Warburton, 2001; Mowbray, 2002). Bird populations, especially kereru (*Hemiphaga novaeseelandiae*), kaka (*Nestor meridionalis*), kakariki (*Cyanoramphus novaezelandiae*), whitehead (*Mohoua albicilla*), robin (*Petroica australis*), and bellbird (*Anthornis melanura*) are reported to have increased steadily during the 7-year possum eradication programme on Kapiti Island (Lovegrove, 1986, 1988; Veltman, 2000). Unfortunately, bird populations were monitored for only the first year of the 7-year possum and wallaby eradication programme on Rangitoto Island (Miller and Anderson, 1992), and not at all on Motutapu Island.

The programme to eradicate possums and wallabies on Rangitoto and Motutapu Islands began with an aerial sodium monofluoroacetate (1080)-poisoning operation (on Rangitoto Island only) in October 1990, followed by intensive cyanide-poisoning, trapping, dogging, and spotlight-shooting over a period of 7 years on both islands (Mowbray, 2002). Most (93%) of both possums and wallabies on Rangitoto Island had been killed by the end of 1990 (Pekelharing, 1991). However, ship rats (*Rattus rattus*), house mice (*Mus musculus*), feral cats (*Felis catus*), and stoats (*Mustela erminea*) are still present on both islands (Miller *et al.*, 1994; Miller and Miller, 1995; T. Oron, Department of Conservation, Auckland, N.Z., *unpubl.*). Norway rats (*Rattus norvegicus*) and kiore (*R. exulans*) have not been trapped on either Rangitoto Island (Miller and Miller, 1995) or Motutapu Island (T. Oron, *unpubl.*).

Pohutukawa (*Metrosideros excelsa*), the predominant tree on the lower part of Rangitoto Island, and rewarewa (*Knightia excelsa*) on the cinder cone, appeared to respond to the initial reduction (and subsequent eradication) of possums and wallabies with increased growth and flowering (Miller and Anderson, 1992). The recovery of the vegetation is reflected in figures for commercial production of honey from honeybees (*Apis mellifera*) on the island. This increased from an all-time low of 7.5 kg per hive in the 4 years preceding possum and wallaby control, to 40 kg per hive in the first 4 years, and 57.5 kg per hive in the second 4 years after control started (N. Stuckey, Waitemata Honey Co., Albany, N.Z., *pers. comm.*).

Counts of four bird species, Australasian harrier (*Circus approximans*), silvereye (*Zosterops lateralis*), tui (*Prosthemadera novaeseelandiae*), and greenfinch (*Carduelis chloris*), were reported to have increased 1 year after the 1080-poisoning operation (Miller and Anderson, 1992). Miller and Anderson (1992) predicted that eradication of possums and wallabies from Rangitoto Island would benefit most of the bird populations as a result of improvement in habitat quality. To test this prediction, we repeated the bird counts on Rangitoto Island in 1998 and 1999 (8 and 9 years after the eradication programme started, and 1 and 2 years after it was completed).

Methods

The counts were made at the same time of year (October), using the same method (5-minute count of Dawson and Bull, 1975), by the same observer (S.H.A.), at the same (38 out of 40) counting stations as Miller and Anderson (1992). The stations were located at 200-m intervals around a circuit of approximately 8 km, covering the vegetation types representative of the island (see Fig. 1 of Miller and Anderson, 1992). Because the stations were not located randomly, the results of the counts apply only to the circuit of stations, not to the island as a whole.

Following the routine of Miller and Anderson (1992), the first 28 counts were made during the morning, starting at the Rangitoto Wharf, proceeding up the walking track to the summit of the island (altitude 259 m a.s.l., distance approximately 3.5 km), and then descending along the vehicle track to the junction with the coastal road (approximately 2.5 km). The final 10 counts were made in the 2 hours preceding dusk, starting 200 m from Rangitoto Wharf and heading along the coastal road toward the summit track junction (approximately 2 km). All birds heard and/or seen within a 100-m radius of the observer were recorded. Birds observed during the survey but not recorded in the counts were also noted. The counts were made in fine weather with light to moderate winds. A note was also made on the phenology of rewarewa and pohutukawa, to determine whether fluctuations in flower availability between years influenced bird abundance.

Miller and Anderson (1992) made one count at each station (except station 1) in 1990 (4 October evening and 5 October morning), and two counts at each station in 1991 (17 and 18 October). We made two counts at each station in 1998 (15 and 16 October) and 1999 (13–14 and 29 October).

We re-analysed Miller and Anderson's data by considering the two counts at each station in 1991 as two replicates 1 year after the eradication programme started, and comparing these with counts from the same stations in 1990 using a generalised linear model (degrees of freedom = 1, 2) (McCullagh and Nelder, 1989; McDonald *et al.*, 2000). Likewise, we considered the two counts at each station in 1998 and again in 1999 as four replicates 8 to 9 years after the eradication programme started, and compared these with the counts from the same stations in 1990 using the same generalised linear model (degrees of freedom = 1,4). The assumption that differences between days within a year were comparable to differences between consecutive years was considered reasonable given that there were no significant differences between the mean counts in 1998 and 1999 (*unpublished data*). The analyses used the logarithm of the counts and assumed that the variance was proportional to the mean.

Results

In October 1998/99 (8 to 9 years after the 1080-poisoning operation), only silvereye and tui counts were significantly higher than in October 1990 (Table 1). The counts of all other bird species in October 1998/99 were statistically similar to those in October 1990.

In our re-analysis of the data from Miller and Anderson (1992), only silvereye, tui, and greenfinch

Table 1. Mean ± standard error of the number of birds counted per 5 minutes on Rangitoto Island (untransformed). *F* value derived from a generalized linear model using log-transformed data, *P* = probability of change between years. See text for scientific names of birds.

Bird species	October 1990 (pre-poison) Mean ± SE	October 1991 (1 yr post-poison) Mean ± SE	Probability of change 1990 to 1991	October 1998/99 (8–9 yrs post-poison) Mean ± SE	Probability of change 1990 to 1998/99
Paradise shelduck	0.08 ± 0.08	0.00	(NA)[1]	0.05 ± 0.05	(NA)
Australasian harrier	0.00	0.05 ± 0.05	(NA)	0.00	(NA)
Kingfisher	0.16 ± 0.12	0.36 ± 0.13	(*F*=1.10, *P*=0.36)	0.15 ± 0.16	(*F*=0.002, *P*=0.96)
Welcome swallow	0.16 ± 0.09	0.08 ± 0.04	(*F*=0.77, *P*=0.43)	0.08 ± 0.03	(*F*=0.96, *P*=0.38)
Hedge sparrow	0.03 ± 0.03	0.03 ± 0.03	(NA)	0.01 ± 0.01	(NA)
Blackbird	0.84 ± 0.20	0.76 ± 0.13	(*F*=0.11, *P*=0.76)	0.77 ± 0.10	(*F*=0.11, *P*=0.76)
Song thrush	0.16 ± 0.07	0.03 ± 0.02	(*F*=5.20, *P*=0.08)	0.14 ± 0.03	(*F*=0.07, *P*=0.80)
Grey warbler	1.76 ± 0.35	1.47 ± 0.23	(*F*=0.49, *P*=0.52)	1.16 ± 0.14	(*F*=2.96, *P*=0.16)
Fantail	0.50 ± 0.08	0.61 ± 0.06	(*F*=1.11, *P*=0.36)	0.45 ± 0.04	(*F*=0.38, *P*=0.57)
Tomtit	0.00	0.00	(NA)	0.02 ± 0.02	(NA)
Silvereye	0.95 ± 0.16	3.16 ± 0.21	(*F*=58.3, *P*=0.002)	2.40 ± 0.13	(*F*=35.5, *P*=0.004)
Tui	0.03 ± 0.03	0.33 ± 0.06	(*F*=28.6, *P*=0.006)	0.20 ± 0.03	(*F*=18.9, *P*=0.012)
Chaffinch	0.66 ± 0.15	0.96 ± 0.13	(*F*=2.10, *P*=0.22)	1.01 ± 0.09	(*F*=3.35, *P*=0.14)
Greenfinch	0.03 ± 0.03	0.59 ± 0.17	(*F*=10.2, *P*=0.03)	0.12 ± 0.05	(*F*=2.22, *P*=0.21)
Goldfinch	0.24 ± 0.14	0.62 ± 0.16	(*F*=2.84, *P*=0.17)	0.43 ± 0.09	(*F*=1.01, *P*=0.36)
House sparrow	0.16 ± 0.06	0.42 ± 0.07	(*F*=6.40, *P*=0.06)	0.34 ± 0.05	(*F*=4.20, *P*=0.11)
Starling	0.11 ± 0.11	0.00	(NA)	0.06 ± 0.06	(NA)
Common myna	0.00	0.03 ± 0.03	(NA)	0.00	(NA)

[1]NA indicates insufficient data for analysis.

had significantly higher counts in October 1991 (1 year after the 1080-poisoning operation) than in October 1990 (Table 1). For all other bird species, the counts in 1991 were statistically similar to those in 1990. The mean counts for 1990 and 1991 in Table 1 differ slightly from those published in Miller and Anderson (1992) because we had only 38 counting stations (*cf.* their 40), and we separated the counts for blackbirds (*Turdus merula*) and song thrushes (*Turdus philomelos*) and included counts for paradise shelducks (*Tadorna variegata*), kingfishers (*Halcyon sancta vagans*), welcome swallows (*Hirundo tahitica neoxena*), starlings (*Sturnus vulgaris*), and common mynas (*Acridotheres tristis*). Also, Miller and Anderson (1992) misreported house sparrows (*Passer domesticus*) as hedge sparrows (*Prunella modularis*), and did not account for a single tui recorded in 1990.

A total of 22 bird species were recorded on the island. These include the 18 species in Table 1, plus eastern rosella (*Platycercus eximius*), shining cuckoo (*Chrysococcyx lucidus*), New Zealand pipit (*Anthus novaeseelandiae*), and redpoll (*Carduelis flammea*) observed outside the 5-minute counts. Eastern rosella (an individual observed near the summit in October 1998) and tomtit (*Petroica macrocephala*) (a pair observed feeding during 5-minute counts near the summit in October 1999) were recorded for the first time on the island.

The flowering of both rewarewa and pohutukawa was poor in 1990 but good in 1991. Pohutukawa flowering was again poor in 1998, but heavy in 1999, a year when rewarewa flowering was poor.

Discussion

Bird abundance

The increase in counts of silvereye and tui after the 1080-poisoning operation and subsequent eradication of possums and wallabies on Rangitoto Island is most likely a response to the increased flowering of pohutukawa and rewarewa. Both bird species are mobile and seek out seasonal food sources. However, neither species showed any further increase between 1991 and 1998/99, suggesting that the breeding status of these species on Rangitoto Island might not have changed. The increase in greenfinch counts in 1991 has been attributed to the increase in herbaceous weeds along the roadsides after the 1080-poisoning operation (Miller and Anderson, 1992), although the counts of other finches such as chaffinches (*Fringilla coelebs*) and goldfinches (*Carduelis carduelis*) did not increase. An alternative explanation is that greenfinches, which start singing later than other finches (Falla *et al.*, 1975), were less conspicuous in 1990 because the counts were made 2 weeks earlier that year than in other years.

There are several possible reasons why the counts of other bird species resident on Rangitoto Island were not higher in 1998/99 than in 1990. The most likely is the continued presence of predators. Ship rats, house mice, stoats and cats are still present on both Rangitoto and Motutapu Islands (Miller *et al.*, 1994; Miller and Miller, 1995; T. Oron, *unpubl.*). In addition, the removal of possums and wallabies may have changed the demographics of the remaining predators by increasing their food supply (Innes and Barker, 1999; Veltman, 2000). For example, the removal of possums may have increased the food available to rodents, since possums are known to also consume invertebrates (Cowan and Moeed, 1987; Cowan, 1990). Also, the release from browsing by both possums and wallabies may have increased plant production of seed. If the rodent population increased as a result of the increased availability of food, the stoat and cat populations might also have increased. Research on kiwi (*Apteryx* spp.), kokako (*Callaeas cinerea*), kereru, kaka, robin, and bellbird indicates that the numbers of possums, rodents (especially ship rats) and other predators (especially stoats) all need to be reduced to very low levels before benefits accrue to bird populations (James and Clout, 1996; McLennan *et al.*, 1996; O'Donnell *et al.*, 1996; Brown, 1997; Wilson *et al.*, 1998; Innes *et al.*, 1999; Powlesland *et al.*, 1999; Murphy and Kelly, 2001). Intensive, multi-species control has also been the key to success in increasing bird populations in several other mainland restoration projects (Saunders, 2000).

The continued, and possibly increased, presence of rodents, stoats, and cats is also likely to exert pressure on the food sources of birds on Rangitoto Island, and this may be a contributing factor to the lack of increase in birds counted in 1998/99. Invertebrates were the main component of both rat and mouse diets on the island in 1990 and 1991 (Miller and Miller, 1995), and invertebrates are an important component in the diet of stoats (King, 1990; Murphy and Dowding, 1995) and are eaten by cats (Brockie, 1992). Seeds are also a major component of both ship rat and mouse diets (King, 1990). Thus, despite the successful eradication of possums and wallabies, there may have been little change in resource availability to insectivorous birds such as grey warblers (*Gerygone igata*) and fantails (*Rhipidura fuliginosa*), and to seed-eating birds such as chaffinches, greenfinches and goldfinches, because of the continued presence of rodents, stoats and cats. Similarly, the removal of an increasing quantity of nectar by commercial honeybees on Rangitoto Island may be reducing the amount of food available to nectar-feeding birds such as silvereyes and tui, limiting the response of these species to the eradication of possums and wallabies.

The phenology of both pohutukawa and rewarewa varies annually, and this may have influenced our results. Bird populations also fluctuate naturally from season to season and from year to year (Dawson *et al.*, 1978; Spurr *et al.*, 1992; Veltman, 2000). Our study suffers from not having a more extensive pre-treatment monitoring (as a consequence of the 1080-poisoning operation occurring with little prior notice), and not having a non-treatment comparison (because the whole island was poisoned at once).

The method of assessment may also have influenced our ability to detect changes in bird populations. Extraneous factors such as time of day, time of year, weather and observer were the same or similar throughout this study, so although different species have different probabilities of detection, within a species the counts should have reflected the numbers present each year. For species with an average count of 1 per 5 minutes, 38 counts should enable detection of a 45% change in numbers, and 76 counts a 32% change in numbers (Dawson, 1981). However, for species with an average count of 0.5 per 5 minutes, the same number of counts would enable detection of only 64% and 45% changes in numbers, respectively. Most bird species on Rangitoto Island had an average count less than 0.5 per 5 minutes (Table 1), so only large changes in numbers could have been detected. This illustrates the limitation of 5-minute counts to detect changes in species that are uncommon and/or patchy in distribution.

Bird species diversity

The number of bird species we recorded on Rangitoto Island in 1998/99 was similar to that reported previously (Segedin, 1985; Miller and Anderson, 1992). The only additional species were North Island tomtit (an insectivorous species) and eastern rosella (a shoot, flower, fruit and seed eater). The nearest source populations for tomtits are in the Hunua Ranges, 30 km to the south-east; in regenerating forest at Orewa, 40 km to the north; and in the Waitakere Ranges, 30 km to the south-west (Bull *et al.*, 1985). The tomtits we observed on Rangitoto Island probably originated from birds blown there on the prevailing winds from one of these source populations (Anderson, 2003). The nearest source population for eastern rosellas is Waiheke Island, 10 km to the east. Neither of these species is likely to have arrived as a consequence of the eradication of possums and wallabies. The only land bird species previously reported as present on Rangitoto Island (by Segedin, 1985) but not recorded in our surveys was the morepork (*Ninox novaeseelandiae*), which is nocturnal.

A source population for potential bird colonisers of Rangitoto Island exists on Tiritiri Matangi Island, 18 km to the north. Bellbirds and kakariki have crossed from Tiritiri Matangi Island to the mainland (*c.* 4 km), and bellbirds have crossed from the Poor Knights Islands and from Little Barrier Island to the mainland (*c*. 25 km) (Craig and Douglas, 1984). The forest type on Rangitoto Island is suitable for both bellbirds and kakariki, but the continued presence of predators on the island may be limiting their ability to colonise. Kereru and kaka, both formerly present on Rangitoto Island (Miller *et al.*, 1994), are likely to visit the island, but the loss of complementary forest once present on neighbouring Motutapu Island and the continued presence of ship rats, stoats and cats may also be limiting their ability to sustain resident populations.

The eradication of rodents, stoats and cats from Rangitoto Island (and neighbouring Motutapu Island), advocated by Miller *et al.* (1994), remains a high priority. The continued operation of commercial beekeeping on the island should also be reviewed (A. Stewart, Department of Conservation, Auckland, N.Z., *pers. comm.*). All the vertebrate pest species should be eradicated simultaneously, because eradication of rodents alone may cause stoats and cats to increase their feeding on birds (Murphy and Bradfield, 1992), while eradication of just stoats and cats might cause ship rats and mice to increase in abundance (Fitzgerald, 1990). The concurrent eradication of all vertebrate pests, and a reduction of commercial honeybees, should lead to an increase in bird populations and the restoration of the bird community on the island in the future.

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