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Response of non-target native birds to mammalian pest control for kokako (*Callaeas cinerea)* in the Hunua Ranges, New Zealand

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Abstract Conservation management of threatened species (single-species management) is likely to confer benefits to non-target native species, although there are few studies. We examined the relationship between the relative abundance of New Zealand pigeon/kereru (*Hemiphaga novaeseelandiae*), tui (*Prosthemadera novaeseelandiae*), grey warbler (*Gerygone igata*), fantail (*Rhipidura fuliginosa*) and tomtit (*Petroica macrocephala*), and intensity of mammalian pest control conducted to protect the endangered North Island kokako (*Callaeas cinerea wilsoni*) in the Hunua Ranges, 40 km south-east of Auckland, New Zealand. Study areas were subjected to either high intensity (Kokako Management Area, KMA) or low intensity (Milne Stream and Rata Ridge) pest control, and we established 17 monitoring stations per study area and conducted 17 x 5-minute point counts of forest birds in all 3 areas. Abundances of kereru, tui, tomtit, were significantly higher in the KMA. Our findings suggest that single-species management targeted at kokako also benefits some non-target native birds. The contribution of single species conservation management to overall ecosystem integrity is not well understood, and further research is needed to improve the ecological value and cost effectiveness of such management techniques.

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INTRODUCTION

Since human colonization around 700 years ago (Worthy & Holdaway 2002), 40 % of New Zealand's native birds have become extinct, and >40% of remaining native bird species are classified as threatened: this is a higher proportion than any other country (Clout 2001). Some native species continue to decline, even within large indigenous forest tracts. Consequently, much of mainland New Zealand now harbours a depauparate native bird assemblage, with many species at abundances too low to maintain pre-human ecological processes or ecosystem functioning (Kelly *et al*. 2005; Anderson *et al*. 2006).

A number of human-induced factors have contributed to native bird declines and extinctions, including alteration of native habitats, predation by

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introduced mammals, overharvesting, disease, and possibly climate change (Wilson 2004; Innes *et al*. 2004). However, the primary factor for the ongoing decline of native New Zealand birds is predation by introduced mammals (King 1984; Atkinson 1985; Clout *et al*. 1995; Wilson *et al*. 1998; Medway 2004), particularly ship (*Rattus rattus*), Norway (*R. norvegicus*) and Pacific (*R. exulans*) rats, possums (*Trichosurus vulpecula*), stoats (*Mustela erminea*) and feral cats (*Felis catus*). Ship rats and possums have been implicated as the primary cause of decline in New Zealand pigeon (*Hemiphaga novaeseelandiae*) (hereafter, kereru) (Pierce & Graham 1995; Innes *et al*. 2004), and North I kokako (*Callaeas cinerea wilsoni*) (Innes *et al*. 1999). Stoats are considered to be the main cause of decline in yellowhead (*Mohoua ochrocephala*; Elliott 1996), kaka (*Nestor meridionalis*; Greene & Fraser 1998) and brown kiwi (*Apteryx australis*; McLennan *et al*. 1996). Dietary overlap between birds and introduced herbivorous mammals such as possums and red deer (*Cervus elaphus*), also suggest that competition for food can contribute to avian declines (Mills & Mark 1977; Veltman 2000; Innes *et al*. 2004). Native species are considered particularly susceptible to mammalian pests due to the absence, apart from a few species of bats, of land mammals throughout New Zealand's evolutionary history.

There is general agreement that the control or eradication of introduced mammalian predators is essential to recovery of native bird assemblages (Pierce & Graham 1995; Mander *et al*. 1998), and ecological restoration of native ecosystems in general (Saunders & Norton 2001). Conservation managers in New Zealand have achieved considerable success in removing a range of exotic mammals from increasingly large offshore islands, and in progressively controlling mammalian pests over larger and more remote areas on the mainland (Innes *et al*. 1999; Saunders & Norton 2001). In many instances, rapid recovery of native birds and other species has been attributed to control or eradication of mammalian pests. On Kapiti I, forest bird densities doubled between 1982 and 1988 when possums were removed (Lovegrove 1988; Veltman 2000). Bellbird (*Anthornis melanura*) nest success was 4 times higher with stoat control (66.4%) than without (16.4%), where video-monitoring showed stoats to be the main predator (Kelly *et al*. 2005). Likewise, kaka nesting success at sites with predator control was significantly greater (≥80%) than at unmanaged sites (≤38%; Greene & Fraser 1998).

Control of introduced mammals is often conducted to facilitate the recovery of threatened or endangered species such as the kokako (Innes & Flux 1999), and pest management strategies have been developed to maximise threatened species recovery for the lowest possible cost. For example, research

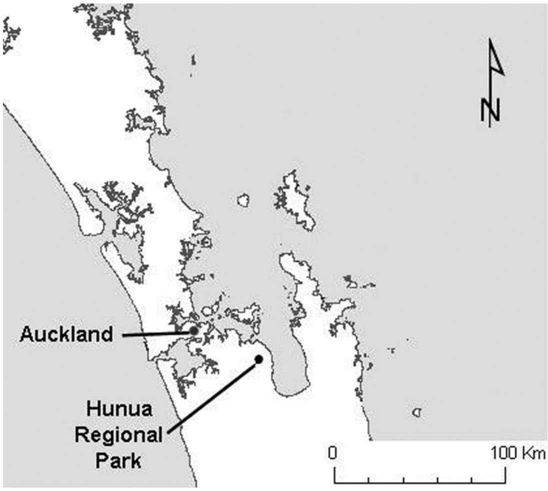

Fig. 1. Map of central and upper North I showing the location of Hunua Regional Park with an inset showing location of study sites (Kokako Management Area, Milne Stream, and Rata Ridge) within the Hunua Ranges Regional Park.

suggests that kokako recovery is predominately dependent on the effective management of possums and ship rats, rather than management of the entire suite of mammalian pests (Innes *et al*. 1999). Correspondingly, mammalian pest control focused on kokako recovery was estimated at $116/ha at Mapara (Fairburn *et al*. 2004), compared with $165/ha for mammalian pest management in New Zealand's mainland island ecosystem restoration programmes (Saunders & Norton 2001).

The single-species management approach has been increasingly criticized in recent years as ecologists have become more focused on restoring the functioning of whole ecosystems (Tracy & Brussard 1994; Christensen *et al*. 1996; Simberloff & Suter 1998; Fairburn *et al*. 2004). Nevertheless, it is possible that pest control focused on one species may confer benefits to non-target native taxa, and therefore contribute to overall ecosystem health. However, the benefits of single-species management to non-target native taxa are rarely studied.

The objective of this study was to determine if pest control to protect kokako conferred benefits to non-target native birds. We assessed the response of kereru, tui (*Prosthemadera novaeseelandiae*), tomtit (*Petroica macrocephala*), fantail (*Rhipidura fulginosa*) and grey warbler (*Gerygone igata*) to intensive mammalian pest control in the Kokako Management Area (KMA) of the Hunua Ranges near Auckland. The Hunua Ranges is one of 23 key sites recommended in the North Island Kokako Recovery Plan (Innes & Flux 1999) for management of the endangered kokako.

METHODS

Study area

All study sites occur within the Hunua Ranges, which lie approximately 40 km south-east of Auckland (Fig. 1). The 17,000 ha of native forest consists predominately of tawa (*Beilschmiedia tawa*) and taraire (*B. tarairie*), or tawa and kohekohe (*Dysoxylum spectabile*) with emergent podocarps. Areas of rimu (*Dacrydium cupressinum*), hard beech (*Nothofagus truncata*) and kauri (*Agathis australis*) forest also occur (Barton 1972, 1989, Tyrell *et al*. 1999). The elevation ranges from 100 – 688 m asl, with rainfall ranging from 1200-2400 mm, depending on altitude, and the mean annual temperature is 14^0C (Barton 1972, 1989). Considerable areas of the forest were felled or burned before 1930, but since then this has regenerated into seral forest communities.

The Kokako Management Area (KMA) is an 850 ha area within the Hunua Ranges where intensive mammalian pest control was initiated in 1994 to protect the relict population of kokako (Gatland 2006). The forest canopy is dominated by mature tawa but includes northern rata (*Metrosideros robusta*), rewarewa (*Knightia excelsa*), and rimu, with abundant tawheowheo (*Quintinia serrata*) at higher altitudes. The KMA varies from 400 – 688 m asl. Pest control consists of bait stations and traps (*ca*. 1/ha) aimed at controlling mammalian predators, particularly rats, possums, and stoats to extremely low levels. The poison bait used was Pestoff® possum pellets containing 20 ppm brodifacoum, which is effective against rats and possums. The poison was delivered in Philproof® mini-possum bait stations, which were baited between Aug and Mar each year. Mustelids were killed with Fenn traps placed under wooden or wire mesh tunnels and baited with hen eggs or pieces of fresh rabbit. The programme closely follows management protocols and operational goals outlined in the Department of Conservation's Kokako Recovery Plan (Innes & Flux 1999). Target pest control indices were 1% residual trap catch (RTC) and 1% tracking tunnel rate for possums and rats respectively by 1 Nov each year (see Innes *et al*. 1999). Feral goats (*Capra hircus*) and feral pigs (*Sus scrofa*) have been controlled by shooting, with a follow-up programme for feral goats using radio-tagged sentinel goats across the entire Hunua Ranges and numbers are currently below 1 goat/20 ha (Frank Pavitt, *pers. comm*.). Small numbers of feral pigs (*Sus scrofa*) are also present, but feral deer (*Cervus* spp.) are absent from the Hunua Ranges.

The Rata Ridge site (ca. 200 ha) lies 3 km south-east of the KMA (Fig. 1). It has similar tawa-dominated forest to the KMA, but its elevation is lower (300-450 m asl). The Milne Stream catchment site (*c*. 200 ha) lies 8 km south-east of the KMA and has younger, regenerating tawa forest, ranging in altitude between 150 and 300 m asl. These latter 2 sites have a history of baseline possum control, which is conducted over the entire Hunua Ranges on about a 3-4 year cycle using a combination of Victor® leg-hold traps, and Feratox® cyanide and brodifacoum poison baits. In addition to the baseline control above, Feratox (cholecalciferol) poison bait was used in the Milne Stream catchment in Sep 2005 to control rats. However, monitoring with rodent tracking tunnels suggested that this baiting was ineffective and the bait was withdrawn after 3 months.

Monitoring design and data collection

Bird counts were conducted between 10-21 Nov 2005, by 2 teams of 2 researchers. At all 3 study areas, we collected data at 17 bird monitoring stations at 300 m intervals along 5 km of tracks. Sampling days were alternated among the 3 study areas and the 5 or 6 monitoring stations sampled each day were separated by at least 900 m. Stations occurred along the entire track network at Milne Stream and Rata Ridge. In the larger KMA, we used a stratified procedure for determining the location of monitoring stations to ensure that all areas of the KMA were represented, but with the constraint that the furthest sampling stations could be reached in a 4 hour return walk. Because the stations were not located randomly, the results apply only to the circuit of stations, not the area as a whole (Spurr & Powlesland 2000). We sampled each monitoring station (n = 51) once.

We conducted 5-minute counts (see Dawson & Bull 1975) at each monitoring station to provide a relative index of abundance of kereru, tui, tomtit, fantail and grey warbler, based on sightings and calls. We started counting 2 minutes after arrival at each monitoring station. During the first 2 minutes we subjectively recorded details of the predominant surrounding forest type (mature > 50 years, or regenerating, < 50 years), weather (heavy rain, light rain, cloudy, partly cloudy, sunny), noise due to streams and leaves (loud, moderate, slight), and wind (very windy, moderately windy, very light/no wind). If possible, we avoided counting when it was wet or windy as these conditions affect bird behaviour and conspicuousness (Spurr & Powlesland 2000).

To minimise bias associated with time of day, sampling was conducted only between 0930 and 1600 NZST (outside dawn and evening chorus) and the order of sampling was alternated, so that adjacent monitoring stations were not sampled at similar times of the day (Spurr & Powlesland 2000). To minimise observer bias, the 2 research teams alternated monitoring stations, and the 2 members in each research team alternated data recording.

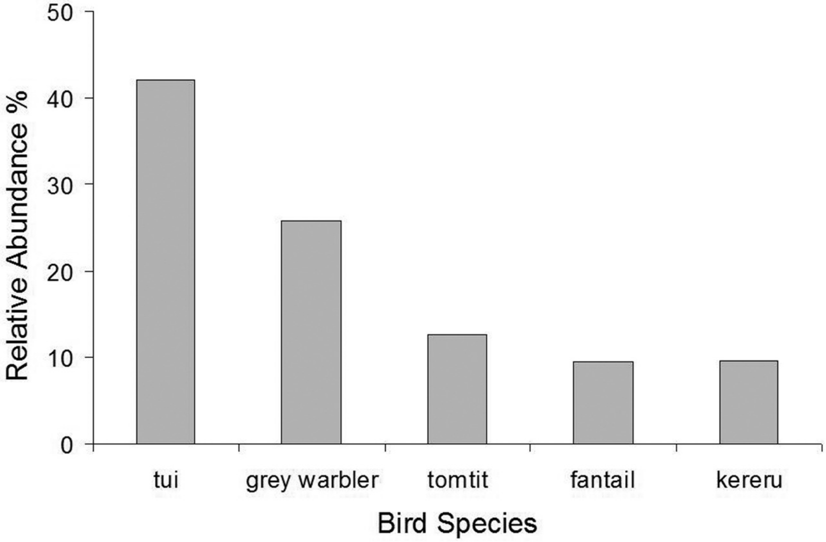

Fig. 2. Relative abundance (%) of targeted native bird species detected during 5-minute counts over the course of the study, 10-21 Nov 2005.

Pest monitoring

To link differences in the relative abundance of birds between sites to pest control, we measured rat indices using footprint tracking tunnels (see Innes *et al*. 1999) in the 3 study areas. At each site, we randomly placed 3 lines, with each line consisting of 10 stations spaced at 50 m intervals. Each station comprised a single tracking tunnel with a card with a central inked pad baited with a small blob of peanut butter in the centre of the inked section. At each site, tracking tunnels were run over a single fine night, but logistic constraints meant that there was up to a 2-week gap between sites in running the tracking tunnels. Monitoring of other mammalian predators was not specifically conducted for this study.

Data Analysis

To determine if the mean abundance of species per monitoring station differed with respect to pest-control study area, we conducted analysis of variances (ANOVA) for tui, and grey warbler, and Kruskal-Wallis tests for fantail, tomtit, and kereru. Kruskal-Wallis tests were performed where data did not conform to assumptions of normality after data transformation. Bonferroni pairwise comparisons were performed on tui abundance (data was non-parametric and significant among study areas), to determine differences between study areas. Significance was set at $P < 0.05$ and the statistical analysis was conducted using SYSTAT 11.0 (SPSS 2005)

RESULTS

We counted a total of 326 birds in the 3 study areas. The most common species was the tui, and the least common was the fantail (Fig. 2). Although seen and heard within the KMA during this study, no kokako were recorded during the 5 minute bird counts. The response of bird species to pest control varied (Fig. 3). Tui (ANOVA, $F_{2,48} = 11.05$, $P < 0.0001$), kereru (Kruskal-Wallis, $T_{2,48} = 16.55$, $P < 0.0001$), and tomtit (Kruskal-Wallis, $T_{2,48} = 12.29$, $P = 0.002$) differed significantly among study areas (Fig. 3). These species attained higher relative abundances in the KMA (>12 years of pest control) than at Rata Ridge or Milne Stream (both baseline pest control). There were also no significant differences in tui, kereru and tomtit counts between Rata Ridge and Milne Stream ($P > 0.05$, Fig. 3). Neither fantail (Kruskal-Wallis, $T_{2,48} = 1.13$, $P = 0.33$) nor grey warbler (ANOVA, $F_{2,48} = 0.02$, $P = 0.99$) counts differed significantly among the 3 study areas (Fig. 3). The vegetation assessment conducted during the bird counts showed that the count stations were predominantly in mature forest in the KMA and at Rata Ridge, while Milne Stream had fewer count stations in mature forest.

Rat Tracking Indices (RTI's) were 8% in the KMA, 37.5% at Milne Stream, and 40% at Rata Ridge. Since the tracking indices indicated that rodent control using cholecalciferol had been ineffective at Milne Stream, this area was considered to be a baseline pest control site. Moreover, possum RTC in the Hunua Ranges in Oct 2005 was 5.55 ± 1.82% (standard error) (ARC, *unpubl. data*).

DISCUSSION

This study examined the relative abundance of several native birds in sites subjected to different levels of pest control in the Hunua Ranges, Auckland. Our findings suggest that several species, namely tui, kereru, and tomtit respond

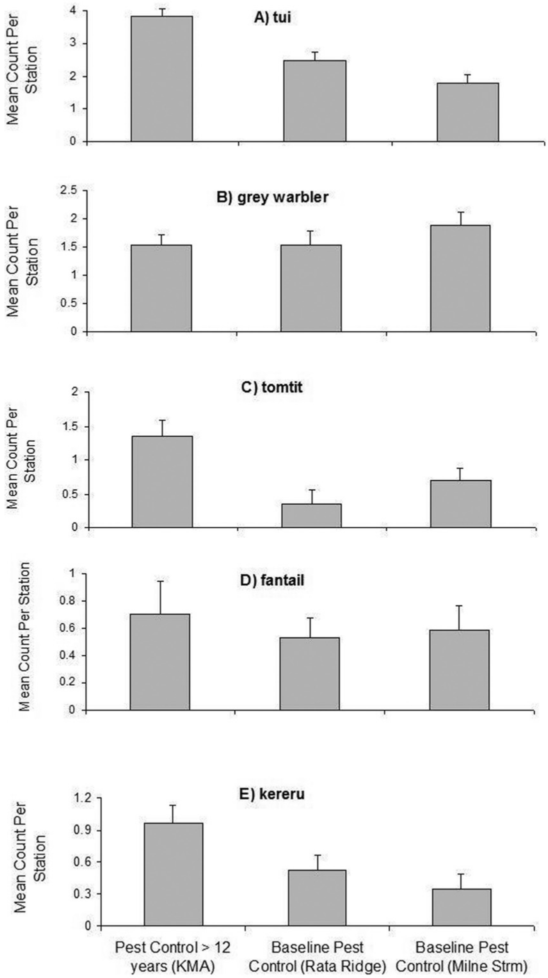

Fig. 3. Mean relative abundance of 5 species of native birds (A-E) during 5 minute counts in relation to sites with different levels of pest control.

positively to the levels of pest control conducted in the Kokako Management Area. Thus single-species management for the endangered kokako may confer benefits to non-target native avifauna.

Tui and kereru are known to respond positively to pest control in other locations. Innes *et al.* (2004) documented significant increases in the relative abundances of tui and kereru, probably as a result of pest control, at Motatau, Northland. Similarly, significant increases in relative abundances of tui and kereru have been recorded at Kakepuku Scenic Reserve, Waikato (OSNZ, *unpub. data*), and Boundary Stream Mainland I, Central Hawkes Bay (Ward-Smith *et al.* 2004). We also found a significantly higher relative abundance of tomtit in the KMA. In the Waitakere Ranges, kereru, tui and tomtit all increased between 1997 and 2005, following intensive possum control (K.A. Parker & T.G. Lovegrove, *unpubl. data*). However, in some studies, tomtit numbers did not increase following pest control (e.g., Innes *et al.* 2004). The abundance of tui, kereru, and tomtit may be significantly higher in the KMA because of reduced levels of predation on these species by rats and possums (James & Clout 1996; Brown 1997), although increases in food supplies may also be a contributing factor (Lovegrove 1988, Graham & Veitch 2002). Spurr and Anderson (2004) attributed increases in abundance of tui on Rangitoto Is to increased food supplies following eradication of possums. Food supply may determine the number of breeding attempts and thus productivity (Spurr & Anderson 2004).

The abundance of fantails and grey warblers did not differ with respect to pest control in this study. Likewise, no significant difference in the abundance of fantails or grey warblers in relation to pest control was documented at Boundary Stream, Hawkes Bay (Ward-Smith *et al.* 2004). Abundance of grey warblers actually declined after pest management in both Te Urewera National Park (Jones 2000) and Trounson Kauri Park (Coad 2001, see also Diamond & Veitch 1981). The reasons for differing responses among studies are unclear, but these might be explained by seasonal or annual variations, changes in food-web interactions, and differences in habitat characteristics.

Kereru and tui appear to be useful indicator species for measuring the success of mammalian pest control or eradication in mature native forests. Moreover, both species have important roles in native forest ecosystems. The kereru is one of the most important seed dispersers in New Zealand because of its widespread distribution, mobility and the diversity of fruit eaten (at least 70 species) (Clout & Hay 1989). No other common native bird is capable of swallowing fruits greater than 12 mm in diameter and dispersing their seeds intact (Clout & Hay 1989). Similarly, tui play important ecological roles as pollinators and they are significant seed-dispersers of plants with medium-sized fruits (Heather & Robertson 1996).

The importance of taking an ecosystem approach to species conservation is well documented in the literature (e.g., Tracy & Brussard 1994; Christensen *et al.* 1996; Simberloff & Suter 1998). Consequently, single-species management has been increasingly challenged as our understanding of the need to incorporate an ecosystem approach has developed (Fleming & Alexander 2002). This study suggests that intensive pest control, specifically focused on recovery of the endangered kokako is also benefiting non-target native bird taxa. Moreover, Baber *et al.* (*unpubl. data*) found that the abundance of the threatened Hochstetter's frog (*Leiopelma hochstetteri*) was 4 times higher in the KMA than at Milne Stream or Rata Ridge. Pest control in the KMA thus appears to be leading to improved ecological integrity and ecosystem health well beyond the intended goals of the kokako recovery programme.

To our knowledge, the benefits of single-species management programmes to non-target native wildlife are generally not factored into the cost-benefit calculations of single-species management programmes, largely because the responses of non-target species are rarely monitored (Spurr & Powlesland 2000; Fairburn *et al*. 2004). We recommend further research into baseline ecological monitoring at multiple taxonomic levels, to understand better the effects of single species management on non-target wildlife and ecosystem processes. Such research should attempt to incorporate a BACI (Before After Control Impact, Underwood 1993) experimental design with adequate within and among-site replication and sampling duration, as well as more direct evidence on rates of predation. The results of such research might allow managers to determine with more confidence what pest control is needed to improve ecosystem function to desired levels beyond merely single-species management.

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