Mohoua ochrocephala abundance in the Catlins following aerial 1080 control

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Abstract

Pest control using aerially-distributed 1080 bait could threaten non-target native bird species either by primary or secondary poisoning. To understand the impact of aerial 1080 control on the abundance of mohua (*Mohoua ochrocephala*), a vulnerable endemic forest bird, we analysed bird counts from the Catlins State Forest Park recorded over the period 1998-2002. Statistical modelling showed that mohua occupancy varied during the study and actually increased after 1080 control in 1999, but not significantly so. Concurrently with high predator numbers in the area during a beech (*Nothofagus* spp.) mast event, mohua abundance significantly declined in 2001 but then recovered in 2002. In conclusion, this study shows no negative effect for the nationally vulnerable mohua following a single aerial 1080 possum (*Trichosurus vulpecula*) control operation. In fact, with improvements in the experimental design and survey effort this study suggests future work could show positive effects of aerial possum control on populations, based on the increase in mohua occupancy observed directly after 1080 application.

Keywords: 1080, Maclennan Range, mohua, New Zealand, pest control, possum *Trichosurus vulpecula*, sodium fluoroacetate, yellowhead.

Introduction

Introduced mammalian pests such as stoats (*Mustela erminea*), ship rats (*Rattus rattus*) and possums (*Trichosurus vulpecula*) pose a significant threat to native forest birds in New Zealand by direct predation of eggs, chicks and adults, thereby limiting populations of a number of endangered species (Innes et al., 2010). Possums also impact forest structure by direct browsing and spread bovine TB (*Mycobacterium bovis*) to cattle and farmed deer (Sadleir, 2000). Due to these impacts pest control is applied over large areas of native forest in New Zealand, benefitting populations of native birds and plants (Baber et al., 2009, Nugent et al., 2010, O'Donnell & Hoare, 2012). On a landscape scale, pest control is often carried out by aerial broadcasting of sodium fluoroacetate (1080) poisoned bait (Eason et al., 2011) targeting possums and rodents, while predators (especially stoats) die from secondary poisoning after scavenging on poisoned carcasses (Murphy et al., 1999). However, aerial 1080 control is associated with a risk of poisoning non-target species like forest birds, either directly by bait uptake or indirectly when transferred through the food-web (Veltman & Westbrooke, 2011).

The mohua (or yellowhead, *Mohoua ochrocephala*) is a small, insectivorous, forest passerine, endemic to the South Island of New Zealand. The species has had strong declines over the past decades (Dilks et al., 2003, O'Donnell, 1996) and has disappeared even from extensive areas of relatively unmodified native forest, thus this species is classified as "Nationally Vulnerable" (Robertson et al., 2012). The breeding strategy of mohua, which is a hole-nester with a long incubation time in late summer, makes their populations especially vulnerable to mammalian predators, which are highly abundant at the same time (Elliott, 1996). In particular, stoats were thought to be a main reason for the dramatic population declines in mohua (O'Donnell et al., 1996) when increasing in response to high rodent numbers after beech (*Nothofagus* spp.) tree mass seeding (masting) events (Choquenot, 2006). Nonetheless, ship rats (*Rattus rattus*) can also predate heavily on mohua after rapid population increases connected to factors like mild winters, beech masting or possibly high levels of stoat control (Dilks et al., 2003, Innes et al., 2010).

The aim of this study was to quantify any impact from of a single aerial 1080 control operation on mohua abundance in the Catlins State Forest Park and thereby contribute towards a better understanding of the risks and benefits these control operations have for non-target native bird species.

Materials and methods

Study area

This study was conducted from October 1998 to November 2002 in the Maclennan Range of the Catlins State Forest Park, located in the south eastern corner of the South Island of New Zealand. The Catlins State Forest Park lies on the boundary between the Otago and Southland regions, between Balclutha and Invercargill. Approximately 50 % of the area in the Maclennan ranges is southern beech forest habitat and was designated as priority area for mohua conservation (O'Donnell, 1993).

Bird monitoring

Two different methods were applied to monitor mohua abundance in this study. Firstly, 1-km grid square search as described in O'Donnell & Dilks (1986) was carried out with the following modifications. At least 30 minutes was spent in each square and deliberate searches for mystery birds were permitted, to overcome differences in observer experience and weather conditions. Also a bird 'squeaker' was used to stimulate mohua calling. Additionally, at least one five-minute bird count was usually conducted in each grid square, following the standard method described in Dawson & Bull (1975). The monitoring work was conducted annually over the four years 1998-2002 in October and early November, being the time of greatest mohua calling (Table 1).

Aerial 1080 control

Aerial 1080 control was conducted in the study area in winter 1999 with bait containing sodium fluoroacetate (1080). The 1080 control operation used Waimate RS5 cereal-pollard baits, which were dyed green and cinnamon lured. Bait was sowed at 3 kg/ha with a 1080 concentration of 0.15 % w/w and no prefeeding of non-toxic bait was applied. This control operation was primarily targeting possums with funding provided by TB Free NZ to minimise the risk of TB spreading to nearby cattle and deer herds. For further details on pest control see current standard operating procedures by DOC (Department of Conservation, 2016a)

Statistical analysis

The presence/absence data from the grid search was analysed with a Generalized Linear Mixed Effects Model (GLMM) with a binomial error distribution. As some of the squares were revisited each year, a random intercept for the square ID was used to control for non-independence of these observations. Significance of fixed effects was evaluated with a type III Wald chi-square test. These analyses were carried out using R v. 3.1.2 (R Core Team, 2016), the 'lme4' package v. 1.1-7 (Bates et al., 2015) and the 'car' package (Fox & Weisberg, 2011). Where significant differences existed, post-hoc means testing was conducted using Tukey contrasts with the 'multcomp' package (Hothorn et al., 2008).

Differences in the mean numbers of birds observed during 30-minute searches was analysed using ANOVA. The five-minute bird count data were analysed using a Generalized Linear Model with a Poisson error distribution. Where significant differences existed, post-hoc means testing was conducted using Fishers LSD test. These analyses were carried out in GenStat version 15.

Table 1. Mohua monitoring effort 1998-2002 in the Maclennan Range. Aerial 1080 control in the study area was conducted in winter 1999, between the first and second sampling period.

Survey date	1-km grid squares surveyed	1-km grid squares with mohua present	No. of five min. bird counts
6/10 – 6/ 11/98	84	53	83
6/10 – 7/ 11/99	37	26	32
4/10 – 6/ 11/00	55	42	32
1/10 – 1/ 11/01	78	38	72
7/10 – 8/ 11/02	112	88	101

Results

Mohua occupancy

The number of squares surveyed for mohua occupancy varied substantially over the study years, with lower survey effort in years 1999 and 2000 (Table 1). The estimated average proportion of squares with mohua occupancy showed strong annual variation (X^2_{360} = 13.93, P = 0.008; Fig. 1A) with a high in 1999, shortly after the aerial 1080 drop; however, this increase was not statistically significant (Tukey post-hoc test, P = 0.24). After a predation irruption observed in the study area during late 1999 (G. Loh, pers comm., DOC, 2006), average mohua occupancy declined sharply over the next two years to a minimum in 2001 that was significantly lower than years 1999 and 2002 (Tukey post-hoc test, both P = 0.02).

Mohua abundance

There was little variation in the numbers of birds observed during searches of occupied grid squares ($F_{4,239}$ = 2.41, P = 0.6), with a mean of five individuals found per square over all years. In contrast, the five-minute bird count data over all surveyed squares indicated a small but non-significant decrease in the average mohua per five minute count in 1999 compared to 1998 (Fig 1B). Further pairwise comparisons showed that the average value of birds counted for 2001 was significantly lower than the values for 1998 (Fisher post-hoc test , P = 0.005) and 2002 (Fisher post-hoc test, P = 0.007). The five-minute bird counts were generally conducted following a grid square search, therefore the annual variation in effort was similar to the these surveys (Table 1).

Discussion

The results from this study show that possum control did not have a detectable impact on mohua in the Maclennan Range, since no significant differences were found comparing either occupancy or abundance of mohua before and after the aerial 1080 drop in winter 1999. In fact, mohua occupancy increased from 70 % to 90 % in the study area following aerial 1080 broadcasting (Fig. 1A), suggesting a positive effect of the control operation. However, this substantial increase was not statistically significant and this is most likely attributed to the lower number of surveys conducted post-1080 control in 1999 (37, compared to 84 in 1998). Similarly, mohua abundance also did not show a significant difference before and after possum control. Based on the above results we conclude that the aerial 1080 control in 1999 did not have any unwanted non-target effects for mohua in the months and years following the control operation. This hypothesis is also supported by more research conducted since this study. For example, an 11 year study conducted by O'Donnell & Hoare (2012) who monitored mohua status with 1080 control for rats and possums in the Landsborough Valley also demonstrated no negative impact of multiple control operations. Thus the direct impact of aerial 1080 drops on mohua populations is now viewed as most likely either negligible or highly beneficial (cf. Veltman et al., 2014).

Nevertheless, the ongoing bird monitoring in our study showed a significant decline in both mohua occupancy and abundance occurring two years after a predator irruption was first observed in summer 1999. This high predator abundance was most likely related to the heavy beech masting that occurred in

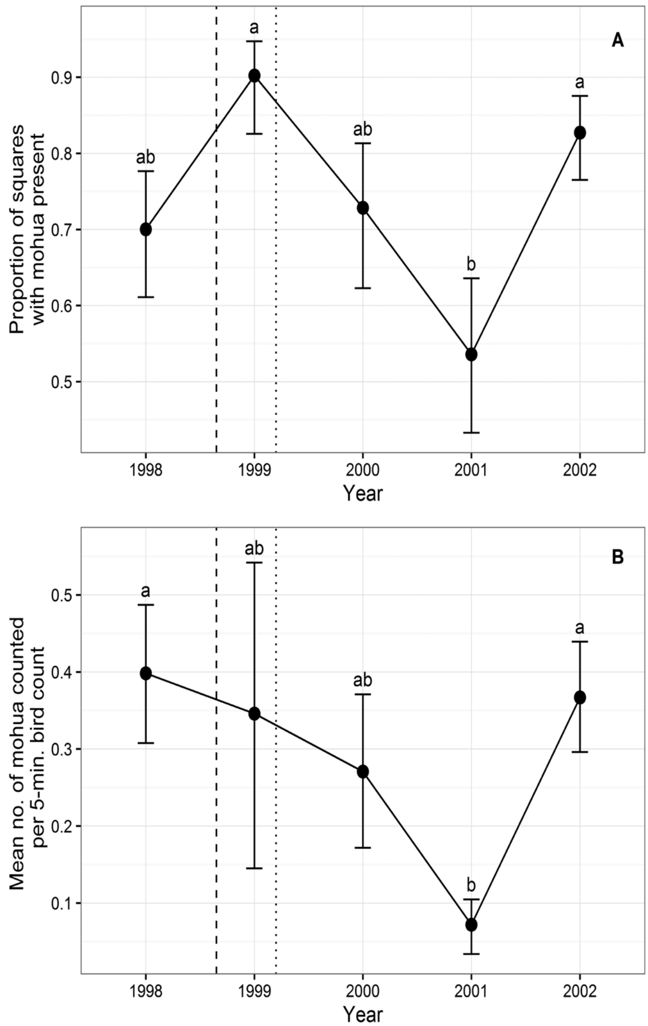

Figure 1. (A) proportion of squares with mohua occupancy in October 1998-2002 in the Maclennan Range estimated with a binomial GLMM fitted on grid square data. Error bars show SEM while lowercase letters indicate significant differences from a post-hoc analysis of means by Tukey contrasts. (B) numbers of mohua per October five-minute count in the Maclennan Range 1998-2002 estimated from a Poisson GLM. Error bars show SEM while lowercase letters indicate significant differences from a post-hoc analysis of means by Fishers LSD test. Dashed lines denote the timing of aerial 1080 drop, dotted lines indicate when predator irruption was first observed.

the study area during autumn 1999 (G. Loh, pers comm., DOC, 2006). Similar beech mast events were seen in Eglinton Valley (Fiordland National Park) during 1999 and 2000, overlapping with several anecdotal reports of major increases in rodent abundance in many areas of the South Island during 2000 and 2001 (Dilks et al., 2003). High densities of rodents after such beech mast events can lead to unusually high densities of stoats (O'Donnell & Hoare, 2012), which then also prey on native birds. This can have devastating effects, for example killing up to 50 % of nesting females in a mohua population and destroying nearly 70 % of the nests (Elliott, 1996, King, 1983). While the predator irruption was first observed in our study area in late 1999, a significant reduction in both mohua occupancy and abundance was not detected until 2001. Again, it is likely that the lower number of monitoring surveys conducted post 1080 control potentially masked the detection of an earlier effect by decreased statistical power.

In any case, two years of decline following a major irruption event are expected for mohua populations in situations without predator management (O'Donnell et al., 1996), and in 2002, both occupancy and abundance of mohua recovered. Based on the available literature it seems highly likely that the mohua population decline observed in our study was due to predation by abundant mammalian pests. Our results also showed that mohua numbers in occupied areas remained stable throughout the study period. In combination, this indicates that mohua responded to predation by disappearing completely from some areas, while numbers remained constant in others. This suggests that some parts of the study area are marginal habitat for mohua during predator irruptions, and similarly, mohua territories decreased with increased predator abundance in the Eglinton Valley (Dilks et al., 2003). Mohua population declines can otherwise be associated with extreme cold spells (Dilks, 1999), but no such extreme weather events were recorded throughout the study period. Additionally, because the experimental design of the study did not encompass a control area, natural variation cannot be ruled out completely as a driver of changes in mohua abundance as well. Accordingly, future studies should adopt a BACI (Before-After Control-Impact) design (Underwood, 1994) with consistent sampling effect to assess impacts on threatened animal populations over multiple years.

In conclusion, this and complementary research on other bird species lead to the development of the "Battle for our Birds" campaign in 2014 in reponse to a signifcant beech mast event (Department of Conservation, 2016b, Department of Conservation, 2016c). Research conducted in the Dart Valley following 2014 aerial 1080 control indicated mohua nesting success of 89 % following 1080 control, compared to only 58 % recorded in 2011, another season with very high rat and stoat abundance (Department of Conservation, 2015). Based on these results, further 1080 control is planned in 2016 in response to another high beech seeding event. Finally, more research is warranted to better understand the indirect effects of pest control on non-target species over multiple years and where possible an integrated approach taking into account all pest species for management in an area should be adopted.

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