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# Control of a stoat (*Mustela erminea*) population irruption to enhance mohua (yellowhead) (*Mohoua ochrocephala*) breeding success in New Zealand

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**Abstract** The mohua or yellowhead (*Mohoua ochrocephala*) is an endangered, hole-nesting forest bird endemic to New Zealand. Mohua suffer periodic population crashes due to severe predation by the introduced stoat (*Mustela erminea*). In 1990, a stoat population irruption provided an opportunity to reassess the impact of stoat predation on mohua and to test two linked hypotheses: that adequate control of stoats by trapping is possible, and that it is a viable management option to assist mohua recovery. The primary experiment (summer 1990/91) was repeated in the summers of 1991/92 and 1992/93 when stoat numbers were lower. Mohua productivity and adult female mortality were compared in two study areas, one trapped and one untrapped, in the Eglinton Valley, Fiordland. Sixty-two stoats were caught in the 50 ha trapped area during summer 1990/91. The fledging of many first clutches, and the laying of second clutches, coincided closely with the period when high numbers of stoats were being caught in traps. Eighty percent of the nests in the trapped area fledged young, compared with only 36% in the untrapped area. Pairs produced nearly twice as many young in the trapped area. A higher proportion of breeding females disappeared from the untrapped area. In the two subsequent summers, 29 and 14 stoats were caught, and breeding success was higher

than previously recorded in both trapped and untrapped areas. We suggest that trapping in the year following a stoat irruption may also be warranted.

**Keywords** mohua; yellowhead; *Mohoua ochrocephala*; stoats; *Mustela erminea*; predation; breeding success; productivity; Fenn trapping; conservation

## INTRODUCTION

The mohua, or yellowhead (*Mohoua ochrocephala*) is a small, insectivorous, forest passerine, endemic to the South Island of New Zealand. Last century, mohua were among the most abundant and conspicuous forest birds in the South Island, but they have all but disappeared from 75% of their former range since the arrival of Europeans and the introduction of mammalian predators (Gaze 1985), and are now regarded as endangered (O'Donnell 1993).

Population monitoring and intensive research (Elliott & O'Donnell 1988; Elliott 1990) have shown that mohua suffer periodic population crashes due to stoat (*Mustela erminea*) irruptions that follow heavy beech *Nothofagus* spp. seeding. Mohua are particularly vulnerable to predation because they nest in holes, have long incubation and nestling periods, and breed at a time when predator numbers are highest (Elliott 1990). Furthermore, the effect of predation is exacerbated by the fact that only females incubate; most predation is of adult females. In populations with low productivity, the period between crashes is probably insufficient for mohua numbers to recover fully (Elliott & O'Donnell 1988; Elliott 1990).

During most mohua breeding seasons, stoats are uncommon and few birds are preyed upon. However, high stoat numbers build up in beech forests in the summers following heavy seeding of beech trees, on average every 4–6 years (Wardle 1984). With increased seed availability, insect, then mouse (*Mus musculus*), and then stoat numbers irrupt. Female stoats produce more young and more of the young

stoats survive (King 1981a; B. M. Fitzgerald pers. comm.). In two areas studied during seed years, a high proportion of mohua nests was destroyed, apparently by stoats, and c. 50% of nesting females disappeared (Elliott & O'Donnell 1988).

A heavy beech seedfall in autumn 1990 over much of the South Island (O'Donnell & Phillipson 1996) provided an opportunity to reassess the impact of stoat predation on mohua productivity and to test two linked hypotheses: that adequate localised control of stoats by trapping is possible, and that it is a viable management option to assist mohua recovery. If we could successfully enhance the breeding of mohua by trapping, then further development of stoat control techniques would be warranted. We assumed that stoat numbers would be very high during summer 1990/91. The approach we chose was to compare mohua productivity in two similar study areas, one trapped and one untrapped, during the October–February mohua breeding season.

Methods for controlling stoats have been reviewed and tested by King (1980, 1981b), King & Edgar (1977), and King & McMillan (1982). King (1984) concluded that stoat control is probably worthwhile only in the most sensitive areas at a critical time of year, and only for endangered species. Such control has been attempted in New Zealand (see O'Donnell 1996a), but its effectiveness has never been assessed.

The objective of our trapping operation was to reduce the numbers of stoats in a small area of mohua habitat during the time when the birds were most vulnerable to predation, and to assess the effectiveness of our trapping programme by monitoring productivity and mortality of mohua. The experiment was then repeated in the following two summers (1991/92 and 1992/93), when stoat numbers were expected to be low again.

## STUDY AREAS

The study areas were located in the Eglinton Valley in Fiordland National Park (168°01'E, 44°58'S). The trapped area was at Deer Flat (50 ha) and the untrapped area 1 km further up-valley at Knobs Flat (40 ha) (Fig. 1). Both areas were on outwash fans on the valley floor at c. 380 m a.s.l. The areas had similar forest types and topography and were dominated by red and silver beech (*Nothofagus fusca*, *N. menziesii*). See O'Donnell (1996a) for a full description of the study area.

## METHODS

### Predator trapping

Fifty-six wooden tunnels were arranged on a 100 m grid in the Deer Flat study area, and two Mark 4 Fenn Humane Traps were placed in each tunnel with baits (described by Dilks et al. 1996) placed between them (Fig. 1). Traps were operated from 12 October 1990 to 14 March 1991, 18 October 1991 to 13 March 1992, and 22 October 1992 to 12 March 1993. Traps were checked approximately every 4 days, dead stoats were removed, baits replaced if necessary, and sprung traps reset. All stoats were sexed and aged by autopsy.

### Mohua study groups

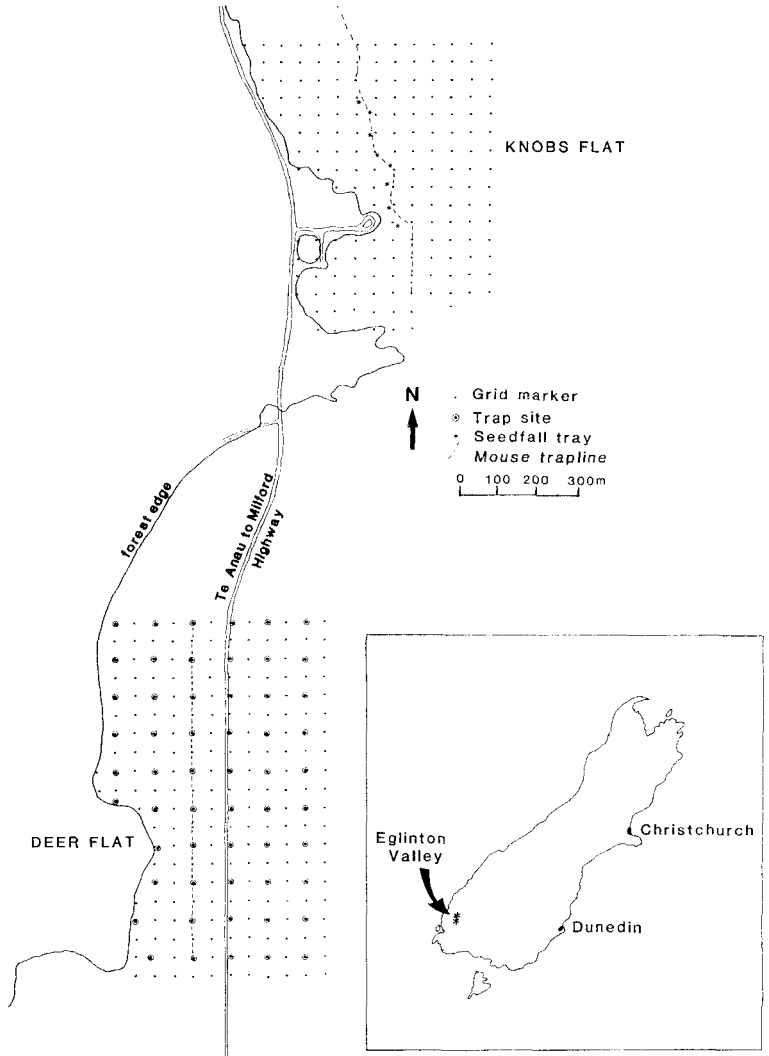
During their breeding season, mohua are territorial and associate in groups including a pair and other subordinate birds. To monitor breeding and movements we individually colour-banded at least one bird from each mohua group. At the end of the study, all but three groups had at least one banded bird, and we were able to identify and monitor unbanded groups from knowledge of adjacent banded groups. Adults and 1 year old birds were distinguished by their plumage colouring and song, and males and females by their different calls and behaviour (Cunningham & Holdaway 1986; Elliott 1990).

### Monitoring mohua breeding and mortality

All mohua groups within or near to our two study areas were monitored from mid October to mid March. Productivity was measured in the trapped area, the untrapped area, and the c. 50 ha between the trapped and untrapped areas. We found nests by following pairs and watching for nesting behaviour, and when breeding commenced, we climbed most trees. A line was placed over a branch above the nest using a slingshot to dispense a lead weight and light line from a fishing reel. The line was then used to pull over a static climbing rope which could be ascended using jumars and descended using standard abseiling equipment. These techniques enabled us to reach nests up to 32 m above the ground. The contents of nest holes were checked every 3–4 days. All nests that fledged chicks were detected. We either found them during the incubation or nestling period, or later saw the adults feeding fledglings. Some nests probably failed before we found them and went undetected.

When a female disappeared from its territory and could not be found elsewhere in the study areas or in suitable surrounding habitat, and when its mate

**Fig. 1** Location of the Deer Flat (trapped) and Knobs Flat (untrapped) study areas, Eglinton Valley.



remained in the territory, we assumed the female had died.

In 1990/91, 18 groups of mohua and 24 nests were monitored; in 1991/92, 20 groups and 16 nests; and in 1992/93, 23 groups and 28 nests.

#### Assessing the effectiveness of trapping

The evidence that stoats are responsible for the decline of mohua is strong but indirect: the destruction of eggs, nestlings, or nesting females has been recorded only during irruptions (Elliott & O'Donnell 1988; Elliott 1990; E. Murphy pers. comm.; pers. obs.). Our test of this relationship was also indirect: we assessed the effectiveness of our measures to protect mohua against stoats by comparing the

productivity and mortality of mohua in areas trapped or untrapped for stoats. We recorded the number of known successful nests, the number of females which disappeared, and the average known number of fledglings per group. Direct comparison of rates of nest predation was not possible because we probably did not find all raided nests—especially if they failed early in incubation. Even when we found a failed nest, we could not always tell if predation caused the loss, as stoats leave little sign of having killed mohua. We assumed that the secondary causes of nest loss, apart from predation by stoats, were the same in each study area (e.g., predation by long-tailed cuckoos (*Eudynamis taitensis*) and moreporks (*Ninox novaeseelandiae*), accidents and

abandonment, and possibly interference by other mohua—McLean & Gill 1988; Elliott 1990). Standardised 5 min counts of all bird species in the trapped and untrapped areas (from August and October 1990, authors' unpubl. data) indicated that bird population densities were similar, and the clutch sizes and the number of young mohua fledged from successful nests did not differ significantly (Table 1).

All groups that nested within the trapped area, or within 70 m of it, were assumed to have benefitted from trapping (70 m was the greatest distance between any nest within the trapped area and a trap).

Early in our study it became apparent that the numbers of mohua nesting in our trapped and untrapped areas were so low that even the largest differences we could expect between productivity and survival in the two areas would not be statistically significant at a 5% level. We were unable to increase the size of either area, and so had the choice of abandoning our experiment or accepting higher probabilities in our statistical tests. For this reason, we simply present the actual probabilities of all our statistical tests, and leave the reader to judge their significance.

To further increase the power of our statistical tests, we used most in the one-tailed form (Sokal & Rohlf 1981). Most of our tests ask questions in the form "is the productivity greater in the trapped area than the untrapped one" rather than simply "does productivity differ between the two areas". Such questions are most appropriately investigated using one-tailed tests.

## RESULTS

### Predator trapping

One hundred and five stoats were caught; 62 in the summer of 1990/91 after the heavy beech seedfall, and decreasing numbers (29 and 14) in the following two summers. The age structure of the stoat population and the timing of the captures differed

between the three summers (Dilks et al. 1996). In the first summer, most animals caught (92%) were juveniles, but in the following summers, most were adults. This pattern of age structures indicated that the expected stoat population irruption was in progress during 1990/91 (King & McMillan 1982).

Four ship rats (*Rattus rattus*) were also caught, all in mid December 1990. Three were autopsied and found to be pregnant females.

### Timing of mohua breeding

Mohua nesting commenced in mid October, and the median laying date varied between 2 November and 13 November. Most first clutches were laid in November, and most second clutches in late December. In 1990/91, the fledging of many first clutches and timing of second clutches coincided closely with the period when high numbers of stoats were being caught in traps (Fig. 2). However, during the following summers, peak capture rates coincided with laying of first clutches.

### Breeding success and female survival in trapped and untrapped areas

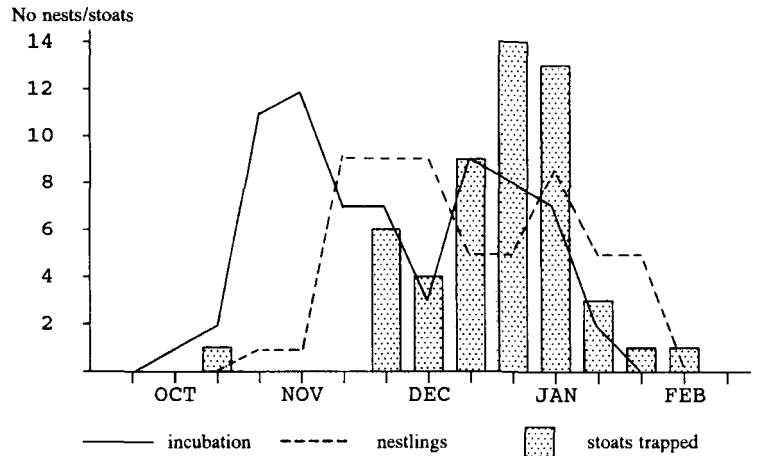
There was a large difference in the nesting success and mortality of mohua between the trapped and untrapped areas during the stoat population irruption (Table 2). Eighty percent of the nests in the trapped area fledged young, compared with only 36% in the untrapped area ( $\chi^2 = 4.6$ ,  $P$  (one tail) = 0.016). Chick production per pair was nearly twice as high in the trapped area ( $U = 23.5$ ,  $P$  (one tail) = 0.063), and fewer females disappeared from the trapped area ( $\chi^2 = 2.1$ ,  $P$  (one tail) = 0.075).

During the following two summers, when the stoat capture rate was lower, breeding success was higher than previously recorded in both the trapped (87–90%) and untrapped areas (75–100%) and there was little difference between them ( $\chi^2 = 11.5$ ,  $P$  (one tail) = 0.11, data combined for both years) (Table 2). The average number of fledglings per pair was also high and similar in the two areas ( $P$  (one tail) = 0.29,

**Table 1** Clutch size and numbers of fledglings from successful mohua nests at Knobs (untrapped) and Deer Flat (trapped) study areas, Eglinton Valley, 1990/91.

	Knobs Flat			Deer Flat			Significance	
	mean	SD	<i>n</i>	mean	SD	<i>n</i>	<i>t</i>	<i>P</i>
Clutch size	2.83	1.17	6	2.50	0.55	6	0.63	0.55
No. fledged	1.83	0.75	6	2.14	0.69	7	0.77	0.45

**Fig. 2** The relationship between the timing of the mohua breeding season and a post-seedfall irruption of stoats (based on numbers caught per 10 day period), Eglinton Valley, 1990/91.



data combined for both years). Only one nest was destroyed (in the trapped area), and the predator was not identified.

### Changes in the mohua population

In 1990/91, there were eight groups in the trapped area, and 10 groups in the untrapped area. All pairs were breeding, and home ranges were approximately 3–4.5 ha in size. In the year following the stoat irruption (1991/92), six breeding pairs and one lone male remained on the trapping grid; but on the untrapped area, there were seven groups of one or more males, some of which had bred the previous summer, and only three breeding pairs. These differences confirm the impact of predation on adult females during the previous summer. The mohua population had recovered markedly by 1992/93. At least five males had acquired mates and bred successfully with them in the untrapped area. Judging by the

dark plumage of the new breeding females, they were probably all 1 year old birds. There were six breeding pairs on the trapping grid. There also appeared to be an increase in the number of pairs around the edge of the grid, and particularly between two study areas, from 1991/92 to 1992/93.

### DISCUSSION

Since mammalian predators were introduced to New Zealand, many bird species have become extinct or reduced to small populations on predator-free islands (Towns et al. 1990). Studies of mohua confirm that introduced predators are still having an impact on mainland bird populations and that the process of decline is continuing. This example provides the first quantified evidence of the magnitude of stoat impacts on an endemic bird species (Elliott &

**Table 2** Mohua breeding success in trapped and untrapped study areas in relation to stoat control, Eglinton Valley, 1990–93. ("Between areas" refers to forest between the trapped and untrapped areas where mohua were also monitored).

	1990/91		1991/92			1992/93		
	Trapped	Untrapped	Trapped	Between areas	Untrapped	Trapped	Between areas	Untrapped
No. breeding groups	8	10	6	3	3	6	6	8
No. nests monitored	10	14	9	4	3	10	6	12
No. successful	8	5	8	4	2	9	5	9
%	80	36	87	100	66	90	83	75
No. females lost	1	4	0	0	0	0	0	0
%	13	40*	0	0	0	0	0	0
Mean No. fledglings/group	2.1	1.1	2.6	2.5	2.5	2.7	2.3	1.9

\*One further female was unaccounted for, but because it was not colour-banded, its disappearance could not be confirmed.

O'Donnell 1988; Elliott 1990; this study). Similar threats also face the New Zealand forest parrots, the kaka *Nestor meridionalis* (Beggs & Wilson 1991) and parakeets *Cyanoramphus* spp. (pers. obs.), the New Zealand robin *Petroica australis* (pers. obs.), and perhaps other species.

The experimental design contained one treatment and one control, and there were no physical or biological differences between the two blocks that we could measure. Although it was not possible to replicate the experiment during the stoat population irruption, the results from other years and other study areas provide temporal controls for the experiment. Mohua population declines of the same magnitude have been recorded during the previous stoat irruptions in Eglinton Valley (Elliott 1990), Hawdon Valley (in two seasons; Elliott & O'Donnell 1988; O'Donnell unpubl.), and in other areas of the South Island in the Landsborough, Poulter, and Dart Valleys (O'Donnell 1996b). Elliott (1990) also found that during a previous stoat irruption in 1987/88, only 40% of nests were successful, and 50% of adult females were killed. This result is almost identical to that from the current study. These results confirm that predation by introduced stoats poses a significant threat to remaining mohua populations, and we conclude that the inferences resulting from the experiment are applicable to other areas within the remnant range of mohua.

Following heavy beech seeding, mouse numbers began increasing in winter 1990 and stoat numbers irrupted during the summer of 1990/91, as was observed in 1976/77 and 1979/80 in Eglinton Valley (King 1983). In King's study, stoats were trapped monthly all year round along a transect line of 20 km, which might explain why the stoat population returned to normal in the following year. We trapped only in summer, and found that the stoat population was still higher than normal in the following year and continued to decline for a further year (Dilks et al. 1996). In 1991/92, when stoat numbers were about half what they had been in the irruption year, mohua breeding success in both trapped and untrapped areas was higher than had ever been recorded (Elliott 1990) and the population increased. By contrast, after the 1987/88 stoat seed year, before any trapping began, the mohua population declined not only during the stoat irruption but also in the following year (Elliott 1990, unpubl.). Two years of decline after stoat irruptions is probably normal for mohua in the absence of any management, and the increase we recorded in our untrapped area in subsequent years may be a result of our trapping in the second

summer. During the irruption of 1990/91, stoat numbers were so high that our trapping probably benefited only mohua in the immediate vicinity of our traps. Trapping seemed to have no effect on our untrapped area only 1 km away, as breeding success and female survival rates were about the same as during the previous stoat irruption of 1987/88 when there was no trapping (Elliott 1990). In 1991/92, however, numbers of adult stoats still appeared to be relatively high, but there were no juveniles present to reinvade once most of the adults had been removed, so our trapping probably depressed stoat numbers not only in our trapped area but also in a much larger area of surrounding forest.

The difference between breeding success in the trapped and untrapped areas indicates that the reduction in stoat numbers caused by trapping was sufficient to increase mohua breeding success significantly. Stoats were not eradicated during trapping, and we failed to catch adult female stoats before their young became independent, or to catch large numbers of stoats before mohua began breeding (Dilks et al. 1996). The majority of stoats caught during the irruption were juveniles, and there was re-invasion of the trapping grid: three of 25 stoats caught and ear-tagged in the untreated area were later killed in the trapped one (Murphy & Dowding 1995). Nevertheless, enough stoats were caught to make a difference to the birds' productivity and adult female mortality.

We have no evidence of ship rats damaging mohua nests through the experiment. However, rats were caught only during the same summer as the stoat irruption, and they may be more important predators of hole-nesting birds in beech forests than our results from Eglinton suggest. King (1983) has shown that ship rat numbers increased in both the Eglinton and, especially, the adjacent Hollyford Valleys in 1977 after the beech mast of 1976. In the Routeburn Valley (B. Lawrence pers. comm.) and at Arthur's Pass (S. Phillipson pers. comm.), rat numbers rose much higher after a beech mast than they did in Eglinton. Higher rat populations in other forest types may explain why mohua have already disappeared from much of the South Island.

This study has demonstrated that intensive trapping of stoats can reduce their numbers to a level where productivity and survival of their prey (mohua) is measurably improved. Development of better control techniques is warranted. Management of predator populations will be essential if mohua populations are to recover or even survive in the future (cf. O'Donnell 1993; Elliott 1996). Targeting

specific age or sex classes of stoats is probably not necessary or even possible. Thus, control needs to focus on removing stoats quickly and efficiently over large areas of forest. Further development should focus on refining techniques for cost-effective trapping, and on searching for new techniques (e.g., poison, biological control). Trapping could be improved by finding more effective lures, tunnel designs, and trapping layout.

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