Large scale stoat control to protect mohua (*Mohoua ochrocephala*) and kaka (*Nestor meridionalis*) in the Eglinton Valley, Fiordland, New Zealand.

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Abstract: To enhance the breeding success and survival of kaka (*Nestor meridionalis*) and mohua (*Mohoua ochrocephala*), we initiated stoat (*Mustela erminea*) control in the Eglinton Valley (13 000 ha), Fiordland, New Zealand using a single 40 km line of traps spaced 200 m apart with traps set continuously. This low intensity stoat control regime permitted successful kaka breeding and fledgling survival was high. A large irruption of rats, probably due to two consecutive years of heavy seeding by beech and mild winters, complicated assessment of the benefits of the technique for protecting breeding mohua. However, no stoat predation on breeding was recorded.

Keywords: breeding success; kaka; mohua; *Mustela erminea*; predator control; stoat trapping.

Introduction

The beech forests of New Zealand flower and seed heavily (mast) at irregular intervals (usually three to five years) (Wardle, 1984; Schauber *et al*., 2002). The increase in food supply is a boon for seed eating birds such as kakariki (*Cyanoramphus auriceps*) and kaka (*Nestor meridionalis*) which usually nest only in such years (Elliott *et al*., 1996; Wilson *et al*., 1998). Mice (*Mus musculus*) and rats (*Rattus rattus*) also benefit and their numbers can irrupt, which in turn results in prolific breeding by stoats (*Mustela erminea*); for example female stoats can raise up to 13 young in years when mice and rats are abundant (King, 1983; 1989). The timing of stoat breeding is controlled by day-length, resulting in an influx of young stoats at the same time each year (King, 1989). Thus from late November large numbers of juvenile stoats are present in the forest (a stoat population irruption).

Stoats are important predators of many forest birds in New Zealand and improved techniques for their control continue to be sought. Both kaka and mohua (*Mohoua ochrocephala*) have greatly reduced distribution and populations mainly due to introduced predators (Elliott, 1996; Wilson *et al*., 1998; Dilks, 1999). Stoat control being carried out at present is mostly over small areas of a few hundred hectares. Research into control techniques for stoats has been undertaken in the Eglinton Valley since 1990. Initially, small *c*. 40 ha areas were trapped (O'Donnell *et al*., 1996) and mohua breeding success in trapped and untrapped areas was compared to assess the effectiveness of the stoat control. Trapping proved to be effective at significantly reducing stoat predation on breeding mohua during a stoat population irruption (O'Donnell *et al*., 1996).

Subsequently, the use of toxic eggs (injected with 1080) was trialed over relatively small areas of approximately 100 ha (P Dilks, *unpubl.*). Although these trials only ran over the summer months, it appeared that stoat numbers were being reduced, as it became increasingly difficult to catch enough animals to radio-tag. As intensive stoat control over small areas appeared to have reduced stoat numbers, we decided to test a method of stoat control for the entire Eglinton Valley. This paper summarises the outcomes of such trapping (in terms of stoat numbers, rodent numbers, and kaka and mohua breeding success) from 1997 to 2001.

We set out to assess the effectiveness of controlling stoats over the whole of the Eglinton Valley using a low density of Fenn traps that were set continuously. Due to the size of the area we were trapping, we were not able to set up an experiment with trapped and non-treatment areas and replication. Instead, the breeding success and survival of mohua and kaka were the measures of the effectiveness of stoat control. From past research here and in beech forests elsewhere we had data on the breeding success of both mohua and kaka in areas with and without predator control (Elliott, 1996; O'Donnell *et al*., 1996; Wilson *et al*., 1998; Dilks 1999; Moorhouse *et al*., 2002).

Methods

Study area

The Eglinton Valley is located in Fiordland National Park (44°58' S, 168°01' E). The valley is glaciated with steep sides rising to around 1500 m a.s.l., and a flat floor which is 0.5 to1.0 km wide (Fig. 1). The Te Anau to Milford Sound highway runs the length of the valley and provides ready access to the whole valley.

The valley floor is at *c*. 380 m a.s.l. and climbs to 532 m a.s.l. at The Divide. The forest is dominated by red beech (*Nothofagus fusca)* and silver beech (*N. menziesii*) with the forest composition ranging from pure stands of silver beech *c*. 20 m tall along the forest margin to stands of red beech up to *c*. 40 m further into the forest. Silver beech becomes more dominant towards the head of the valley. Mountain beech (*N. solandri* var. *cliffortioides*) occurs occasionally in the canopy. Under the canopy the forest is generally open with few understorey plants and a moss ground cover. The most common understorey plants are mountain toatoa (*Phyllocladus alpinus*) and broadleaf (*Griselinia littoralis*).

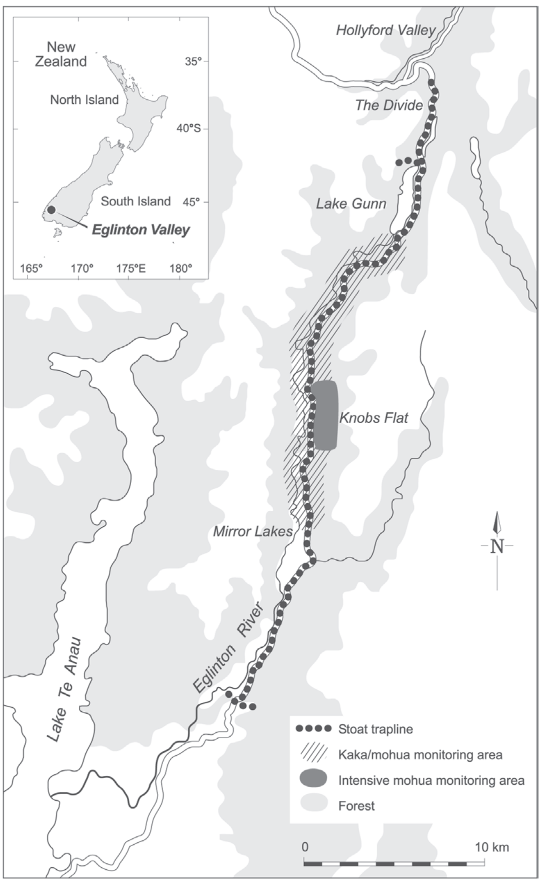

Figure 1. Location of Eglinton Valley study area, Fiordland, New Zealand.

During the period of this study the beech forests of the Eglinton Valley had two mast seeding events. In 1998 beech flowered in early summer and seeded heavily in autumn 1999 (14.5 g/m^2), and the following summer there was an even heavier mast event (30.7 g/m^2). Previous mast events we recorded in Eglinton Valley were in 1990 (8.4 g/m^2) and in 1995 (19.7 g/m^2). It is extremely uncommon for beech to mast heavily in two consecutive years.

Stoat trapping

A stoat trap-line was established from the forest edge at the National Park boundary (the south end of the valley) to the head of the valley where a forested saddle leads into the Hollyford Valley (Fig. 1). The trap line consisted of 193 trapping stations spaced at 200 m intervals for *c*. 40 km, and followed the road along the length of the valley with small cross-valley lines at its southern end and at the northern end of Lake Gunn. Each station consisted of a wooden tunnel (200 x 200 x 600 mm) which contained two Fenn traps with bait placed between them. Bait consisted of a chicken egg and/or a piece of meat, which was changed monthly when traps were serviced and trapped animals were removed. During stoat irruption years, in which there was an influx of newly independent young stoats in early December, the traps were checked at two-weekly intervals during December and January.

The trapline was originally set up in November and December 1997 and the traps set during the first week of December. Traps have since been checked monthly except for two months, May to July 1998, when the traps were closed. Originally each tunnel contained two Mk IV Fenn traps but as ferrets and small cats were being caught, the traps were exchanged for larger Mk VI Fenn traps in May 1999. Up until March 2000, all stoats that were caught were aged and their trap site plotted. The trapping and monitoring is continuing.

As noted above, a stoat irruption is characterised by a large increase in the number of juveniles. To confirm that a stoat population irruption had taken place, stoats caught during the summer of 1999/2000 were aged by skull measurements (Grue and King, 1984). After stoats are approximately three months old this technique becomes less reliable as the skull shape of juveniles approaches that of adults.

Mustelid and rodent monitoring

A 16 km line comprising 160 tracking tunnels at 100 m intervals was established in the Eglinton Valley in 1995 to record the abundance of stoats and rodents. This line was centred on Knobs Flat and also followed the road. Animals were lured into the tunnel with a small piece of meat, they walked across an inkpad, then brown paper, where they left footprints. Tunnels were serviced, rebaited and paper checked for footprints, weekly. The tracking tunnel line was only run during the summer months, usually between November and March, though the dates varied from year to year.

Bird monitoring

The breeding success of mohua in the study area and kaka in habitat similar to that of the study area, both in the presence of stoats, and where stoats had been controlled, was known from earlier studies (Elliott, 1996; O'Donnell *et al.,* 1996; Wilson *et al*., 1998). As an indicator of the effectiveness of our stoat control, breeding kaka and mohua were monitored along a 12 km section of the central Eglinton Valley between Mirror Lakes and Lake Gunn (Fig. 1). Kaka were monitored over three breeding seasons (1998/1999, 1999/2000 and 2000/2001). Mohua breeding was intensively monitored only during the 1999/2000 season. However, a census of an intensively studied population in the central valley was undertaken each year. Different techniques were used for monitoring each species (see below).

Kaka

Kaka were caught using *c*. 20 m high rigs of mist nets erected in the forest. Birds were attracted to the area using recorded kaka calls and by switching calls from side to side of the net rig we were able to encourage them to fly into it. Each bird was individually colour-banded and females had a small two-stage radio transmitter (Sirtrack Limited, Goddards Lane, Havelock North, New Zealand) attached. Female kaka were tracked regularly using a hand-held receiver (Telonics TR4) and aerial which enabled their nesting tree to be located. We climbed up to each nest using single rope climbing techniques, and were able to monitor the contents and fate of each nest. Whenever possible, nestlings were removed temporarily from their nest just before fledging for colour-banding. A sample of fledglings was also radio-tagged.

Outside the breeding season kaka could be tracked from a vehicle using a scanning receiver (ATS scanner) and vehicle-mounted aerial. All birds were located at regular intervals to monitor survival and dispersal. We could determine that birds were active (alive) by listening from a stationary vehicle for a fluctuating signal as the birds moved. Chicks that had been radio-tagged in the nest wore a "mortality" transmitter where the pulse rate would double from 20 to 40 pulses per minute if the transmitter was not moved for a 12-hour period.

Radio tags were first attached to female kaka in the spring of 1998 and the birds were monitored through the following three breeding seasons. There was heavy beech seed production (mast) in the first two summers (1998/1999 and 1999/2000) and all adult female kaka nested. There was little seed production in the last summer (2000/2001) and no kaka nested.

Mohua

Mohua were caught using mist nets set on 2.5 m high aluminium poles (Dilks *et al*., 1995). The birds were attracted using recorded calls. Each bird was individually colour-banded and their breeding territory was determined by following their movements. By observing the behaviour of the pairs we could determine when they were nesting, and nests were located by following the female when she returned to the nest after foraging. We climbed to these nests using the same techniques as for kaka, and monitored the nests' contents and fates.

Some kaka and mohua nests were also monitored using video cameras with infra-red light sources. For mohua, the camera was attached to the tree in such a position that it filmed the nest entrance. For kaka, most cameras could be usually placed inside the nest so they filmed the nest contents. A 50-m cable ran from the camera to a video recorder (powered by a 12-volt battery) on the ground. The video recorder was run on 24-hour mode and recorded five frames per second, allowing a standard three-hour videotape to record for 24 hours. Batteries and tapes were changed and tapes viewed daily.

Results

Stoat and rodent monitoring

The number of stoats caught in the Eglinton Valley increased substantially in December/January 2000 and December/January 2001 (Fig. 2a). This was due to prolific breeding following rodent population irruptions as a result of heavy beech seedfall the previous summers. The number of rats trapped also increased following the first seedfall in 1999, but unlike stoats, rat numbers stayed high through winter then increased to even higher levels after the second seedfall (Fig. 2b).

Apart from rats, only small numbers of other

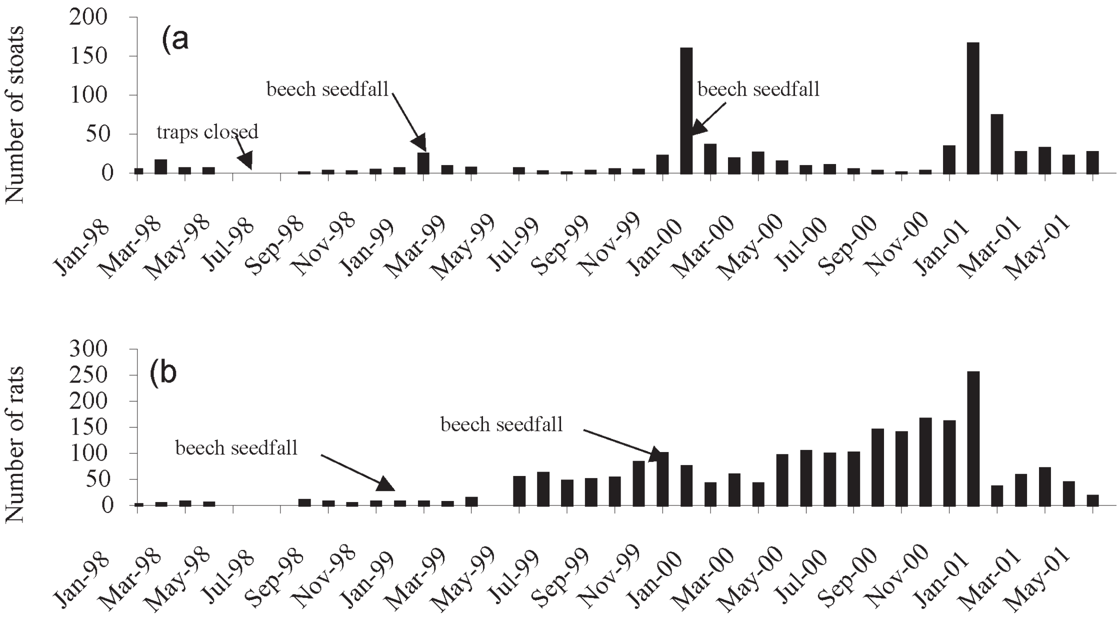

Figure 2. (a) Number of stoats caught in the Eglinton Valley between January 1998 and July 2001. (b) Number of rats caught in the Eglinton Valley between January 1998 and July 2001. Note traps were closed for three months to July 1998.

animals [weasels (*Mustela nivalis*), ferrets (*Mustela furo*), cats (*Felis catus*), rabbits (*Oryctolagus cuniculus*), possums (*Trichosurus vulpecula*) and hedgehogs (*Erinaceus europaeus*)] were caught on the trapline (Appendix 1). The increase in the number of cats caught after June 1999 is most likely due to the change to larger traps in larger tunnels which would have been more accessible to cats. However, the increase in rat numbers may also have resulted in more successful cat breeding and more animals being present to be caught. The number of traps that were still set (having not sprung or captured an animal) was recorded each month and expressed as "% empty" (Appendix 1). These were still available to catch an animal.

Using tracking tunnels, the longer-term pattern of rat numbers in the Eglinton Valley had shown a large increase during the previous beech mast in 1995/1996, with low numbers in non-mast years (1996/1997 and 1997/1998; Fig. 3). By November 1999, rat numbers were much higher than had been previously recorded. However, an even heavier beech seedfall in 2000 resulted in rat numbers increasing even further (Fig. 2b). Unfortunately, the tracking tunnel line was discontinued after the 1999/2000 summer, but other tracking lines in the valley showed a doubling of the rat tracking rate between the 1999/2000 summer and the 2000/2001 summer (P Dilks, *unpubl.*).

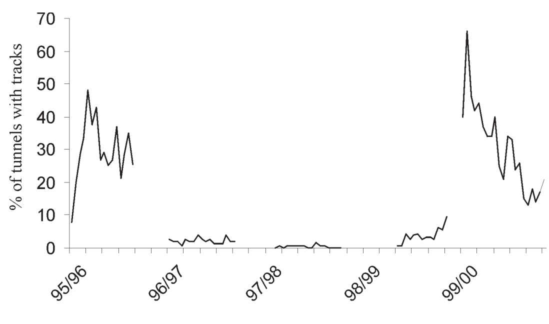

Figure 3. Tracking rate of rats in the Eglinton Valley 1995–2000. Note, the lines were run only over the summer months, thus there was no data in the gaps between years.

Kaka monitoring and nesting success

During the 1998/1999 season, 10 female kaka and 11 nests were monitored (one bird reared two broods of chicks). The following summer 13 female kaka and 14 nests were monitored (one female renested after her first nest was preyed on). Overall, 25 nests were monitored, with 80% of these successfully fledging young. Using a hip-chain we measured the distance from each nest to the nearest Fenn trap and the height of the nest hole above the ground. The average height of successful nests (13.22 m ± 1.12 SE) was not significantly different from unsuccessful nests (9.34 m ± 2.40 SE) (two sample t-test; t = 1.54, df = 23, P = 0.138), but the average distance from the nearest trap for successful nests (297.7 m ±65.36 SE) was significantly shorter than that of unsuccessful nests (664.4 m ±71.96 SE) (t = 2.68, df = 23, P = 0.014).

Apart from two females that were killed on their nests, no other radio-tagged kaka died during the study. Thirteen kaka chicks were radio-tagged while in the nest and all survived to three months post-fledging. At this time, one radio transmitter failed, but the remainder (2 tagged in 1998/1999 and 10 tagged in 1999/2000) were alive in 2000/2001.

Video cameras were placed on eight kaka nests. Only one of these had the eggs eaten, but the camera was outside the nest and the culprit (almost certainly a stoat) managed to enter the nest without being filmed. The remainder of these nests successfully fledged young.

Mohua monitoring and nesting success

Mohua territories in the central valley at Knobs Flat, which have been monitored each year since 1990, reached a high of 40 in 1995 but crashed to 11 following an extremely cold spell during the winter of 1996 (Fig. 4) (Dilks, 1999). Although rat numbers reached high levels during the beech mast in 1995/1996 (Fig. 3) no predation was recorded on breeding mohua that were being monitored (P. Dilks, *pers. obs*.). With two consecutive beech masts in 1999 and 2000, coupled with mild winters rat numbers irrupted (Fig. 2b). This resulted in significant predation on mohua during both the breeding season and the following winter, an event not previously recorded in the Eglinton Valley. During the 1999/2000 summer, 27 pairs of mohua and 38 nests were intensively monitored in a larger study area in the central valley (Fig. 1). Ten nests failed when the female was killed. At least six of these were due to rat predation; video cameras recorded rats preying on female mohua on four occasions and sign left in another two nests was identical to that in the filmed nests. One female was probably killed by a falcon (*Falco novaeseelandiae*) or a cat, and in the other three cases the predator was unknown. An additional three nests failed but the female survived; one nest was abandoned and two had their contents eaten by a rat, long-tailed cuckoo (*Eudynamys taitensis*) or stoat. Twenty-five nests (66%) successfully fledged young.

At the start of the 2000/2001 summer, the mohua study area was searched repeatedly but where there had been 27 pairs the previous year, only nine pairs and nine lone males were found. Only one pair was intact from the previous summer, in all other cases the bird had lost a mate and re-paired with a member of another broken pair. There was little sign of the large numbers of juveniles that had fledged the previous season, and overall, only a fraction of the total population was left in the central intensive study area (Fig. 4).

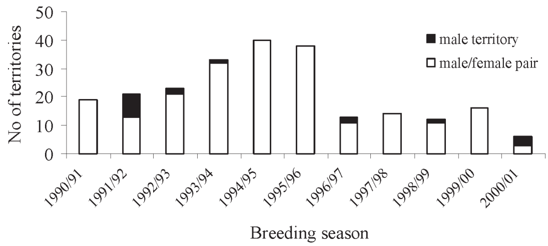

Figure 4. Number of mohua territories in the central Eglinton Valley study area.

Discussion

The monthly capture rate of stoats followed the expected trend, with low numbers of animals, mostly adults, being caught initially, and large increases in stoat captures occurring in December 1999 and 2000 following heavy beech seedfall the previous autumns. The majority of animals caught in November and December 1999, and January 2000 were juveniles. In the following spring (2000/2001) the capture rate followed exactly the same pattern and, although animals were not aged, it is likely that the age ratios were much the same. During the two stoat irruption years juveniles were first caught in November, whereas in the year prior to the first irruption juveniles were not caught until January. This was possibly because with fewer stoats present (only 35 animals caught from November to January 1999, compared with 217 and 274 in the two subsequent years) the newly independent young stoats could more readily find food and were therefore less likely to be caught in traps. Alternatively high rodent numbers in irruption years may have meant that food was more readily available enabling the young to become independent earlier.

In all years young stoats were caught throughout the valley, indicating that some breeding females were resident in the valley or in side valleys, and young animals dispersed from there. During the first year of trapping few young stoats were trapped and most of the adults were caught at the head of the valley where a forested saddle allowed ready immigration of stoats from the Hollyford Valley where no stoat control was undertaken. A stoat population irruption in conjunction with a rat irruption meant that in some months a large proportion of the traps were occupied by animals, especially during the second irruption year when rat numbers reached their peak. This may be why the capture rate of stoats was slower to decline in the 2000/2001 summer.

In the Eglinton Valley, where stoat control was undertaken, kaka breeding success (80% fledging) and juvenile survival (100%) was high. Although we were not able to have replication and a non-treatment area here, elsewhere in New Zealand where kaka were being monitored and there was no predator control, breeding success was much lower. In beech forests at Nelson Lakes only 10% of nests produced young (Wilson *et al*., 1998; Moorhouse *et al*., 2002). However, in beech forests at Nelson Lakes where the Rotoiti "Mainland Island" project applied intensive predator control, 86% of nests successfully fledged young (Moorhouse *et al*., 2002). We recorded a similar result in the Eglinton Valley, with 80% of nests fledging young, even though we applied far less intensive stoat control.

Rotoiti "Mainland Island" comprises 825 ha and was protected with 298 Fenn trap sites (0.36 sites/ha). Bait stations containing Talon were deployed on a 100–150 m grid and 62% of a sample of 54 stoat livers were found to contain brodifacoum. Thus it appeared that, as well as trapping, further stoat control was taking place due to secondary poisoning, after stoats ate rats and mice that had fed on poison (Moorhouse *et al*., 2002). In contrast, the area of the Eglinton Valley where stoat trapping was carried out comprises 13 000 ha with 193 Fenn trap sites (0.015 sites/ha); with much less effort in stoat control giving equally good kaka breeding results.

Three of the five unsuccessful kaka nest sites were across the Eglinton River from the trapline. The other two were on the same side as the trapline but were the furthermost nests from a trap on that side. It appeared we were protecting all kaka nests on both sides of the Eglinton River in an approximate 800 m strip along the valley floor (approximately 400 m either side of the trapline). Given the wide area over which stoats range, trapping would also have resulted in a lower stoat population and improved breeding success for kaka throughout the valley. This was supported by the fact that some distant nests fledged young. In the past, when there was no stoat control, stoats preyed on all five kaka nests we found in the Eglinton Valley (P. Dilks, *pers. obs*.) and, despite spending large periods of time in the field, we never encountered kaka fledglings.

There was also a marked difference in the survival of juvenile kaka between the Nelson Lakes and our Eglinton Valley study site. All twelve radio-tagged Eglinton birds survived to one year old, compared with only 15 of 30 Rotoiti fledglings. Similarly, only 11 of 18 fledglings survived to one year at the Waipapa Ecological Area in the North Island (Moorhouse *et al*., 2002) where predator control was also carried out. These differences in survival were probably due to the size of the area over which stoat trapping was carried out. In the Eglinton Valley, all young kaka stayed within the protected Eglinton Valley until they were at least 4–6 months post-fledging. The other two study areas were smaller and have extensive areas of adjacent untrapped habitat into which young kaka could disperse.

The large increase in rat numbers during this study appeared to have no direct effect on kaka. The only recorded interaction was during the 1999/2000 breeding season when a rat was filmed visiting a kaka nest after it had been preyed on by a stoat. During the 2000/2001 breeding season, when rat numbers were at their peak, kaka did not breed as there had been no beech seeding that summer.

The effectiveness of the Eglinton stoat trapping on mohua breeding success and survival was complicated by the presence of very high numbers of rats and their predation on mohua. However, in spite of the rat predation, the rate of fledgling survival was higher than previously recorded in stoat irruption years with no stoat control. During the 1990/1991 stoat irruption, only 5 of 14 (36%) mohua nests fledged young compared with 25 of 38 (66%) in 1999/2000. This difference was at the margin of significance at 5% level (2-sided Fisher's Exact Test, P = 0.065). Differences in survival of females between the 1990/1991 stoat irruption (5 of 10 females preyed on) and 1999/2000 (10 of 27 killed) was not significant (P = 0.708).

Anecdotal reports indicate that rat numbers increased markedly in many areas of the South Island during 2000 and 2001. Ship rats have been implicated in the disappearance of mohua from Mt Stokes in the Marlborough Sounds in 2000 (Gaze, 2001). The presence or absence of stoat control appears to have little effect on the increase in rat numbers. For example, at Lake Rotoroa (where there was no stoat control) and at the Rotoiti "Mainland Island" (where there was stoat control) rats increased to numbers higher than that recorded in the Eglinton Valley (Moorhouse *et al*., 2002). It appears probable that rat numbers during this period were determined by good climatic conditions and food availability, rather than by any limiting effect of stoat predation *per se*, despite high stoat numbers in that year.

It is possible that trapping and removing stoats in the Eglinton Valley may have permitted the large increase in rat numbers there. If sustained stoat control results in a permanently higher rat population, with much higher peaks than usual for areas with stoats, then this could be disastrous for the Eglinton Valley mohua population in the long term. The mohua population has already reached an extremely low level and this makes it vulnerable to chance events such as a cold winter like that of 1996. However, if we assume that the rat irruption was a rare event, a result of warm winters and two consecutive beech masts, then it is likely that during "normal" years (i.e. non-mast, with low rat numbers) the stoat control regime would provide effective protection for mohua (O'Donnell *et al*., 1996). In the meantime, the mohua population in the Eglinton Valley has declined to such a low level that it could be a considerable time before we see obvious benefits of any stoat trapping.

Several researchers (Alterio, 1998; Murphy and Dowding, 1994; 1995) have investigated home range size of stoats in beech forest. Home range size varied between 69 and 124 ha for females and between 93 and 223 ha for males. To put all stoats at risk of capture it is necessary to have at least one trap within each animal's home range (Moller *et al*., 1996; Miller *et al*., 2001). Although our traps were set out on a line, not a grid, there would be, on average, three or more traps within each stoat home range on the valley floor. All stoats that have been radio-tracked in the Eglinton Valley were most often found on the valley floor, and it was not unusual for individuals to travel several kilometres and cross the Eglinton River between days.

This method of stoat control is particularly suited to valleys like the Eglinton with mountains along the sides that provide barriers to stoat immigration, with most animals entering via the lower-altitude valley ends. The technique may not be as effective in a less mountainous landscape. However, there are many South Island valleys similar to the Eglinton where similar cost-effective stoat control regimes could be established. Trap checking could be carried out even less frequently in years when stoat and rat numbers are low.

The stoat trapline in the Eglinton Valley will continue to be run and monitoring of stoat, rat, mohua and kaka populations is also continuing. As of November 2002, rat numbers have returned to their low pre-beech mast levels and the on-going research will reveal how these species interact in future years during more normal conditions.

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Appendix 1. Captures on the Eglinton Valley Fenn trap line.

Month	Stoat	Weasel	Ferret	Rat	Cat	Rabbit	Possum	Hedgehog	% empty
Jan 98	5		4	42					*
Feb	16			4	1			5	*
Mar	6		1	7	1			1	*
Apr	6		5	5	1			5	*
May									Traps
Jun									Closed
Jul									3
Aug	1			10					97
Sep	3		1	7					97
Oct	2		2	4			1		97
Nov	4			7					96
Dec	6			7		1			94
Jan 99	25	1		7				4	84
Feb	9			6				8	88
Mar	7			14			1		90
May	6			54					83
Jun	2		2	62	2		2	4	81
Jul	1			47	2	1	1	1	81
Aug	3		1	50		1		2	82
Sep	5		1	53		4		4	80
Oct	4			83		2	5	15	65
Nov	22	2	1	100		4	4	12	60
Dec	159	3		75	7	1	1	5	63
Jan 00	36			42	4	1	2	10	72
Feb	19		1	59	3		1	9	85
Mar	26		3	42	1			7	69
Apr	15		1	96	3		1	3	55
May	9			104	1		1		59
Jun	10	1	1	99	2				62
Jul	5			101			1		66
Aug	3			145		1			52
Sep	1	1	2	140		2		1	55
Oct	3	4	1	166		4	1	2	47
Nov	34			161	1	1	1	1	36
Dec	166	3	1	255	8			1	31
Jan 01	74			36	5			4	58
Feb	27	1		58	5		2	2	71
Mar	32			71	3		1	8	66
Apr	22			44	2		1	1	78
May	27		1	18	1			2	85
Jun	40		1	30	1				79
Total	841	16	30	2311	54	23	27	117	

*sprung (empty) traps not recorded
Traps were not checked in April 1999 (May includes captures from 2 months).