

## Lack of movement of stoats (*Mustela erminea*) between *Nothofagus* valley floors and alpine grasslands, with implications for the conservation of New Zealand's endangered fauna

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**Abstract:** Little is known about the movement of stoats in alpine grassland, where several species of native birds, reptiles and invertebrates are potentially at risk from predation. Radio-tracking, live trapping and tracking tunnel techniques were used to sample stoats in two adjacent habitats to determine whether the home range of stoats in beech forest valley floors extends into neighbouring alpine grasslands in the Ettrick Burn Valley, Fiordland. If this is the case then trapping stoats in the more easily accessible beech forest valley floors might serve to protect endangered species inhabiting the adjacent but more remote alpine grasslands. Between December 2000 and March 2001, 415 radio locations were collected on 15 stoats and none were observed to make any significant movements between the two habitats. Stoats were active in alpine grasslands, and trapping in the adjacent beech forest valley would not have caught those stoats during the time-frame of this study. Further research is needed to determine long term impacts of trapping in beech forest on stoats in alpine grasslands. During the timeframe of this research stoats were more abundant in beech forest than in alpine grasslands, and tracking tunnels showed this trend to be consistent at other sites.

**Keywords:** *Mustela erminea*; home range; *Chionochloa*; radio-tracking; takahe

### Introduction

The stoat (*Mustela erminea* Linnaeus) is a small mammalian carnivore from the family Mustelidae (King, 1983). During the 1880s stoats were introduced into New Zealand in an attempt to control rabbits (King, 1990). Since then, stoats have been implicated in the decline of many native species (Elliott, 1996; Elliott *et al.*, 1996; McLennan *et al.*, 1996; Wilson *et al.*, 1998). If stoats are to be effectively controlled over large areas, an understanding of their spatial ecology is necessary. In particular information on home range size, distribution and territoriality is required for conservation managers to determine the most effective trapping regime. Home range analysis can provide information for effective spacing of control devices. Home range in this study is defined as "that area traversed by the individual in its normal activities of food gathering, mating and caring for young" (Burt, 1943).

Another important aspect of spatial ecology is habitat use. Habitat provides the food and cover essential for a population to survive. By observing an animal's movements, one can gain an understanding of whether certain habitats are preferred, avoided, or used in a random fashion (White and Garrott, 1990). When it comes to protecting endangered species from

stoat predation, understanding habitat use has important implications in terms of setting priorities as to where traps are set or assessing whether trapping in one habitat will control stoats in other habitats.

Although several studies of stoat home range and habitat use have been undertaken in New Zealand, all of this research has been confined to either lowland forest or coastal grasslands (Alterio, 1994, 1998; Murphy and Dowding, 1994, 1995; Miller *et al.*, 2001), with little emphasis on alpine grasslands (with the exception of Cuthbert and Sommer 2002). Alpine grasslands host many rare and endangered species which may be at risk from stoat predation including takahe (*Porphyrio hochstetteri*), brown kiwi (*Apteryx mantelli*), rock wrens (*Xenicus gilviventris*), kea (*Nestor notabilis*), and several species of large weta. The nature of stoat movement, residency and population size in alpine grasslands is poorly understood.

This research was carried out prior to the implementation of a long-term stoat trapping operation over 14 000 ha in the Murchison Mountains, Fiordland, by New Zealand's Department of Conservation (DOC). The aim of this operation is to protect takahe from stoat predation. Takahe are an endangered rail that nest above tree-line in alpine grasslands during summer. During the planning phase of this operation, DOC expressed interest in whether the more cost-effective

approach of trapping stoats in the easily accessible beech forest valley floors might protect takahe nesting above tree-line, as the rugged nature of alpine grasslands makes trapping there costly and logistically difficult. In this study we measured the movement of individual stoats to determine whether stoats that inhabit beech forest valley floors are the same individuals that occupy adjacent alpine grasslands, and therefore whether trapping in valley floors alone might serve to protect endangered species that inhabit alpine grasslands. We also aimed to identify which of the two habitats contained more stoats, so that the more populated habitat could be targeted more extensively in any long-term trapping regime, reducing its potential as a source population for reinvasion into adjacent areas.

## Methods

### Study site

The main study sites for this research were the Ettrick Burn and the adjacent Dana Peaks area of the Murchison Mountains (NZMS260 C42 675435), Fiordland National Park. The dominant canopy species in the Ettrick Burn valley floor is red beech (*Nothofagus fusca*), while silver beech (*Nothofagus menziesii*) and mountain beech (*Nothofagus solandri* var. *cliffortiodes*) dominate the valley sides. Tree-line in the area varies between 900–1000 m a.s.l. Above the treeline snow tussocks (*Chionochloa* spp.) dominate the alpine grasslands, with *Chionochloa pallens* constituting 70% of the plant cover in the Dana Peaks area (Lee *et al.*, 1988). Tracking tunnel lines were replicated in Plateau Creek and the Chester Burn valleys, located 7 and 12 km west of the Ettrick Burn respectively. The Murchison Mountains are the only place where the endangered takahe is known to occur naturally, with approximately 130 birds inhabiting the area (Maxwell, 2001).

### Live trapping

Two 3 km-long live-capture lines were set up in the Ettrick Burn, the first along the valley floor on the true left of the river, 4.5 km upstream from Lake Te Anau, and the second through the Dana Hut Basin and along its western ridge, into the Mid Dana Basin. Each line consisted of 30 traps spaced 100 m apart. Traps were baited alternately with hens' eggs and red meat. In total, 50 Elliot and 10 Edgar live-capture traps were arranged so that every fifth trap on each line was an Edgar trap. Both lines were pre-baited between 21 and 30 November 2000. The lines were run concurrently and set every two to four days of every fortnight, between December 2000 and March 2001. All stoats caught were aged (adult males were identified by the presence of mature testicles, adult females were identified by the presence of exposed nipples), sexed,

ear-tagged and fitted with a radio-collar except for those juvenile females deemed too small to carry a radio-collar. Stoats caught in the last trapping period had their radio-collars removed. All stoats live-trapped were ear-tagged. Animal ethics approval for this study was granted by the University of Otago Animal Ethics Committee (AEC #: 3/2000).

### Radio-tracking

Because of sexual dimorphism in size (King *et al.*, 1994) radio-collars weighing 12–14 g and having a battery life of 4 months were used on the larger males, and radio-collars weighing 9.5 g with a battery life of 2.4 months were used on females (all radio-collars were provided by Sirtrack Ltd., Havelock North, New Zealand).

Radio-tracking was undertaken between December 2000 and March 2001, stoats were radio-tracked daily following their first capture. The radio-tracking technique used in this study was ground truth fixing, where radio locations were collected by tracking to within 50 m of a radio-collared stoat. Attempts were made to collect two or three radio locations for each stoat per day, taken at least 3 h apart to minimise serial auto-correlation (Rooney *et al.* 1998).

### Tracking tunnels

Due to logistical limitations, we were unable to replicate the live-trapping study elsewhere. Therefore at our main study site, we attempted to calibrate live-trapping results with tracking tunnel rates, as it was cheaper and simpler to replicate the tracking tunnels over a larger spatial scale.

Four lines of tracking tunnels were set in the Ettrick Burn valley floor, and another four on the ridges and faces of the Dana Peak area. Lines consisted of five tunnels spaced 100 m apart (spanning 400 m), with lines approximately 1 km apart. All of the tracking tunnel lines were centred on our live-trap lines. This design was replicated (in the absence of live-traps) in both the Chester Burn and the Plateau Creek area; Plateau Creek had only three lines in the alpine grasslands and three lines in beech forest habitat as there was no space for a fourth line. Line direction was randomised.

All tracking tunnels were baited with red meat and set for three nights each month, after which papers and bait were removed. Lines left for longer periods risk papers being tracked out, and individual stoats learn to track the whole line (Murphy *et al.*, 1999). This system was based on the methodology described by Brown and Miller (1998), and Gillies and Williams (C.A. Gillies and D. Williams, Department of Conservation, Hamilton, N.Z., *unpubl. data*). However, the requirement that lines be run simultaneously was

violated between sites due to logistical reasons; but was not violated within sites except in the Chester Burn where valley floor lines were run for the three nights immediately after the alpine lines were run (again due to logistical constraints). Tracking tunnels in the Ettrick Burn were run in December, January and February while tracking tunnels in the Chester Burn and Plateau Creek were run during December, February and March. All lines within a given habitat and at a given site were run simultaneously.

### Home range and habitat use

We used 100% minimum convex polygons (MCPs) (Mohr 1947) to estimate home range because we needed to describe the full extent of each stoat's movements; techniques such as kernel contouring (Seaman *et al.*, 1999) and bivariate ellipses (Jenrich & Turner, 1969) tend to smooth outer movements. 100% MCPs were drawn around the movements of all radio-tracked stoats, to provide descriptive information on movement between habitats. Only stoats with fully revealed home ranges were used for more detailed analysis of sex and age differences in home-range size. A stoat was declared to have a fully revealed home range when the number of locations plotted against home range area approached an asymptote.

The outer edge of a home range may be influenced by excursions. Core areas within home ranges can be used to provide more accurate descriptions of an animal's territory and can be used to determine trap spacing; i.e. a stoat is much more likely to encounter a trap placed within its core area than one placed in the outer periphery of its home range. Core areas were separated from excursive areas by identifying the point of inflection on a utilisation plot (percentage of radio locations plotted against the percentage of home range estimated) for each animal (Kenward, 2001). We described the core areas using kernel contouring (Worton, 1989) on the proportion of radio locations falling below the point of inflection on the utilisation plot.

### Statistical analyses

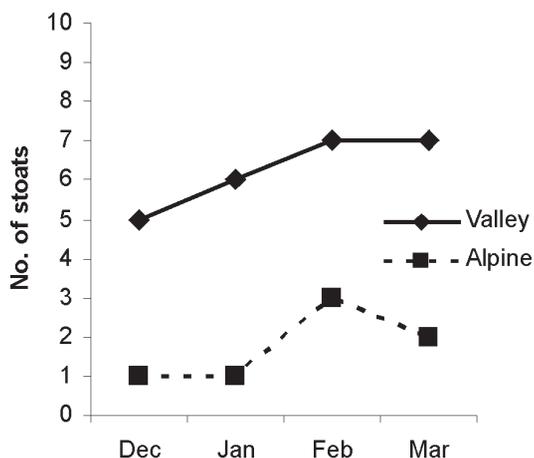
Home ranges were estimated using Ranges V software (Kenward and Hodder, 1996). The total number of stoats live-trapped in each habitat was compared using a chi-square contingency table. Tracking tunnel data were analysed in a multi-factorial ANOVA using a general linear model due to unbalanced design. Because of a positive skew in the data, home range size and core area of use were log-transformed and comparisons between females and males were undertaken with *t*-tests. The minimum number of stoats known to be present (through live-trapping and radio-tracking) was calibrated with the number of tracking tunnel lines

tracked (at our Ettrick Burn study site only) during each sampling interval using a Pearson's Product Moment Correlation Coefficient. The minimum number of stoats known to be present was chosen over classical indexes such as captures per 100 trap nights (Nelson and Clark, 1973) because such indexes were developed for use on kill-trapping data, and therefore are unable to deal with recapture probability parameters. Although calculating the minimum number of stoats known to be present does not give a probability of recapture it enables us (through radio-tracking) to identify individuals which have been captured previously that were still present in the study area, but were not captured during a given trapping session.

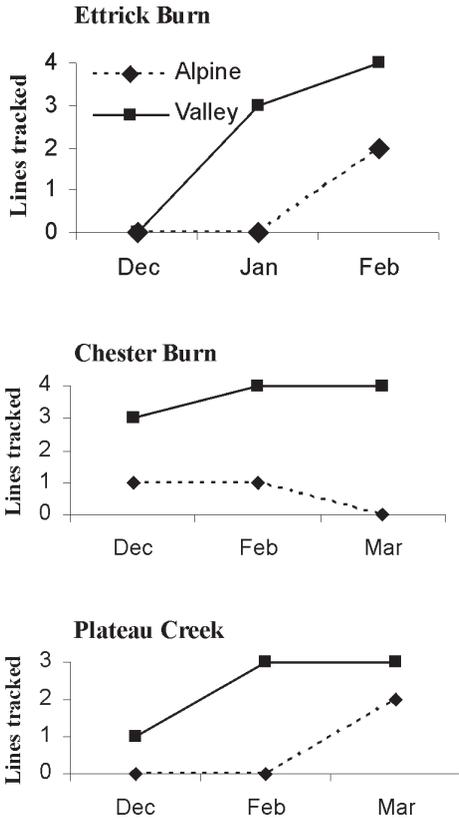
## Results

### Live trapping and tracking tunnels

More stoats ( $n = 13$ ) were live-trapped in the beech forest valley floor during 532 trap nights (corrected for sprung traps; Nelson and Clark 1973) than in the alpine grassland ( $n = 5$ ) habitat over 530.5 trap nights, a difference that approached formal significance ( $\chi^2_1 = 3.56$ ,  $P = 0.059$ ). Stoats were consistently trapped in higher numbers in the beech forest valley floor than in alpine grasslands (Fig. 1).



**Figure 1.** Number of stoats live-trapped in alpine grasslands ( $n=5$ ) versus beech forest valley floor ( $n=13$ ), from December 2000 to March 2001. The values equal the total number of individual stoats live-trapped and radio-tracked in each habitat for that month (marked individuals from previous months are included if they were recaptured).



**Figure 2.** A comparison of stoa tracking tunnel rates between alpine grasslands and beech forest valley floors at three sites.

More tracking tunnel lines were tracked in the beech forest valley floor than in alpine grassland at all three sites ( $F_{3,10} = 6.92$ ,  $P = 0.008$ ), but no difference between sites was detected ( $F_{2,10} = 0.3$ ,  $P = 0.749$ ) (Fig. 2). However, there was a difference in the numbers of lines tracked between December and February/March ( $F_{2,10} = 4.29$ ,  $P = 0.045$ , Scheffe's post-hoc test,  $P = 0.049$ ), but there was no interaction between date and site ( $F_{4,6} = 1.14$ ,  $P = 0.420$ ). At our main study site there was a strong correlation between the absolute number of lines tracked and the minimum number of stoats known to be present at the time the tracking lines were run ( $r = 0.97$ ,  $df = 4$ ,  $P = 0.002$ ).

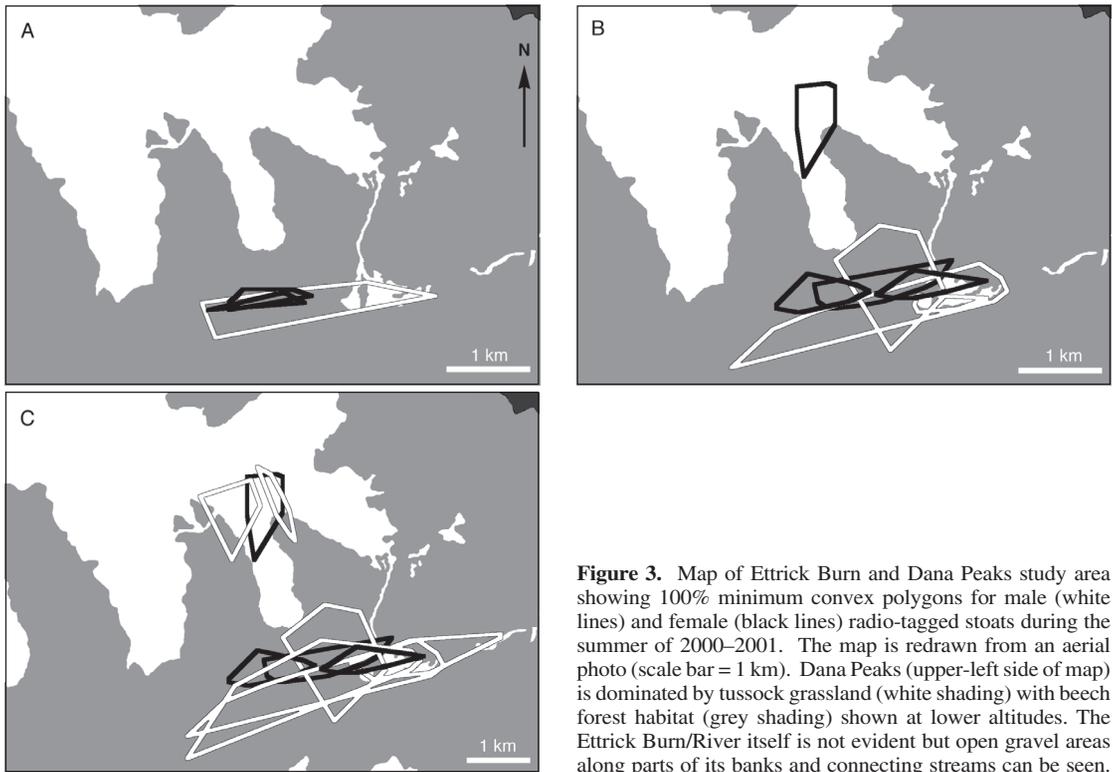
### Home range

Fifteen out of eighteen live-trapped stoats were successfully radio-collared: twelve in the valley floor and three in alpine habitat. Home ranges of eleven radio-collared stoats were fully revealed (Table 1); nine in the valley floor (6 adult males, 2 adult females, 1 juvenile female) and two in the alpine habitat (1 juvenile female, 1 juvenile male). The number of fixes taken to approach an asymptote varied between 5 and 30 for each individual stoat (see Table 1).

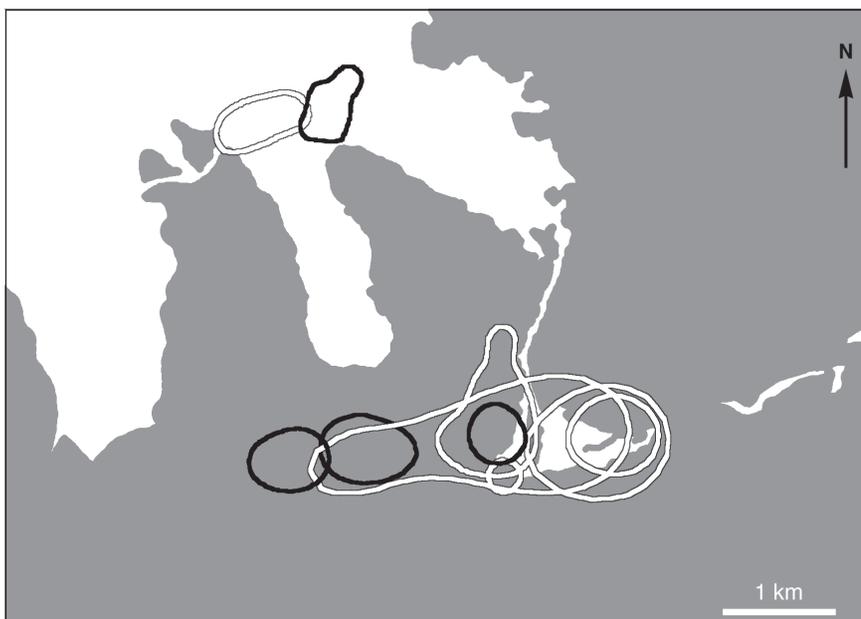
The mean ( $\pm 1$  S.E.) home range size for stoats was  $108.43 \pm 26.52$  ha in the beech forest valley floor ( $n = 9$ ), and  $57.27 \pm 4.63$  ha ( $n = 2$ ) in the alpine grassland. With only two alpine stoats with fully revealed home ranges, sample size was too small for quantitative comparison between the two habitats. Average ( $\pm 1$  S.E.) home range size for females (habitats combined) was  $49.88 \pm 7.73$  ha ( $n = 4$ ), while for males it was  $127.27 \pm 30.42$  ha ( $n = 7$ ). This difference between

**Table 1.** Home ranges of stoats live-trapped in two different habitats in the Ettrick Burn (Murchison Mountains-Special Takahe Area). Number of locations = the number of radio locations collected on each stoat. Asymptote = the number of locations taken to approach an asymptote.

Habitat	Stoat	Sex	Age	Number of locations	Asymptote	Tracking period (days)	Home range (ha)	Core area (ha)	Range length (km)
Beech forest	MV1	Male	Adult	28	20	17	128	111	3.41
	MV2	Male	Adult	35	17	52	81	35	2.39
	MV3	Male	Adult	29	25	32	251	162	3.97
	MV4	Male	Adult	39	20	25	163	57	1.8
	MV5	Male	Adult	24	18	7	16	5	1.05
	MV6	Male	Adult	48	12	24	187	80	4.15
	FV1	Female	Juvenile	28	5	39	34	16	1.61
	FV2	Female	Adult	39	12	66	70	33	2.04
	FV3	Female	Adult	31	18	39	42	25	1.37
Alpine	MA1	Male	Juvenile	22	18	11	61	24	1.29
	FA1	Female	Juvenile	41	30	35	52	19	1.39



**Figure 3.** Map of Ettrick Burn and Dana Peaks study area showing 100% minimum convex polygons for male (white lines) and female (black lines) radio-tagged stoats during the summer of 2000–2001. The map is redrawn from an aerial photo (scale bar = 1 km). Dana Peaks (upper-left side of map) is dominated by tussock grassland (white shading) with beech forest habitat (grey shading) shown at lower altitudes. The Ettrick Burn/River itself is not evident but open gravel areas along parts of its banks and connecting streams can be seen.



**Figure 4.** Map of Ettrick Burn and Dana Peaks study area showing core areas for male (white lines) and female (black lines) radio-tagged stoats during the summer of 2000–2001. Map and habitat areas as described in Figure 3.

male and female home range size was not significantly different ( $t_7 = -1.87$ ,  $P = 0.10$ ) when an outlier (MV5) was included. MV5, an adult male in the valley floor that had a considerably smaller home range (16.76 ha) than all other stoats, died part way through the study and may have been ill; when MV5 was omitted from the analysis males had significantly larger home ranges than females ( $t_7 = -3.78$ ,  $P = 0.007$ ). The mean ( $\pm 1$  S.E.) size of a female core area was  $23.74 \pm 3.59$  ha, and for males it was  $68.35 \pm 20.69$  ha (Table 1). There was a significant difference between male and female core area size ( $t_7 = -3.20$ ,  $P = 0.015$ ).

### Habitat use

During 14 weeks of fieldwork, 415 radio locations were collected on 15 radio-collared stoats. No stoats were observed to move between the two habitats (Fig. 3). The two stoats in the alpine zone with fully revealed home ranges did use a small amount of forest edge (6% and 22% of each home range), but their core areas consisted exclusively of alpine habitat (Fig. 4). None of the stoats radio-collared in the valley made excursions into alpine habitat.

## Discussion

Nearly all stoats live-trapped in the Etrick Burn during this study were adults. If this study was repeated during a year of high juvenile recruitment it is likely that some immigration might be observed between alpine grasslands and the beech forest valley floor. However, this study clearly shows that trapping of stoats in one habitat could not have been relied upon to remove stoats from the other habitat at our Etrick Burn study site during the time frame of our study. During the course of their daily activities, the stoats we observed in the alpine habitat would not encounter a trap set in the valley floor, nor would stoats observed in the beech forest valley floor encounter traps set above tree line. In order to have protected native species inhabiting alpine grasslands from stoat predation at our study site during this period, it would have been necessary to kill-trap within alpine grasslands. However, further research is needed over extensive areas and during different seasons before the effect of long-term trapping in beech forest valley floors on stoat populations in adjacent alpine grasslands can be determined. During the period of this study, stoats were in higher densities in the surrounding beech forest, but whether this is always the case can only be shown through replication of this research. However, managers interested in conserving fauna in alpine grasslands need to be aware that surrounding beech forest might act as a source for repopulation into alpine grasslands, highlighting the

need for dual control of the two habitats.

The stoat home ranges observed in this study were broadly similar to those of Murphy and Dowding (1994, 1995) but sample sizes were too small to allow for statistical comparison. Cuthbert and Sommer (2002) observed much smaller home ranges in alpine grasslands than we observed in the beech forest in this study. However, this is likely due to the hyper-abundance of food provided by the Hutton's shearwater (*Puffinus huttoni*) colonies. Given the absence of Hutton's shearwater colonies, the Etrick Burn Valley study site is more likely to be representative of alpine grasslands in New Zealand than the study site of Cuthbert and Sommer (2002). In the Etrick Burn Valley male stoats generally had larger home ranges and core areas than females, which is consistent with the findings of Alterio (1998) and Miller *et al.* (2001).

The strong correlation between the number of stoats known to be present through live trapping/radio-tracking and the number of lines tracked at our main study site indicates that trapability and trackability varied together, and therefore it was appropriate to use tracking tunnels to replicate our live trapping. Between December 2000 and March 2001 stoats were in higher numbers in the beech forest valley floor compared with the alpine grasslands at our main study site. This same trend was seen in tracking tunnels at our main study site and at two other independent locations in the Murchison Mountains. There were also higher numbers of stoats present in February and March, compared with December. Similarly, tracking tunnels showed an increase in the number of lines tracked at all three sites between December and February/March. Potential reasons for this might include the increasing independence of the season's juveniles, and adult females becoming less wary following the breeding season. The fact that tracking tunnels were not run concurrently did not influence the general trends of higher tracking in valley floors, and a rise in tracking in late summer.

For most effective control, conservation managers should ensure that the trap spacing they use results in at least one trap within a stoat's core area. If trap spacing is assessed simply on home range size, traps may fall into areas of a home range that are rarely visited by a stoat. Analysis of the core areas in the Etrick Burn Valley suggests that a trap spacing of 200 m is satisfactory; 300 m might be more cost-effective, however a trap spacing of 400 m will exclude some of the smaller (female) range cores.

Asymptotes (of radio locations versus home range area) provide a mechanistic means of determining whether or not an animal is moving in a single direction; if an asymptote is approached it means that during the period of observation the animal did not move outside of the area that it had already been observed to use.

Stoats MA1 and FA1 (Table 1, Fig. 3) were observed to move back and forth within their given areas over 11 and 35 days respectively. Further research is needed to determine how long stoats maintain such spatial use of habitats in alpine grasslands and how these spatial movement patterns change seasonally and with food supply.

The key time to protect takahe from stoat predation remains unknown, as the rate at which stoats deplete the takahe population and the stage of the breeding cycle at which takahe are most vulnerable remains undefined. Takahe nest in the alpine grasslands between October and December and continue to graze these areas with their dependent chicks until late autumn. During the winter, as access to *Chionochloa* as a food resource becomes limited by snowfall, takahe move down into the beech forest where they grub for the roots of *Hypolepis millefolium* (Maxwell, 2001). Therefore, during the winter takahe might become at risk of predation from stoats inhabiting beech forest. The impact that stoats have on other endangered species that inhabit alpine grasslands needs to be urgently assessed.

Controlling a population lowers the density of animals in an area causing a *per capita* increase in the availability of resources. This can attract not only dispersing animals but also nearest neighbours, which expand their home ranges into the removal area—termed the ‘vacuum effect’ (Efford *et al.*, 2000). It has not been demonstrated that such an effect occurs amongst populations of trapped stoats, but intuitively it seems possible. Therefore the question might be raised as to whether trapping in beech forest valley floors might cause a vacuum effect enticing stoats in alpine grasslands to move down into the trapped area. However, the stoats we live-trapped in alpine grasslands were 3 km from the beech forest valley floor, thus potentially there were unsampled stoats inhabiting the intermediate altitude between the beech forest valley floor and the alpine grasslands (Fig 3). Stoats in this intermediate altitude are more likely to make such single direction movements into the trapped area.

Alpine grasslands are a significant feature of much of New Zealand’s conservation estate and are home to several rare and endangered species that may be under threat from stoat predation. This research indicates that managers working in such areas need to take alpine grasslands into account when planning control operations.

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