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RANGE AND DIET OF STOATS (*MUSTELA ERMINEA*) IN A NEW ZEALAND BEECH FOREST

Summary: Home range and diet of stoats inhabiting beech forest were examined by trapping and radio-tracking. Eleven stoats (6 female, 5 male) were fitted with radio-transmitters. Minimum home ranges of five females averaged 124 ± 21 ha and of four males 206 ± 73 ha. Range lengths of females averaged 2.3 ± 0.3 km and of males 4.0 ± 0.9 km. These differences were not statistically significant. Adult female stoats appeared to have mutually exclusive home ranges. Two females and one male had home ranges that were bisected by the Eglinton River. All three crossed the river regularly and could only have done so by swimming. Bird remains were found in 54% of stoat guts and scats examined, lagomorphs in 33%, and invertebrates in 34%. Australian brushtail possum remains were found in 11% of samples overall, but only in guts and scats from male stoats. A road through the study area affected the behaviour of stoats. Females avoided the road but males preferred it and were found scavenging road-kills, which may explain why they are more frequently found as road-kills themselves. In most years, New Zealand beech forest may be marginal habitat for stoats. No breeding was detected in the year of our study but there had been high productivity in the previous season. Stoats probably survive in this habitat because they are flexible in their diet and because their breeding biology allows them to respond rapidly to a sudden increase in food availability.

Key-words: stoat; *Mustela erminea*; home range; range length; habitat use; radio-tracking; beech forest; *Nothofagus*.

Introduction

The endemic fauna of New Zealand evolved in the absence of mammalian predators and has proved particularly vulnerable to some of the mammals introduced since human settlement began about 1000 years ago (King, 1990). The avifauna, for example, has been seriously depleted by Pacific rats (*Rattus exulans* Peale), ship rats (*R. rattus* L.), Norway rats (*R. norvegicus* Berkenhout), feral cats (*Felis catus* L.), and mustelids (*Mustela* spp.). Stoats (*M. erminea* L.) were introduced from England in the 1880s in an attempt to control rabbits (*Oryctolagus cuniculus* L.) and spread rapidly; they are now widely distributed in a variety of habitats in both North and South Islands, from sea-level to sub-alpine areas (King, 1990).

The stoat is now the most common carnivore in New Zealand beech (*Nothofagus* spp.) forests in the South Island, where it may become numerous (King, 1983). In *Nothofagus* forests, huge synchronous production of seeds (mast years) occurs at intervals of 3 to 11 years (Wardle, 1984). Mice (*Mus musculus* L.) become very numerous in beech forests during mast years but remain at very low densities at other times. Stoat density fluctuates widely between years, but is particularly high in the year following a mast year. This increase is caused by an intense breeding effort, which may be due to the increase in food available to stoats when mouse density is high (King, 1983). Stoats have one litter a year; they mate after giving birth in September - October but implantation of the embryos is delayed until the following spring. The young become independent in December or January (King, 1990).

Many New Zealand forest bird species continue to decline in range and number, with introduced fauna, especially predators, still regarded by some as the most frequent proximate cause (Innes and Hay, 1991). Although stoats were implicated in the decline of some native bird species soon after their introduction (Moors, 1983; King, 1990), the extent to which they have contributed to the decline of native birds overall is poorly understood. It is clear, however, that predation by stoats on birds can be locally heavy (e.g., Fitzgerald, 1964; Moors, 1983; Beggs and Wilson, 1991). For example, the yellowhead (*Mohoua ochrocephala* Gmelin), an endemic hole-nesting passerine now largely confined to beech forest (Gaze, 1985), continues to decline and is known to be particularly at risk in years of high stoat density (O'Donnell, Dilks and Elliott, 1992). Local control of stoats may therefore be

necessary to protect vulnerable endemic bird species.

Our knowledge of stoats in New Zealand has been derived largely from autopsy studies (e.g., King and Moody, 1982) and one live-trapping study (King and McMillan, 1982). These have given detailed information on density, demography, and diet but still relatively little is known about the ecology and behaviour of the animal in New Zealand. Our study aimed to determine home range size, activity patterns, and diet of a population of stoats living in beech forest, primarily to assist in the design of more effective control strategies. The study was undertaken two years after a mast year, when mouse density was very low and stoat density had fallen from the peak of the previous year.

Methods

The study was undertaken in the Eglinton Valley (44°50'S, 168°05'E), a glaciated valley with steep forested sides, in Fiordland National Park. The valley floor in the study area consisted of a strip 11 km long and 1620 ha in area at 350-400 m a.s.l. Approximately 35% of the valley floor was open terrain (mostly grassed but including a braided river and a main road) and the remainder was forested. The forest was almost entirely dominated by red beech (*Nothofagus fusca* Hook) and silver beech (*N. menziesii* Hook), with some mountain toatoa (*Phyllocladus aspleniifolius* var. *alpinus* (Labill.) Hook f.), broadleaf (*Griselinia littoralis* Raoul) and *Coprosma* spp. in the shrub layer. Australian brushtail possums (*Trichosurus vulpecula* Kerr) were present in the forest. Rabbits and hares (*Lepus europaeus* de Winton) were found in open grassed areas and river margins on the valley floor. Ferrets (*Mustela furo* L.) and weasels (*M. nivalis* Erxleben) were absent from the study area and densities of feral cats and rats (*Rattus* spp.) were very low.

Seasons were defined by three-month periods: spring (September-November), summer (December-February), autumn (March-May), and winter (June-August). Trapping was undertaken in August, October and December 1991, and January, February and May 1992 using up to 30 Edgar Mk 3 live-traps (King and Edgar, 1977), usually baited with domestic hen eggs. Traps were placed in lines beside the main road and along a walking track through the forest about 300 m from the road. During summer, traps were checked at least daily and in other seasons at least twice a day. Stoats were anaesthetised with Halothane ("Fluothane", ICI New Zealand Ltd., Lower Hutt), ear-tagged, weighed, sexed, and released at the capture site.

Home range and habitat utilisation

Stoats were fitted with a two-stage radio-transmitter incorporated into a brass collar which acted as a loop aerial (manufactured by Sirtrack, DSIR, Havelock North, New Zealand). Transmitter packages weighed between 10-12 g and had a battery life of up to 3.6 months. Stoats (particularly females) have narrow heads and broad necks and most shed their radio-collars within 2 weeks; individual stoats could sometimes be recaptured to replace transmitters when collars were lost. Each animal's position and activity were recorded at a minimum of three-hourly intervals (spot records). Records were obtained from 0800 hr to 2400 hr using a hand-held receiver (Telonics TR4) and 3-element Yagi aerial (Sirtrack, N.Z.).

Triangulation did not give accurate fixes in the beech forest, so positions of stoats were ascertained by tracking to within at most 20 m of moving animals or locating den sites when animals were stationary. Home range, defined as the area within which an animal moves when performing its normal activities, was measured by the minimum convex polygon method (Harris *et al.*, 1990). Cumulative range area was plotted against number of fixes for each individual to determine the number of fixes (see Table 1) required to reach an asymptote, the point at which additional locations result in a minimal increase in range size (Harris *et al.*, 1990).

To examine habitat use, the study area was classified into three categories: forest, forest margin (land within 20 m of a forest edge), and open ground. The proportions of each habitat type in individual stoat home ranges were determined and the proportion of radio-locations within each habitat type was calculated for each stoat. Habitat preferences were determined by the log-ratio differences method of Aebischer and Robertson (1992). Stoats that used a habitat in direct relation to its availability gave a derived log-ratio equal to zero; a positive value indicated a preference and a negative value avoidance.

To determine if the road was having any effect on habitat use by stoats, home ranges were also classified into two categories, road (including a 20m strip either side of the road) and non-road (everything else), and a log-ratio analysis as above undertaken.

Statistical comparisons between females and males were only made in the period January to May when information on each sex was collected concurrently. Means are quoted ± 1 S.E.

Age and diet

Between October 1991 and May 1992, 37 stoats were collected in the Eglinton Valley and autopsied. Of these, 29 (including two of our study animals) were caught away from the study area in Mk 4 Fenn traps

(FHT Works, Worcester, England) as part of an associated study (Dilks, O'Donnell and Elliott, 1992), three (including two of our study animals) were accidentally killed in traps set for other reasons, one was found dead on the road and four study animals were caught and killed at the end of the study. A further two study animals were not caught until November 1992, and were excluded from the diet analysis. All study animals except F89 (who could not be re-captured) were aged by the number of incremental lines in the canine cementum (Grue and King, 1984). Stoats less than one year old are defined here as juveniles.

Of the 37 guts examined, 11 were empty and excluded from further analysis. Scats were also collected, mainly from live-traps and latrines located outside known den-sites. Before analysis all material was washed in a fine sieve and then sorted under a low-power (x10) microscope. Guard hairs from mammalian remains were placed on microscope slides coated with warm 5% gelatin and the scale pattern left after stripping the hair away from the dried gelatin bed was compared to those of reference hairs (Day, 1966). Results of the diet analysis are presented as a frequency of occurrence: i.e., the percentage of scats, or guts with food, containing each prey category.
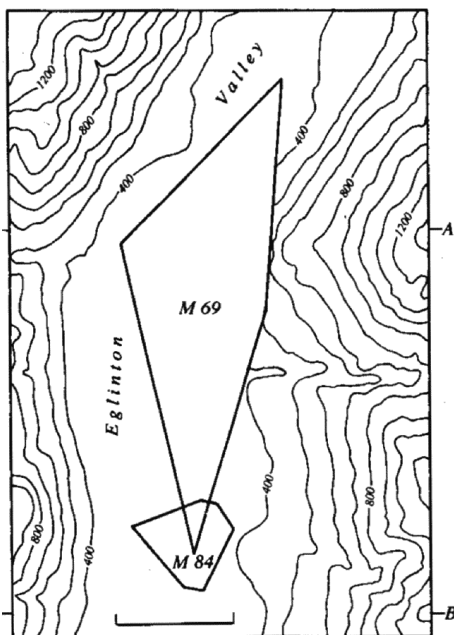
Results

Home range

Home ranges and range lengths of six female and five male stoats radio-tracked between August 1991 and May 1992 varied considerably, particularly for male stoats (Table 1). There was a highly significant correlation between home range size and length for both female and males (for combined data $r = 0.874$, d.f. = 10, $P < 0.001$). We may not have revealed the full extent of the home ranges of two males in October and of three females in January-May (Table 1), and we regard their ranges as minima.

Although the average home range and range length of male stoats were larger and longer than for female stoats, these differences were not statistically significant. The average home range of female stoats (n=5) from January to May was 124 ± 21 ha and that of males (n=4) was 206 ± 73 ha

Figure 1: *Home ranges of two adult male stoats radio-tracked in the Eglinton Valley, Fiordland, in October 1991 (M69 and M84). The contour intervals are 100 m, the scale bar represents 1000 m. The lines A-A and B-B indicate the overlap between the areas shown in Figures 1 and 2.*
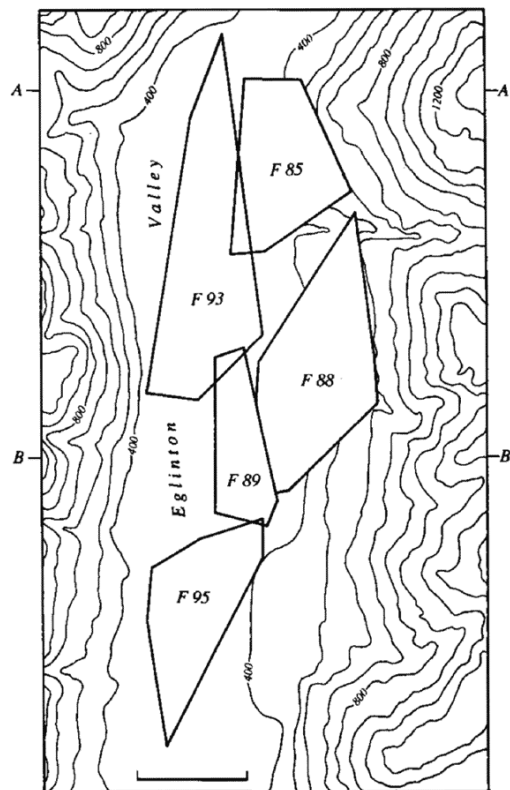

Figure 2: *Home ranges of five female stoats radio-tracked in the Eglinton Valley, Fiordland, between January and May 1992 (F85, F88, F89, F93 and F95). The contour intervals are 100 m, the scale bar represents 1000 m. The lines A-A and B-B indicate the overlap between the areas shown in Figures 1 and 2.*

Table 1: *Home range (HR) and range length (RL) of stoats calculated by the minimum convex polygon method (radio-tracking and live-trapping data combined). Days tracked are consecutive. Ranges marked with an asterisk may not have reached asymptote (defined as ≥ 90% of total range area). F = female; M = male.*

Sex and Stoat	Age (yr)	HR (ha)	RL (km)	Month	No. of records	Days tracked	No. of records to asymptote
F 70	1	20	0.93	Aug	7	4	-
F 85	1	101	1.61	Jan	19	5	15*
F 88	1	156	2.69	Feb	14	5	11*
F 89	?	71	1.64	May	57	12	45*
F 93	1	186	3.34	May	60	17	23
F 95	1	104	2.21	May	45	12	26
M 84	1	29	0.97	Oct	38	9	31*
M 69	3	273	4.25	Oct	15	4	12*
M 69	3	99	2.17	Dec	33	10	24
M 69	3	290	3.82	Jan	29	8	18
M 87	1	368	6.61	Feb	24	7	9
M 94	1	75	2.77	May	33	8	17
M 96	1	92	2.82	May	37	8	20

Table 2: *Log-ratio differences indicating habitat utilisation within home ranges for individual stoats. A positive value indicates preference and a negative value avoidance.*

Stoat	Habitat			
	Forest	Margin	Open	Road
F 85	- 1.14	1.84	- 2.31	- 3.73
F 88	3.73	- 2.31	- 3.43	no road
F 89	0.30	2.51	- 2.46	- 1.80
F 93	- 1.32	4.80	- 2.91	- 4.32
F 95	1.29	- 0.50	-1.33	- 0.71
Female mean	0.57	1.27	- 2.49	- 2.64
S.E.	0.92	1.23	0.35	0.84
M 69	0.53	- 3.73	- 0.29	0.59
M 87	1.28	0.71	- 4.82	2.13
M 94	1.45	0.69	- 6.15	3.07
M 96	- 2.25	4.94	- 5.58	2.50
Male mean	0.25	0.65	- 4.21	2.07
S.E.	0.86	1.77	1.34	0.53
Overall mean	0.43	0.99	- 3.25	- 0.29
S.E.	0.60	0.98	0.65	1.00

(independent *t* test on log-transformed values, *t* = 0.86, d.f. = 7, *P* = 0.42). The average range length from January to May for female stoats was 2.3 ± 0.3 km and that of males was 4.0 ± 0.9 km (independent *t* test on log transformed values, *t* = 2.21, d.f. = 7, *P* = 0.06). The mean number of fixes for male and female stoats over this period was not significantly different (*t* = 0.8, d.f. = 7, *P* = 0.5).

In October 1991 (breeding season), two males had very different home range sizes, M69's being more than nine times larger than M84's (Table 1).

There was overlap between the two ranges (Fig. 1) and this overlap was within the range of an adult female (F70). On one occasion, M69 was caught in a live-trap in the area of overlap; M84 was found denning within 2 m of that trap and there was fresh digging around the trap. Stoat M69 was resident in the study area from at least February 1991, was radio-tracked in three different months, and the calculated home range was different for each month (Table 1). There was a large overlap in the area he used each time however, and if the data are combined he covered a total of 497 ha with a range length of 4.87 km between October 1991 and January 1992. Home ranges were therefore either not fixed over long periods or they were very large and we were only measuring part of them in each tracking session.

Other observations also suggest that ranges of males (at least) were not fixed or were larger than we measured. In November 1991, M84 was killed in a Fenn trap 2.3 km further south than he had been previously recorded. In late January 1992, M69 was also killed in a Fenn trap 1.3 km further south than he had been previously recorded. In February 1992, an adult male (M87) was caught within M69's former home range. He had the largest home range (368 ha) and longest range length (6.61 km) recorded within a tracking session (Table 1). In early May 1992, he was killed in a trap set for hares 0.5 km further south than he had been previously recorded.

Five female stoats radio-tracked between January and May 1992 had discrete home ranges with very little overlap (Fig. 2). Two of these females (F93 and F95) were first caught in the study area in May 1992 and appeared to be recent immigrants (they had not been caught during periodic but intensive trapping over the previous 20 months); F93 was first caught in

Table 3: *Percent frequency of prey occurrence in the gut contents and scats of stoats collected between October 1991 and May 1992.*

Prey category	Gut samples			Scat samples			
	Frequency (%) of prey occurrence in stoats			Frequency (%) of prey occurrence in stoats			
	Males (n=15)	Females (n=11)	Total (n=26)	Male (n=17)	Female (n=18)	Unknown (n=9)	Total (n=44)
Bird	47	64	54	53	44	78	55
Invertebrate	27	36	31	47	33	22	36
Lagomorph	27	18	23	41	44	22	39
Possum	20	0	12	29	0	0	11
Unidentified	13	0	8	0	0	0	0

February 3 km to the north.

Kill-trapping in the associated study (Dilks *et al.*, 1992) to the south of our study area ceased in March 1992. Within two months we trapped and radio-tracked one male (M96) and one female stoat (F95) resident in the area.

Both females and males were capable of large distance movements in the three to five hour periods between records, but in over 50% of cases no movement was detected (Fig. 3). In only one of 123 records (0.8%) was a movement greater than 1.5 km recorded for a female stoat, whereas 12 of 73 (16.4%) movement records of males were between 1.5 and 4 km. The greatest movement detected in under five hours was by an adult male stoat (M87), who moved at least 3.7 km in 3 hr 15 min. All measurements are straight-line (and therefore minimum) distances.

Habitat

Habitat use by stoats was non-random. All stoats avoided open areas within their home ranges (Table 2). Although there were differences between preferences of individual stoats for use of forest and forest margin habitats within their home ranges (Table 2), there was no overall preference shown ($t = 0.49$, d.f. $= 16$, $P = 0.63$).

All four male stoats radio-tracked and four of the females had home ranges that included part of the road. There was a significant difference between female and male use of the road habitat ($t = 4.76$, d.f. $= 6$, $P = 0.003$). Female stoats under-utilised road habitat while males showed a preference for it (Table 2). Male stoats were often found denning near road-killed possums and rabbits and one (M96) dragged a road-killed possum into a nearby den. Female stoats were never found near road-killed carcasses. Of 10 stoats found road-killed in the Eglinton Valley in 1991 and 1992, nine were males and one was female ($\chi^2 = 4.9$, d.f. $= 1$, $P = 0.03$).

Three stoats (M69, F93 and F95) had home ranges that were bisected by a fast-flowing river. All crossed the river regularly and could only have done so by swimming.

Diet

Birds were the most frequent prey item in guts and scats of both sexes of stoats from the Eglinton Valley (Table 3). No rodent remains were found in any gut or scat sample and no possum remains were in any female gut or scat sample. Sample sizes were too small to detect any significant differences between the diet of females and males.
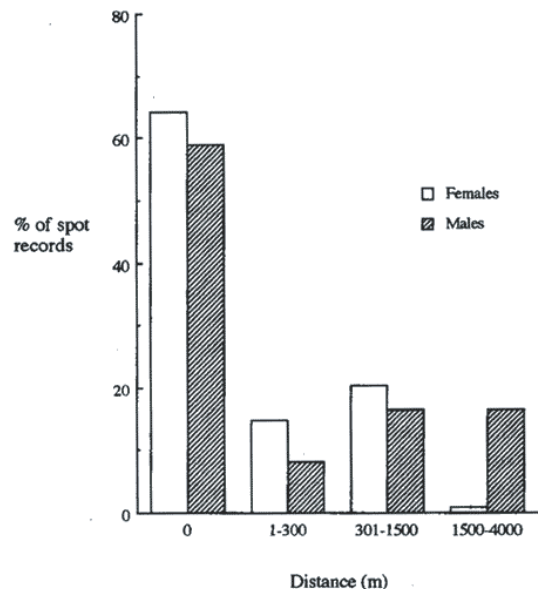

Figure 3: *Minimum distances moved by female and male stoats in the 3-5 hour periods between spot records, January to May 1992. For females n=123 records, for males n=73 records.*

Discussion

Home range sizes of stoats worldwide vary from 2 to 254 ha (King, 1989). Nearly all the home ranges in our study were in the upper part of this range, with values similar to that recorded in Scottish farmland by Pounds (1981). M87's range of 368 ha, measured over seven days in February 1992, appears to be the largest recorded over a short period outside the breeding season, although roaming males in Sweden covered much larger areas in spring (Erlinge and Sandell, 1986). Three males and one female in our study were eventually recovered outside their known ranges; one male had slightly different ranges in each of three months, and at least two females we tracked were recent immigrants. Together, these observations suggest that range size and location of stoats in this habitat may not be fixed over long periods. Stoats vary greatly in size across their geographic range (King, 1989) but there is no evidence for a relationship between body size and home range size: Irish stoats (which are similar in size to New Zealand stoats) had very much smaller home ranges (Sleeman, 1991) than those reported here. Vaisfeld (1972) found stoats in Russia had larger home ranges in forest (where rodents were scarce) than in meadows and scrub (where they were common), suggesting that food supply is a more important factor in determining home range size.

No significant difference was found between average female and male stoat home range size, although in other countries home ranges of males are generally reported to be larger (King, 1989). At an average of 124 ha (and with some ranges possibly minima), range sizes of females in New Zealand beech forest are among the largest recorded. With the exception of mast years, rodents are uncommon in this habitat; in most years food supply could therefore be limiting, which may explain the large home ranges found for both sexes in our study. Our finding that adult female stoats in New Zealand have mutually exclusive home ranges agrees with the results of studies in other countries (Erlinge, 1977; Pounds, 1981; Debrot and Mermod, 1983). However, at least two of the five females radio-tracked in our study appeared to be recent immigrants, suggesting that adult females may not be as sedentary in this habitat as they are in other habitats overseas (Erlinge, 1977; Debrot and Mermod, 1983).

We were unable to gather much information on spacing of male stoats. Four of the males tracked in our study area at various times roamed outside the area and were killed in traps set for other purposes. In Sweden, Erlinge and Sandell (1986) found that in spring-summer dominant males adopted a roaming behaviour and visited many females, whereas yearling males were either transient or remained in one area and maintained contact with few females. In our study, the ranges of two adult males in spring overlapped and the overlap was within the range of a female. M69 was three years old and had a much larger home range than M84, overlapping the home range of at least two females. M84 was one year old and his home range overlapped part of the home range of only one female.

In our study, stoats sometimes moved large distances within the three to five hour periods between records. In Scotland, Pounds (1981) also found that stoats could move large distances quickly, with one female moving 4.5 km in 2.5 hr. This contrasts with the findings of Sleeman (1987), who recorded only small movements (up to 400 m) for stoats in Ireland. As in our study, Pounds (1981) recorded almost no movement on some days and large movements (2 km or more) on others.

In Europe and North America, stoats rarely enter forest and exhibit a preference for early successional communities and grasslands where their principal prey, voles and lemmings (subfamily Microtinae) typically occur (Aspisov and Popov, 1940; Simms, 1979; Debrot and Mermod, 1983). At a study site in Ireland where voles were absent, stoats showed a highly significant preference for woodland (Sleeman, 1993). In our study, stoats preferred forest and avoided open areas; this may reflect the scarcity of small rodents in New Zealand.

The behaviour of the male stoats we studied was affected by the presence of the road. It seems very unlikely that stoats are able to kill possums, but possums (and rabbits) are often found as road-kills in the study area. Our evidence suggests that males scavenge more than females, which may explain why King and Moody (1982) found that male stoats ate significantly more possums than females. The fact that males scavenge more readily than females would also explain why they are more frequently found as road kills (Sleeman, 1987; this study). Although females avoided the road and males showed a preference for it, the shapes of their home ranges were similar; male home ranges were not more elongated than those of females. Local topography may have influenced the shape of the animals' ranges; the valley floor, the river and the road are oriented roughly north-south, as were the long axes of nearly all the home ranges (Figs. 1 and 2).

In higher northern latitudes rodent numbers fluctuate greatly and there is a close relationship between stoat density and the abundance of small rodents, their main prey (Aspisov and Popov, 1940; Erlinge, 1983). This has led to the suggestion that

stoats are adapted morphologically and behaviourally to feed on small mammals. Although this may be the case, stoats are also found in temperate climates; in these areas lagomorphs and birds become just as important (if not more important) as prey items (Day, 1968; Potts and Vickerman, 1974; Tapper, 1976; Brugge, 1977). In our study birds were the most commonly occurring prey item but lagomorphs (and for males also possums) may have provided the most bulk. No rodents were detected in the diet, and this reflects the stage of the beech mast cycle; our study was undertaken two years after a mast year and mouse density was very low (C. O'Donnell, P. Dilks and G. Elliott, *unpublished data*).

Densities of rats and feral cats are very low, and ferrets and weasels are absent from the Eglinton Valley (King, 1983; E. Murphy and J. Dowding, *unpublished data*), suggesting that this habitat is not sufficiently productive overall to support viable populations of most of the small mammals now found in New Zealand. Pure beech forest has low botanic diversity and generally carries lower densities of possums and rats and has lower invertebrate biomass than mixed forest types (Wardle, 1984; Innes, 1990; Brockie, 1992). With the exception of mast years, New Zealand beech forest is probably also marginal habitat for stoats. Stoat density is normally low between mast years and there is little or no breeding at these times (King, 1989). No breeding was detected in the year of our study, although the age structure of the animals caught (Table 1) reflected high productivity in the previous season. Stoats probably survive in this habitat because they are opportunistic in their diet, and because their breeding biology allows them to respond very rapidly to a sudden increase in food availability.

Our study suggests that rapid re-invasion after localised stoat control may be a problem, even when stoats are not at peak density; two adults probably colonised an area within two months of an intensive six-month kill-trapping programme. Our finding that adult female stoats avoided the road indicates that trapping along roads, although logistically easier, may bias trapping. We also found that a fast-flowing river, which might have been expected to restrict their movements, was not an effective barrier to stoats.

Acknowledgements

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