Importance of ground weta (*Hemiandrus* spp.) in stoat (*Mustela erminea*) diet in small montane valleys and alpine grasslands

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Abstract: Most research into the diet of stoats in New Zealand has been in low altitude valleys such as the Eglinton and Hollyford Valleys. Yet much of New Zealand's national parks (e.g. Fiordland National Park) consist of many small montane valleys and alpine areas. This research identified the key prey species of stoats inhabiting such small montane valleys and alpine grasslands. Stoats were collected from Department of Conservation kill-trap lines in the Murchison Mountains in Fiordland National Park over two summers (1999/2000 and 2000/2001) that followed heavy and moderate beech and snow tussock seed-fall events respectively. During the first summer mice were the most common prey item in stoat stomachs (68%), however in the second summer ground weta occurred most commonly (59%). These results support previous stoat research and suggest that ground weta may be an important prey species for stoats in the Murchison Mountains.

Keywords: *Mustela erminea*; *Hemiandrus* sp.; diet; Fiordland; weta; stoats

Introduction

Stoats (*Mustela erminea*) were introduced into New Zealand in the 1880s in an attempt to control rabbits (*Oryctolagus cuniculus*) (King, 1990). Since then, they have become widespread throughout a variety of New Zealand habitats and have been implicated in the decline of several native species (Elliott, 1996; Elliott *et al.*, 1996; McLennan *et al.*, 1996; Wilson *et al.*, 1998). Understanding stoat diet is critical for developing stoat management strategies. In particular, diet analysis can be used to formulate hypotheses about types of prey that might be driving the population biology of stoats. Diet parameters can identify primary and secondary prey species, an important concept for modelling stoat management and the consequent impacts on target conservation species (Barlow and Choquenot, 2002). Diet studies can also provide linkages for stoat population studies that attempt to describe interactions between predators and their prey.

Stoat populations are resource dependent, and in New Zealand are thought to respond to increased densities of mice (*Mus musculus*) that result from irregular heavy beech (*Nothofagus* spp.) seedfall events (King and McMillan, 1983). Such numerical responses are normally detected in the spring and summer following heavy beech seed-fall. These seed-fall events occur on average every 4–6 years. New Zealand's alpine grasslands are dominated by snow tussocks (*Chionochloa* spp.) which also show strong annual variation in flowering and seed production. In general, high snow tussock flowering years are synchronised with beech flowering years (Schauber *et al.,* 2002). Populations of some invertebrate species increase markedly after heavy snow tussock seeding (Kelly *et al.,* 2000). However, it is not known whether a relationship exists between stoats and snow tussock flowering, similar to that observed between stoats and beech seed-fall.

Fiordland National Park, in the south western corner of the South Island of New Zealand, is the refuge of many rare and endangered species. For example, the Murchison Mountains within Fiordland National Park are the only place where the endangered takahe (*Porphyrio hochstetteri*) still occurs naturally. Stoats are listed amongst a number of factors thought to threaten takahe survival (Maxwell, 2001). With the exception of Lavers and Mills (1978), the only previous research into stoat diet in Fiordland has been carried out in the Eglinton and Hollyford Valleys (King and Moody, 1982; Murphy and Dowding, 1995). Although the Eglinton and Hollyford Valleys are typical of some large, low altitude beech forest valleys in the South Island, much of Fiordland is made up of smaller, montane valleys and alpine habitat like the Murchison Mountains, where the diet of stoats could differ substantially, particularly as lagomorphs are not present, and distributions of prey species are likely to differ over an altitudinal gradient. The aim of this research was to identify the key prey species of stoats inhabiting small montane valleys and alpine grasslands in the Murchison Mountains, and to identify whether these key prey species differ from stoats inhabiting larger lower altitude valley systems such as the Eglinton and the Hollyford.

Methods

Study area

Stoats for the diet analysis came from four sites in the Murchison Mountains (45° 10'S, 167° 20'E) where they are being controlled for conservation purposes; the Mystery Burn, Takahe Valley, the Point Burn and the Te Ana-au caves. The dominant forest canopy species in the Murchison Mountains varies from site to site and includes red beech (*Nothofagus fusca*), silver beech (*Nothofagus menziesii*) and mountain beech (*Nothofagus solandri* var. *cliffortiodes*). Treeline in the area varies between 900–1000 m a.s.l. Above the treeline, snow tussocks (*Chionochloa spp.*) dominate the alpine grasslands (Lee *et al.*, 1988). However, around lake-edge sites such as the Te Ana-au caves the beech forest is mixed with species such as kamahi (*Weinmannia racemosa*) (D. Smith, *pers. obs.*). Trap lines in the Mystery Burn, Point Burn and Takahe Valley ran for approximately 4–6 km along the valley floor through beech forest and red tussock (*Chionochloa rubra*) into the alpine head basins, occurring between 800–1200 m a.s.l (Fig. 1), while trapping at the Te Ana-au Caves occurred at 300 m a.s.l and consisted of just three traps checked every day during the first season, and a 6 km trap line checked every two to four weeks during the 2000/2001 season.

Beech and *Chionochloa* seed fall

Department of Conservation monitors beech seed fall at three sites in the Fiordland area; Princhester Creek (which is primarily silver beech) 30 km south east of the Murchison Mountains in the Takitimu range, Takahe Valley (which is primarily mountain beech) and the Eglinton Valley (which is primarily red beech) 20 km north east of the Murchison Mountains. Each site has a line of eight trays approximately 50 m apart. Trays are set annually on 1 March and beech seed is collected from them on the 1 June of each year. Landcare Research monitors snow tussock seed output in Takahe Valley, using single transects of 100 plants for each of six species (*Chionochloa rigida, C. crassiuscula, C. pallens, C. teritifolia, C. rubra* and *C. spiralis*). The number of flower stems is counted for each plant and from these 100 plants ten are chosen through restricted randomisation for counting the total number of tillers and flower heads (W. Lee, Landcare Research, Dunedin, *unpubl. data*).

Kill trapping

Kill-trapping undertaken by the New Zealand Department of Conservation commenced in the Murchison Mountains during spring 1999 and is ongoing; the stoats used in this study were trapped between November 1999–April 2000 (Season 1) and November 2000–April 2001 (Season 2). Stoats were trapped using two Mark IV Fenn traps set inside

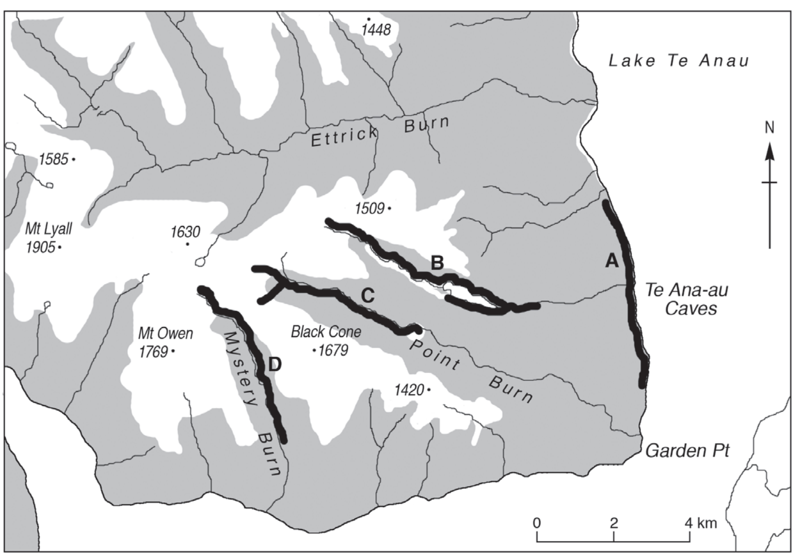

Figure 1. The locations of stoat trap lines in the Murchison Mountains during the 1999/2000 and 2000/2001 field seasons. All lines are in solid black, A = Te Ana-au Caves, B = Takahe Valley, C = Point Burn, D = Mystery Burn.

wooden tunnels (designed to prevent non-target species from being trapped) and spaced 200 m apart. Tunnels were baited with chicken eggs that were placed in the middle of the tunnel between the two traps; this ensured that stoats had to cross a trap in order to get to the bait regardless of which end of the trap they entered from. Traps were checked every two to four weeks during the summer with date and trap site recorded for each stoat capture.

Diet analysis

Not all trapped stoats were used for the analysis because some of their stomachs were empty or decomposed (i.e. were fly-blown). Those that were able to be analysed had the contents of their stomachs and small intestine removed and stored in 75% ethanol. Later, stomach contents were washed through a 500 μm sieve and sorted into the following prey categories defined by King and Moody (1982): feathers (bird remains), egg shell, hair (small mammal remains), lizard skin, exoskeletons of invertebrates, and other items.

Mammal remains were identified by preparing casts of guard hairs found in stomach samples in casting medium of 50% polyvinyl acetate and 50% distilled water (Day, 1966; Brunner and Coman, 1974). Scale patterns left in the casts were compared with the plates in Brunner and Coman (1974) and a reference collection created from specimens collected in the field. This method enabled us to identify small mammal remains to genus. Where possible a minimum of six guard hairs were taken from each sample.

Feathers were identified by examining the nodes and inter-nodal distances in the downy barbule region of the feather. Specimens were compared to the plates in Day (1966) and to the key in Brom (1980), along with a reference collection taken from the study area, Te Anau Wildlife Park, and from examples supplied by the Otago Museum. This system allowed birds to be identified to order.

Exoskeletons of invertebrates were identified to order, except for ground weta (*Hemiandrus* spp.) which were identified to the species level by Anthony Harris (Otago Museum), and Peter Johns (University of Canterbury). Ground weta are relatively large (15–22 mm in length) flightless Orthoptera (Family: Anostostomatidae) that are widespread but patchily distributed throughout New Zealand (Johns, 2001).

Presentation of results

The frequency of different prey categories were quantified, by calculating the percentage of the total number of stomachs containing food items, which had that prey category in them. This method assumes that the time which prey items remain in the gut, and the probability of correctly identifying them, are equal across all samples without assuming that they are the same for all prey categories (King and Moody, 1982). The prey category ‘eggshell’ was excluded from our major analysis because chicken eggs were used as bait at trap stations. All samples used in this research were from individual stoats, therefore each sample is independent. Because of the large movements (i.e. 3 km per day) that stoats are known to make (Murphy and Dowding, 1995; Smith, 2002) no attempt was made to associate stoat diet to a particular habitat in which an individual was trapped.

Statistical analysis

Ninety-five percent confidence intervals around the percent frequency of occurrence of prey items were calculated using the bootstrapping technique described by Reynolds and Aebischer (1991), with each value bootstrapped 1000 times. Differences in the frequency of prey items between sites and years were compared using chi-square contingency tables.

Results

Beech and *Chionochloa* seed fall

Counts of beech seed in autumn 1999 indicated heavy seeding for all species of beech, while counts in

Table 1. Beech seed-fall (m^2) recorded at three sites in Fiordland National Park during 1999 and 2000 (reproduced with the permission of Department of Conservation, Te Anau).

Year	Site	Species	Total seed	Viable seed	% viable
1999	Princhester	Silver beech	4198	3728	88
2000[1]		Silver beech	691	-	-
1999	Takahe	Mountain beech	11657	8580	73
2000[1]		Mountain beech	5423	-	-
1999	Eglinton	Red beech	3503	2220	63
2000[1]		Red beech	3504	-	-

[1] The number of viable seeds was not recorded for 2000.

Table 2. A summary of stomach status (decomposed, empty or full) for stoats captured in the Murchison Mountains (Values are the number of stoats caught with the proportion of these stoats to the number of stoats caught at that site in brackets).

Site	Season	Status	Juvenile male	Adult male	Juvenile female	Adult female	Unidentified[1]
Takahe Valley	1999/2000	Decomposed	6(0.12)	0	0	0	6(0.12)
		Empty	0	0	3(0.06)	0	0
		Full	17(0.34)	2(0.04)	7(0.14)	2(0.04)	7(0.14)
	2000/2001	Decomposed	0	0	0	0	3(0.38)
		Empty	0	0	0	0	0
		Full	0	4(0.5)	0	1(0.13)	(0)
Mystery Burn	1999/2000	Decomposed	1(0.04)	1(0.04)	0	0	0
		Empty	0	0	0	0	1(0.04)
		Full	7(0.29)	2(0.08)	8(0.33)	0	4(0.17)
	2000/2001	Decomposed	0	3(0.18)	1(0.06)	0	5(0.31)
		Empty	0	1(0.06)	0	0	0
		Full	1(0.06)	3(0.19)	2(0.13)	0	0
Point Burn	1999/2000	Decomposed	7(0.23)	0	2(0.07)	0	4(0.13)
		Empty	0	0	2(0.07)	0	1(0.03)
		Full	8(0.27)	1(0.03)	5(0.17)	0	0
	2000/2001	Decomposed	0	0	0	0	2(0.4)
		Empty	0	0	0	0	0
		Full	0	0	0	2(0.4)	1(0.2)
Te Ana-au Caves	1999/2000	Decomposed	0	0	0	0	0
		Empty	1(0.04)	0	0	0	0
		Full	19(0.83)	2(0.09)	1(0.04)	0	0
	2000/2001	Decomposed	0	2(0.1)	2(0.1)	2(0.1)	7(0.35)
		Empty	0	0	0	0	0
		Full	2(0.1)	4(0.2)	0	1(0.05)	0

[1]Unidentified = Age or sex unidentified

Autumn 2000 indicated moderate seeding for mountain beech, and heavy seed fall for red beech (Table 1). In Takahe Valley the proportion of flowering tillers per tussock was estimated to be 80% across all species during the summer of 1998/1999 and 18% in 1999/2000 (W. Lee, Landcare Research, Dunedin, *unpubl. data*).

Diet analysis

Ninety-three (73%) of 128 the stoat stomachs from 1999/2000 and 22 (44%) of 50 from the 2000/2001 season had food items in them, while the rest were either empty or were decomposed. The distribution of flyblown stomachs was not higher amongst any particular site, age class or sex (Table 2). All data presented in the following figures and used in the following analyses are percent frequency occurrences of non-empty, non-decomposed stomachs. Sixty-seven of the stoats containing food items during the 1999/2000 field season were male while 26 were female. Estimated confidence intervals suggested data were too few for comparisons between sex and age class (data not shown).

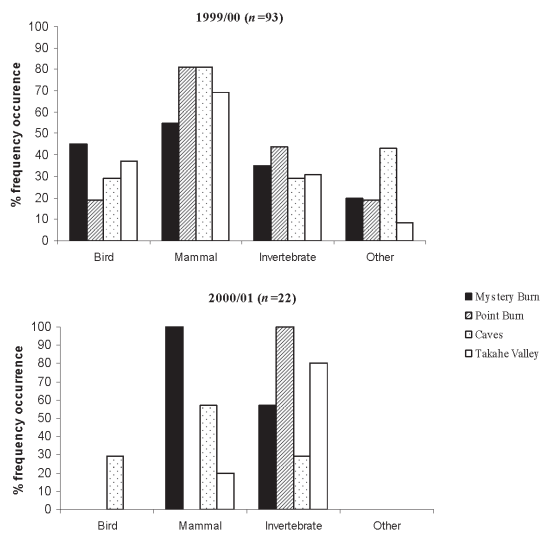

Figure 2. The diet of stoats at four sites in the Murchison Mountains, Fiordland

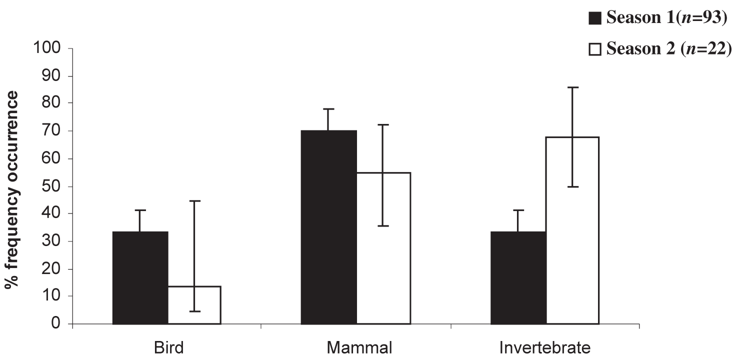

Figure 3. Change in diet of stoats trapped over two seasons in the Murchison Mountains, Fiordland. Vertical bars represent ninety-five percent binomial confidence limits.

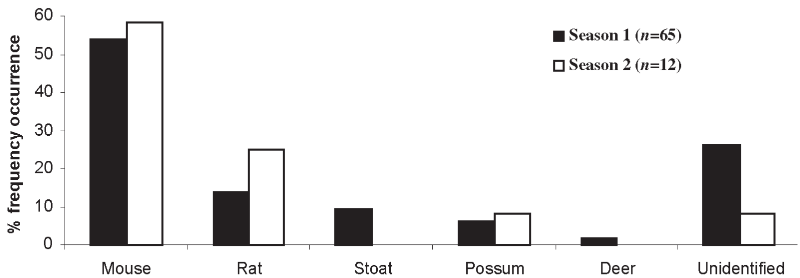

Figure 4. Frequency of mammal species as a percentage of those stomachs containing mammal remains, for stoats trapped over two seasons in the Murchison Mountains, Fiordland.

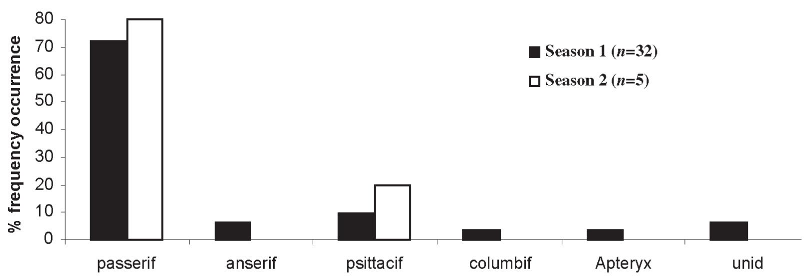

Figure 5. Frequency of bird orders as a percentage of those stomachs containing bird remains, for stoats trapped over two seasons in the Murchison Mountains, Fiordland. Passerif = Passeriformes, anserif = anseriformes, psittacif = psittaciformes, columbif = columbiformes, unid = unidentified.

Difference in diet between sites was only tested for 1999/2000 (*n* = 93), as sample size for 2000/2001 (*n* = 22) was too small for between site comparisons. There was no significant difference between the four trapping sites in the proportion of each of the three major prey categories (bird, mammal, invertebrates) (χ^2 = 4.009, d.f. = 6, *P* = 0.75). Across all sites, mammals were the most commonly occurring prey item while birds and insects occurred in similar numbers (Fig. 2). When data from the four sites were pooled for a between year comparison there was a significant change in the type of prey eaten between the two seasons (χ^2 = 6.667, d.f. = 2, *P* = 0.05). Ninety-five percent confidence intervals indicate this was due to an increase in invertebrates in stoat diet in 2000/01 (Fig. 3).

Mammal remains were found in 70% of stomachs in 1999–00 and in 54% of stomachs in 2000/01. Mice and rats were the most commonly eaten mammal species in both years (Fig. 4). Significantly more mice were eaten than rats over both years (χ^2 = 16.96, d.f. = 1, *P* = 0.001). Stoat, possum (*Trichosurus vulpecula*) and deer (*Cervus elaphus*) remains were all found in less than 9% of stomachs (deer would have been eaten as carrion). All five possum remains were found in the stomachs of males. Seventeen (26%) stomachs in 1999/2000 and one (8%) in 2000/01, had unidentifiable mammal remains; these items usually constituted clumps of under hairs, with no identifiable guard hairs that could be cast.

Bird remains were found in 33% of stomachs in the first year and 14% of stomachs in the second year. Passeriformes dominated, and were found in 72% (*n* = 32) of stomachs with bird remains in them in 1999/00, and 80% (*n* = 5) in 2000/01. Anseriformes, Psittaciformes, Columbiformes and Apteryx were also identified in small numbers of stomachs (Fig. 5).

Thirty-three percent of identifiable prey items in stoat stomachs in 1999/00 and 68% in 2000/01 were invertebrate. The most commonly occurring invertebrate in stoat diet over both years was ground weta, which constituted 89% of invertebrate prey items identified in 1999/00 (*n* = 28) and 87% of those identified in 2000/01 (*n* = 15). In total ground weta constituted 26% of all prey items in 1999/00 (*n* = 25) and 59% of all prey items in 2000/01 (*n* = 13). Ground weta often comprised a whole meal for stoats, with one stomach containing a minimum of nine individual weta. Two species of ground weta were identified from stoat stomachs, *Hemiandrus focalis* and *H. madisylvestris*. Other invertebrate remains identified included Coleoptera, Diptera, Annelids and Hymenoptera.

Discussion

Inter-annual variation in beech seed-fall is hypothesised to be the main driver of mouse and stoat population dynamics in beech forest (King and McMillan, 1983). This research was conducted over two consecutive summers that followed a heavy beech seed fall year (1998/1999) and a moderate beech seed fall year (1999/2000) in Fiordland National Park. Snow tussock flowering was also high during the summer of 1998/1999 and lower during the following summer (1999/2000). The three main prey categories of stoats identified in this study were mammals (mainly mice), invertebrates (mainly ground weta) and birds. The observed difference in the proportion of the two major prey categories (mammal and invertebrate) eaten between years suggests there was a functional change in stoat diet to ground weta as mice numbers declined. However, in the absence of detailed mouse population monitoring, and given the time frame of this research (two years) such links remain tenuous and require further investigation. Future research should also consider whether ground weta populations respond to fluctuations in *Nothofagus* and *Chionochloa* seed output.

Our results support an earlier diet study carried out in the Murchison Mountains by Lavers and Mills (1978), where stoat scats (*n* = 97) were collected from the Point Burn and Takahe Valley area between August 1972 and May 1973 (two years after a heavy beech seed-fall, and one year after moderate seed-fall). Lavers and Mills (1978) found that ground weta occurred as often (55%) in the scats as mammals (56%), while birds occur in 33% of the scats. This is corroborated by a survey in 1973 where ground weta were noted to be abundant in Takahe Valley (Eyles, 1973). During a concurrent study, ground weta were caught as by-catch in a mouse index line situated in alpine habitat in the Murchison Mountains. Ground weta captures averaged 2.96 captures per 100 trap nights, peaking at 5.38 captures per 100 trap nights, suggesting that ground weta are abundant at high altitudes in the Murchison Mountains (Smith, 2002). The two different species of ground weta identified during this study are known to occupy different habitats, in particular *H. focalis* is a tussock species while *H. madisylvestris* is more common in forest (P. Johns, *pers. comm*). Therefore ground weta might be available as prey for stoats in all the habitats described in this research.

Invertebrates have been observed at high frequencies in stoat diet in other parts of New Zealand. In particular, invertebrates occurred in 82% of stoat stomachs (*n* = 44) collected from a lowland podocarp forest in South Westland (Rickard, 1996). Also, King and Moody (1982) noted invertebrates (including ground weta) to occur in 16% of 1250 stoat stomachs collected nationwide.

The diet of stoats in the Murchison Mountains was different to that observed for stoats in the nearby Eglinton Valley during other years. Stoats inhabiting beech forest in the Eglinton Valley during 1990–91 ate mostly birds (56%) followed by mice (54%) (Murphy and Dowding, 1995). King and Moody (1982) also found that birds were the most commonly occurring items of prey (43%, *n* = 250) in their nationwide study. Our results (Fig. 3), together with the findings of Lavers and Mills (1978), indicate that birds were a less frequent prey item of stoats in the Murchison Mountains when compared to mammals or ground weta.

Possum remains in stoats have been identified at low levels in several studies, and are generally thought to be carrion from either road kill or possum control operations (King and Moody, 1982; Murphy and Dowding, 1995). Despite no possum control operations in the Murchison Mountains at the time of this study and no roads in this area, possum remains were identified at low levels. Although this could mean that stoats exhibit some low-level predation upon possums, possums are relatively dense in beech forest (0.5 per ha) and about 15-30% of possums die naturally each year (Cowan, 1990). Therefore with home ranges of 50–100 ha (Smith, 2002), stoats may have regular contact with dead possums.

The dominant prey categories found in stomachs are likely to mirror the most abundant prey species in the area, i.e. mice, ground weta and passerines. Bird counts in the Murchison Mountains have shown passerines to be the dominant order of birds (DOC, *unpubl. data*). The Murchison Mountains is home to many rare and endangered species such as the takahe, brown kiwi (*Apteryx mantelli*) and kaka (*Nestor meridionalis*). The low occurrence or absence of these species in this diet study highlights that they are not drivers of stoat population dynamics, however not detecting them in stoat diet does not mean that such species are not at risk from stoat predation. Because these species occur at low densities a predation rate that is proportionally small compared to overall stoat diet may have a large impact upon them.

Stoats are a highly adaptable species with a wide dietary niche and, in New Zealand alone, have been shown to have diets that include lagomorphs, rodents, insects, annelids, possums, birds, lizards and freshwater crayfish (King and Moody, 1982). When mouse numbers decline in beech forest, stoat numbers also decline (King, 1983). However, in small montane valley systems like the Murchison Mountains, large invertebrates such as ground weta may constitute an important food source for stoats, particularly in locations or years when mice are scarce. Entomologists interested in ground weta conservation need to urgently assess whether ground weta populations can sustain prolonged stoat predation.

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