Diet of stoats at Okarito Kiwi Sanctuary, South Westland, New Zealand

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Abstract: The diet of 871 stoats (*Mustela erminea*) caught within the Okarito Kiwi Sanctuary, South Westland, New Zealand, between 2001 and 2004 was studied by assessment of gut contents. Stoat and ship rat (*Rattus rattus*) captures were used as a measure of relative abundance over time, and rat and mouse (*Mus musculus*) abundance was indexed using tracking tunnels between spring 2002 and winter 2004. There were major increases in rat captures in spring of 2002 and again in spring of 2003. Stoat captures peaked in the following summers, as rat captures declined. Rats and invertebrates were major components of stoat diet, occurring in 41% and 52% of guts respectively; birds were found in 19%. Changes in these percentages with time indicated that stoats shifted their diet from rats to birds and invertebrates as rat abundance (as indexed by tracking tunnels) decreased. The greatest impact on native species is therefore likely to be when rat abundance is declining after major irruptions, as the increased consumption of birds and invertebrates overlaps with the periods of highest stoat abundance.

Keywords: *Mustela erminea;* podocarp forest; prey abundance; *Rattus rattus*; tracking tunnel

Introduction

Okarito brown kiwi (*Apteryx mantelli* 'Rowi') is the rarest population of kiwi, with an estimated 150 surviving (Robertson 2003). They are restricted to c. 10 000 ha of South Okarito Forest, South Westland. Predation of young kiwi, chiefly by stoats (*Mustela erminea*), is probably the most important factor contributing to their decline (Miller & Elliott 1997), as is the case for other kiwi populations around the country (McLennan et al. 1996; Basse et al. 1999).

Stoats also prey on other native bird species, invertebrates, lizards and aquatic fauna. Their main prey items in podocarp forests are, however, ship rats (*Rattus rattus*), mice (*Mus musculus*) and other mammals (King & Murphy 2005). When rat populations are suddenly reduced following pest control operations, stoats prey more heavily on birds (Murphy et al. 1998), but it is not known how the diet of stoats varies with natural fluctuations in rat populations.

To reduce the impact of stoats in South Okarito Forest, the Department of Conservation set up a network of 3000 Fenn traps in April 2001. This extensive trapping operation provided a large sample of stoats with which to investigate stoat diet at Okarito, and its variation over time and with prey abundance.

Methods

Okarito Kiwi Sanctuary comprises c. 10 000 ha of indigenous podocarp–hardwood lowland (0–520 m a.s.l.) forest in South Westland (43°15'S, 170°11'E). The canopy is dominated by rimu (*Dacrydium cupressinum*), southern rātā (*Meterosideros umbellata*) and miro (*Prumnopitys ferruginea*) and the subcanopy by kāmahi (*Weinmannia racemosa*) and quintinia (*Quintinia acutifolia*) (Rickard 1996). In 2002 and 2003 there was heavy seeding by podocarp trees (DOC unpublished data).

Wooden tunnels containing two Mark VI Fenn™ kill-traps were set and baited with hen eggs or occasionally rabbit meat at approximately 200 × 500-m spacing throughout the sanctuary. A buffer line of traps was also established around the outside of the sanctuary. Overall there were 3000 traps, which were set continuously between April 2001 and July 2004. Traps were cleared twice a month in summer and autumn (beginning in May 2001), and monthly in winter and spring. In total, 1950 stoats were caught; of which 1058 were in good enough condition to be autopsied. The gut contents of 871 of these stoats were analysed. The other 187 stoats had empty guts or unidentifiable food remains and were excluded from further analysis, after confirmation that their numbers did not differ by season or sex from the stoats with guts containing identifiable food. Eggshell remains that could not be distinguished from bait material were also excluded, as were maggots, and stoat hairs, which may have been eaten accidentally.

All material was washed and finely sieved before being sorted under a low-power microscope. Identifiable mammal remains included claws, feet, bones and hairs. Hairs were identified by the scale patterns (Brunner & Coman 1974). Bird feathers were classified where possible as passerine or non-passerine by the structure of downy barbules (Day 1966) and further by comparison to a reference collection.

Tracking tunnels were used to monitor rodents from spring 2002 to winter 2004 (Gillies & Williams 2003 unpublished report). Fourteen tracking-tunnel lines were spread throughout the sanctuary and each line consisted of 10 tracking tunnels spaced 50 m apart. Tunnels were baited with peanut butter, and run for one night four times a year (February, May, August and November). Results are expressed as the percentage of tunnels that contained rat and mouse tracks.

Diet results are presented as a percentage frequency of occurrence; i.e. the percent of guts with food, containing each prey category. Differences in the diet between years (year from spring to the following winter), and between male and female stoats in each season, were assessed using chi-squared tests on frequency of occurrence data for each food category separately. Correlations between prey occurrence and rat and mouse abundance were analysed using Spearman rank correlation.

Results

Over 10 000 rats and 1950 stoats were captured in the Fenn traps between April 2001 and July 2004. There were major increases in rat numbers in spring of 2002 and again in spring of 2003 (Fig. 1). Stoat numbers peaked in the following summers, as rat numbers declined.

Overall, rats and invertebrates were major components of stoat diet, occurring in 40.8% and 52.4% of guts respectively (Table 1). Mouse remains were found in 11.5% of guts. Lagomorphs and possums did not feature prominently in the diet. Bird remains were found in 19.3% of guts. Most of the bird remains that could be identified further were passerines, which occurred in 7.5% of guts (and included blackbirds *Turdus merula* and finches). One gull (*Larus* sp.) and one kererū (*Hemiphaga novaeseelandiae*) were also identified. Eggshell remains were found in 4.9% of stoat guts. Lizards (skink remains found in 0.7% of guts and gecko in 0.3%) were a minor component of stoat diet. Invertebrate remains identified further were tree wētā, ground wētā and cave wētā (Orthoptera: Anostostomatidae; found in 20.1% of guts); scarab and carabid beetles (Coleoptera; 11.5% of guts); freshwater crayfish (*Paranephrops* sp.; 4% of guts); moth larvae and adult moths (Lepidoptera; 1.7% of guts); ants, wasps and a bee (Hymenoptera; 1% of guts); flies (Diptera; 1% of guts); earthworms (Oligochaeta; 0.8% of guts); and a cranefly larva (Tipulidae).

There were some significant differences in the frequency of occurrence of the major prey items found

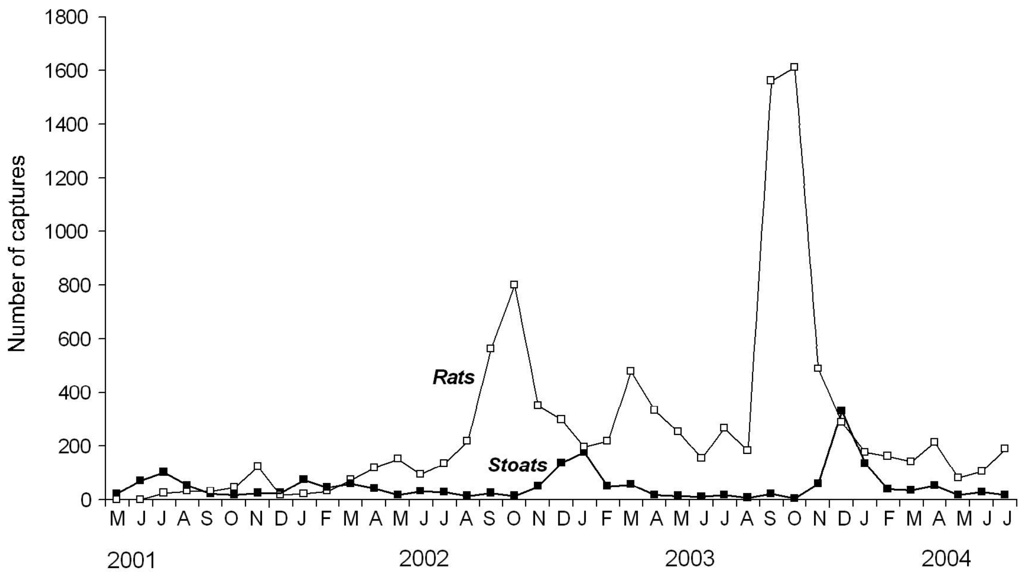

Figure 1. Number of stoats and rats caught in Fenn traps at Okarito Kiwi Sanctuary each month from May 2001 to July 2004.

Table 1. Percentage frequency of occurrence of the prey items found in stoat guts in the Okarito Kiwi Sanctuary, South Westland, from 2001 to 2004, and chi-squared test probabilities for differences in the frequency of occurrence for each food category between males and females each season and overall; **P* < 0.05, ***P* < 0.001, ****P* < 0.0001.

Prey item	Spring		Summer		Autumn		Winter		Total		Grand
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	total§
n	49	83	119	271	62	97	73	104	303	555	871
Rat	36.7	41.0	30.3	45.0*	30.6	53.6*	34.2	42.3	32.3	45.4**	40.8
Mouse	12.2	7.2	20.2	7.4***	24.2	4.1***	20.5	7.7**	19.8	6.9***	11.5
Unidentified rodent	8.2	6.0	3.4	3.7	3.2	4.1	2..7	3.8	4.0	4.1	4.0
Possum	6.1	6.0	2.5	4.8	1.6	4.1	2.7	0.0	3.0	4.0	3.6
Lagomorph	0.0	1.2	0.8	1.8	1.6	2.1	2.7	0.0	1.3	1.4	1.4
Bird	22.4	15.7	20.1	24.7	17.7	16.5	6.8	18.3*	16.2	19.6	19.3
Lizard	4.1	2.4	0.8	0.4	0.0	0.0	1.4	1.9	1.3	0.9	1.0
Fish	0.0	2.4	0.0	1.6	3.2	5.2	1.4	1.0	1.0	2.3	1.8
Invertebrate	40.8	47.0	61.3	53.5	54.8	46.4	60.3	50.0	52.8	47.2	52.4
Vegetation	12.2	13.3	19.3	12.2	4.8	12.4	17.8	14.4	14.9	12.8	14.7

§ Totals include data from 13 stoats of unknown sex

in male and female stoats (Table 1). Guts of female stoats were significantly more likely to contain mice ($\chi^2 = 31.25$ $P < 0.0001$), and significantly less likely to contain rats ($\chi^2 = 13.31$, $P = 0.0003$), than the guts of males.

The frequency of occurrence of the major prey items varied between the three years (bird: $\chi^2 = 12.847$, $P = 0.0016$; rat: $\chi^2 = 17.597$, $P = 0.0001$; invertebrate: $\chi^2 = 9.168$, $P = 0.01$; d.f. = 2). Rat remains in stoat guts were found most often in 2003 when the occurrence of bird remains was lower (Fig. 2). The occurrence of mice in stoat guts did not vary significantly from year to year.

There was a significant positive correlation between the rat tracking tunnel index and the frequency of occurrence of rat remains in stoat guts ($r_s = 0.833$, $P \leq 0.01$) (Fig. 3a). Correspondingly, there was a significant inverse correlation between the rat tracking index and the frequency of occurrence of bird ($r_s = -0.833$, $P \leq 0.01$) and invertebrate ($r_s = -0.762$, $P \leq 0.025$) remains in the guts (Fig. 3b). The frequencies of occurrence of bird, invertebrate and mouse remains in the diet were not significantly correlated with mouse tracking tunnel rates ($r_s = -0.571$, -0.548, 0.268, respectively, $P > 0.05$).

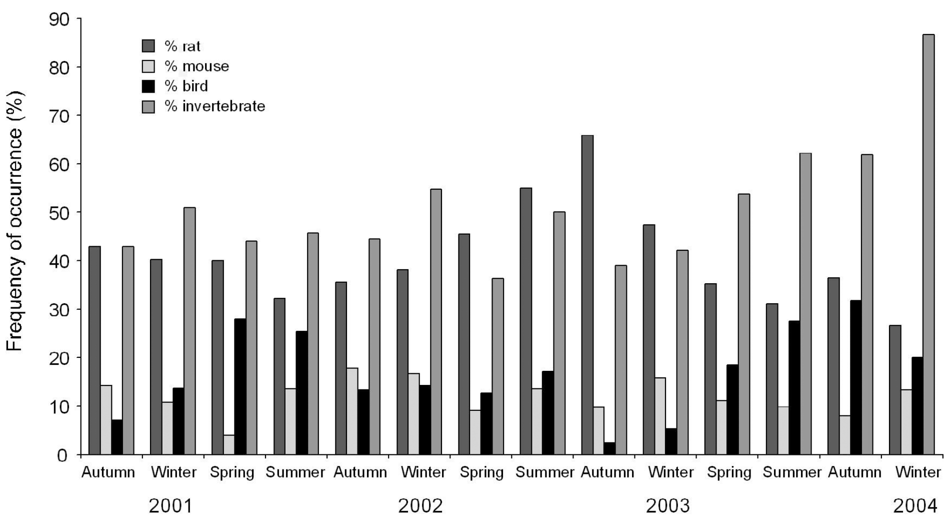

Figure 2. Percentage frequency of occurrence of rat, mouse, bird and invertebrate remains in stoats caught at Okarito Kiwi Sanctuary in each season between Autumn 2001 and Winter 2004.

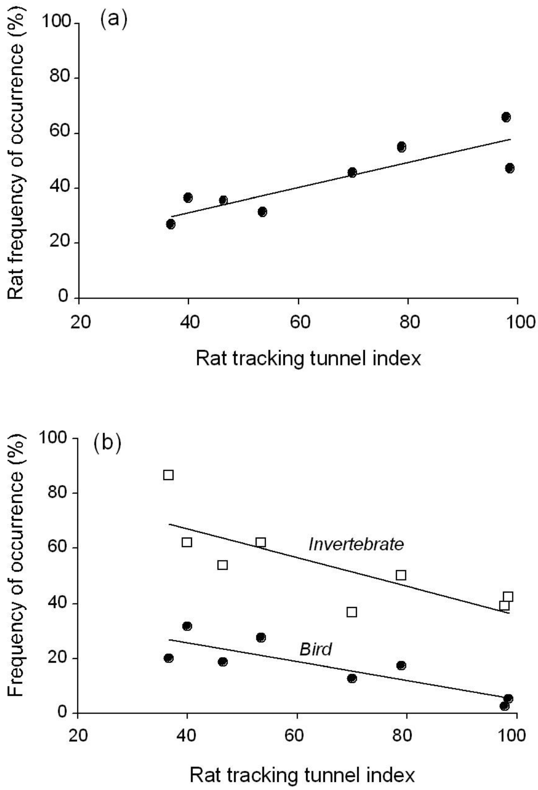

Figure 3. The relationship between the relative abundance of rats at Okarito Kiwi Sanctuary between Spring 2002 and Winter 2004, as indexed by footprints in tracking tunnels, and the percentage of stoat guts containing (a) rats and (b) invertebrates and birds over the same time frame.

Discussion

The relatively high occurrence of rat in the stoat guts sampled in this study confirms the results from a previous smaller-scale study at Okarito (Rickard 1996). It is also similar to the results from other stoat diet studies from podocarp forests in the central North Island (summarised in King & Murphy 2005). Ship rats are ubiquitous in North Island podocarp forest (Innes 2005) and were abundant at Okarito. Stoats appear to be opportunistic in their diet: in more open habitats lagomorphs are eaten more frequently than rats (Murphy et al. 2004), and in beech forest mice are more frequently eaten (King 1983; Murphy & Dowding 1995).

As in this study mice have been shown to occur more frequently in the guts of female stoats caught in some areas (King & Moody 1982), but not in another (Murphy & Dowding 1995). The latter study was in beech forest, where rats were scarce. In general, the occurrence of larger prey items (in our study, rats) is higher in male stoats than in females (McDonald et al. 2000; King & Powell 2007).

The frequency of occurrence of invertebrates in stoat diet was high at Okarito (Rickard 1996; this study) compared with other forest habitats (summarised in King & Murphy 2005). It is usually only in alpine montane valleys and grasslands in New Zealand (where rodents are relatively scarce; Innes 2005) that invertebrates, particularly wētā, make up the majority of the diet (Lavers & Mills 1978; Smith et al. 2005).

The relatively high frequency of occurrence of vegetation in the stoat gut samples in the present study was also noted in stoats from beech forest by Smith (2005). It is assumed that grasses, moss and leaves were consumed accidentally with prey.

The overall occurrence of bird remains in this study was lower than that found in most other stoat diet studies (summarised in King & Murphy 2005) and might be explained by the high number of rats present. The occurrence of bird remains was higher in the summers of 2002 and 2004, however, when rat numbers were declining but stoat numbers were still high. In other podocarp forests, where rats are also the main rodent prey, the frequency of occurrence of birds increased following successful rat control (Murphy & Bradfield 1992; Murphy et al. 1998). Similarly, in the spring–summer after rabbit haemorrhagic disease was introduced and dramatically reduced rabbit numbers in the Mackenzie Basin, the occurrence of birds in stoat diet was higher than in previous or subsequent years (Murphy et al. 2004). A concurrent study in the Mackenzie Basin showed predation rates at nests of banded dotterels were well above normal levels (Norbury et al. 2002). This diet shift by stoats following a reduction in the availability of their major prey is not normally seen in beech forests where mice are the main mammal prey and rats are uncommon (King 1983; Murphy & Dowding 1995; White & King 2006).

In 2001/02, a successful kiwi breeding season, 30% of the kiwi chicks at Okarito survived. From September to December 2002, however, all 14 chicks monitored died (13 killed by stoats, one unknown). In response to this, during the 2003/04 breeding season, all 14 known chicks were removed to an island sanctuary (DOC unpublished data). It is not surprising then that no kiwi remains were identified in the diet of stoats in this study. In addition, the large majority of the bird remains in the samples were unidentifiable, so the chance of encountering an identifiable kiwi feather in one of the stoat guts was very low. This does not, however, indicate that stoats are not impacting on the survival of kiwi at Okarito. Stoats have been shown to be the main predators of kiwi at Okarito (McLennan et al. 1996), so the increased predation pressure on birds when rats are scarce poses a serious threat to kiwi. Considering the scarcity of kiwi chicks, predation by stoats on even a few individuals will limit the sustainability of the kiwi population. To optimise kiwi protection, rat numbers should be regularly monitored at Okarito and the intensity of management for kiwi should be increased when rat numbers begin to decline.

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