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INTRASPECIFIC AND SEASONAL DIFFERENCES IN THE DIET OF FERAL FERRETS (*MUSTELA FURO*) IN A PASTORAL HABITAT, EAST OTAGO, NEW ZEALAND

Summary: This study reports the diet of feral ferrets (*Mustela furo*) in a pastoral habitat, East Otago, South Island, New Zealand. Rabbits (*Oryctolagus cuniculus*) were the most common prey of ferrets, occurring in 86.7% of scats, but birds (12.4%) and invertebrates (11.3%) were also frequently eaten. Female ferrets ate more non-lagomorph prey items, especially invertebrates and birds than males. No significant dietary differences were found between juvenile and adult ferrets except in summer when juveniles ate more lagomorph prey. There were seasonal differences in the consumption of rabbits, invertebrates, skinks, possums (*Trichosurus vulpecula*) and small and large secondary prey items. Seasonal differences in ferret diet are likely to be related to the relative abundance of the various prey items. Lagomorph availability may also be a determinant of the frequency of occurrence of other prey items in the diet. Dietary differences may differentially influence the functional response of adults and juveniles and/or males and females to rabbit control or other manipulations of prey populations.
Bovine tuberculosis (*Mycobacterium bovis*) infections in ferret populations show intraspecific variation with more males than females and more adults than juveniles infected. Intraspecific dietary differences in diet were not observed in the species (possums and hedgehogs (*Erinaceus europaeus*)) considered to be the main sources of infection for ferrets.

Keywords: ferret; *Mustela furo*; mustelid; pastoral habitat; diet; intraspecific differences.

Introduction

The domesticated ferret (*Mustela furo* L.) was introduced to New Zealand in the early 1880s to control rabbit (*Oryctolagus cuniculus* L.) populations which had grown explosively since being released on the mainland in the 1860s. Although ferrets quickly established feral populations, the biology and ecology of feral ferrets in New Zealand is poorly understood. Although ferrets reach their highest recorded abundances in pastoral habitats of semi-arid tussock grassland and semi-improved pasture they are also present in many habitats that have high conservation values, i.e., braided river-beds, forest margins and coastal areas. Ferrets are known predators of threatened endemic species (Murphy, 1996). Ferrets are now recognised as potential vectors of bovine tuberculosis (*Mycobacterium bovis* Karlson and Lessel; Tb) (Animal Health Board, 1995) after field surveys found high prevalence of the infection in ferret populations from Tb Vector Risk Areas (Walker, Reid and Crews, 1993; Ragg, Moller and Waldrup, 1995).

Rabbits are the staple prey of ferrets (Roser and Lavers, 1976; Pierce, 1987; Smith *et al*., 1995; Alterio and Moller, 1997) and it is commonly thought that rabbits are the main determinant of ferret distribution and abundance in New Zealand. Ferrets have been described as opportunistic predators (Smith *et al*., 1995) and differences between diet studies are thought to be related to the availability of prey and carrion items in the different habitats sampled. A greater understanding of the underlying dietary processes may aid in the prediction of functional and numerical responses of ferret populations to manipulations of prey, especially rabbit populations.

Ferrets show a large size sexual dimorphism which is a common feature of the family Mustelidae (Moors, 1980). One hypothesis claims that sexual dimorphism is a strategy for avoiding intraspecific competition by enabling the sexes to exploit different food resources (Dayan *et al*., 1989). Ferret diet studies have found trends that suggest that there are dietary differences between male and female ferrets (see Smith *et al*., 1995). Roser and Lavers (1976) found that female ferrets ate more mice (*Mus musculus* L.) in winter compared to males and Pierce (1987) found that adult males ate more lagomorphs and less skinks (*Oligosoma* spp) and insects than adult female ferrets. However, rabbit control occurred during Pierce's study so it is possible that this result may have been caused by increased exploitative competition between the sexes arising from perturbation rather than a reflection of the normal processes. No differences in diet between juvenile and adult ferrets have been reported.

The study of ferret diet is also pertinent to the investigation of the determinants of Tb infection in ferrets especially as the observed pathology strongly suggests that ingestion is a common route of infection (Ragg, Waldrup and Moller, 1995; Lugton *et al.*, 1997a). Significantly more male ferrets have been found to be infected with Tb (Ragg, Waldrup and Moller, 1994) which may be related to intrasexual dietary differences.

The aim of the present study is to determine whether there are statistically significant sex, age or seasonal variations in the diet of feral ferrets.

Methods

Study area

The diet of feral ferrets was studied in a pastoral habitat at Palmerston (45°S, 170°E), 51 km north of Dunedin, South Island, New Zealand. The study area was grazed by cattle (*Bos taurus* L.) and sheep (*Ovis aries* L.) and was a mixture of developed pasture, grazed tussock (*Chionochloa* spp.), matagouri (*Discaria toumatou* Raoul) and pine (*Pinus radiata* D. Don) plantation. Gorse (*Ulex europeus* L.) and other wood plant species were predominant in some gullies.

Scats were collected from ferrets live-trapped in cages, over a four day period at the beginning of every month from January 1996 until February 1997. Traps were baited with rabbit meat (skin, fur, teeth and claws were removed). Ferrets were ear-tagged, sexed and classified as juvenile or adult. From November (when juveniles start emerging from natal dens) until late March, juveniles were easily distinguishable from adults as they were physically smaller, reproductively immature and had minimal tooth wear and little sagittal crest development. Adult females were distinguishable by evidence of recent lactation and adult males often had scars from fight wounds and bald tails.

Radio-collars were fitted to thirteen females and thirteen males for concurrent studies on den sharing and spatial organisation. Ferrets were radio-tracked during daylight hours to den sites from February 1996 until July 1996. Fresh scats were collected from latrine heaps that were often located near the den.

Scats were also collected from 127 tracking tunnels (described by King and Edgar 1977) that were placed at 200 m intervals on a grid on the study area from April 1996 - July 1996. Scats found whilst radio-tracking or rebaiting traps were also collected.

Scats were soaked for at least four hours in water with detergent and then washed through a 180 mm sieve. Prey remains were removed and identified. Mammals (rabbits, mice (*Mus musculus* L.), rats (*Rattus* spp), cats (*Felis catus* L.), ferrets and possums (*Trichosurus vulpecula* Kerr)) were identified by teeth, claw and hair remains according to Day (1966) and Brunner and Coman (1974); birds by feathers, eggs, beaks and legs; lizards by skin, feet and tails; and invertebrates by mandibles, head capsules and legs. If lagomorph claws were present in the scat, lagomorphs were classified into 'young' (under 500 g) or 'mature' (over 500 g) size classes according to Pierce's (1987) calibration of claw length with body weight. Scats with lagomorph toe bones under 6 mm and lagomorph milk teeth were classified as 'young'. Other lagomorph teeth were measured and compared with teeth from samples that were able to be categorised according to the presence of milk teeth, claw and toe bone length, and assigned accordingly.

Food remains have been termed 'prey items' since there is no reliable method for identifying food items consumed as prey, carrion or otherwise.

All scats were used in the description of the general ferret diet and seasonal changes in diet. As there are differential rates of passage for prey items through the digestive tract of mustelids (Dearborn, 1932; Short, 1961; Sibbald *et al.*, 1962), it is possible to record the presence of a single prey item more than once. To determine whether this had an effect on the results, analyses were repeated after excluding scats collected within four days from the same ferret.

To investigate seasonal changes in diet, all scats were divided into spring, summer, autumn and winter categories. Only scats collected from trapped ferrets were used to analyse for age and sex differences. For these analyses, scats were excluded if a prior scat had already been collected from the same animal within four days. Scats collected from animals over the spring months (September to November) were excluded from age analyses because juveniles of that year were breeding and therefore should probably be regarded as adult and young ferrets had not yet emerged from natal dens. Age analyses were repeated on scats collected from ferrets during summer months as this is the period where any dietary differences between juveniles and adults are likely to be the most obvious as the juvenile ferrets are inexperienced predators and are physically immature.

All results are expressed as the percentage frequency of occurrence (percentage of scats containing each prey item). G-tests (likelihood ratio) for goodness of fit were used to determine whether there were significant age, sex and seasonal differences in diet and whether there were age and sex differences in the consumption of 'young' and 'mature' lagomorphs. Non-lagomorph prey items were re-categorised as 'small' (mice, skinks and insects) or 'large secondary' (birds, cats, possums) and analysed for differences between age and sex.

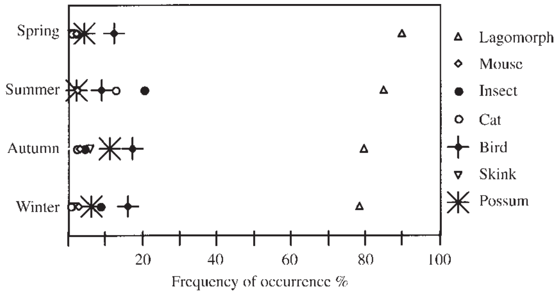

Figure 1: *Diet of feral ferrets expressed as percentage frequency of occurrence. Diet described using all scats* (n=*904) and the subsample which excluded those scats collected from the same animal within four days* (n=*419).*

Results

In total, 904 ferret scats contained identifiable prey out of a total of 1076 collected scats; 819 from trapsites, 132 from den sites, 66 from tracking tunnels and 59 from in the field. Another 172 scats had prey remains that could not be identified or were rabbit bait scats. Of the 819 scats collected from trapsites, 681 contained identifiable prey remains and 138 were classified as rabbit bait scats.

Lagomorphs occurred in 86.7% of the ferret scats with birds (12.4%) and invertebrates (11.3%) also making significant contributions (Fig. 1). Few ferrets ate mice, cats, skinks or possums. When excluding scats collected from the same animal trapped within four days, the contribution made by lagomorphs decreased (G=4.01, *d.f.* =1, *P*=0.045) and invertebrates and small prey items increased (G=5.33, *d.f.* =1, *P*=0.021; G=7.80 *d.f.* =1, *P*=0.005, respectively). Ferret hair was identified in 25 scats (2.8% frequency of occurrence) and on seven occasions in clumps attached to skin.

More birds (G=14.38, *d.f.*=1, *P*=0.034), invertebrates (G=3.91, *d.f.*=1, *P*=0.047) small prey items (G=5.54, *d.f.*=1, *P*=0.019) and large secondary prey items (G=6.10, *d.f.*=1, *P*=0.014) were eaten by females than males (Table 1). More non-lagomorph prey items were eaten by females than males (G=15.5, *d.f.*=1, *P*=0.0001). There were no significant differences in the diet of juveniles and adult ferrets (Table 1) although there was a general trend for adult ferrets to eat more birds than juveniles (G=3.18, *d.f.*=1, *P*=0.078). Juveniles ate significantly more lagomorphs than adults over the summer months (G=5.29, *d.f.*=1, *P*=0.022) with adults tending to eat more non-lagomorph prey items than juveniles (G=3.42, *d.f.*=1, *P*=0.065).

Table 1: *Percentage frequency of prey occurrence from 904 scats collected from feral ferrets in a pastoral habitat, East Otago, New Zealand. Percentage frequency of occurrence of prey items are presented for juveniles, adults, males and females for all scats and the subsample which excluded scats collected from the same animal within four days.*

	All scats				Subsample*			
	Juveniles (n=263)	Adults (n=92)	Males (n=435)	Females (n=246)	Juveniles (n=259)	Adults (n=90)	Males (n=259)	Females (n=160)
Lagomorph	83.3	76.1	87.6	87.0	84.6	77.8	84.9	79.4
Mouse	2.7	4.3	2.3	2.0	2.7	4.4	2.7	4.4
Invertebrate	16.7	20.7	8.7	15.4	17.0	21.1	13.1	20.6
Skink	3.4	5.4	1.8	4.9	3.5	5.6	3.5	4.4
Bird	6.8	13.0	9.7	13.0	6.9	13.3	7.3	13.8
Cat	1.1	1.1	0.9	0.4	1.2	1.1	0.8	1.9
Possum	6.5	4.3	4.6	6.1	6.6	4.4	5.0	6.9
Small secondary prey	26.2	30.4	29.4	22.4	23.2	31.1	19.3	29.4
Large secondary prey	14.4	18.5	15.2	19.5	14.7	18.9	13.1	22.5

*(scats excluded if collected from the same ferret within 4 days)

Table 2: *Percentage frequency of lagomorph, small and large secondary prey occurrence of 904 scats collected from feral ferrets in a pastoral habitat, East Otago, New Zealand divided into spring, summer, autumn and winter seasons.*

	Spring (*n*=89)	Summer (*n*=314)	Autumn (*n*=314)	Winter (*n*=172)
Lagomorph	89.8	85.0	79.6	78.5
Small secondary prey items	5.6	85.0	22.6	13.4
Large secondary prey items	18.0	14.4	22.9	23.3

Seasonal differences were also found in the diet of ferrets (Table 2, Fig. 2). Seasonal differences in the consumption of lagomorphs (G=8.84, *d.f.* =3 *P*=0.032), insects (G=25.48, *d.f.* =3, *P*=0.0001), skinks (G=10.60, *d.f.* =3, *P*=0.014), possums (G=22.40, *d.f.* =3, *P*=0.0001) and small prey items (G=14.77, *d.f.* =3, *P*=0.0001) were found. Fewer lagomorphs were eaten in autumn and winter (G=7.29, *d.f.* =1, *P*=0.007) compared to spring and summer.

Lagomorph size class was determined for 178 samples (Table 3). No significant differences in the consumption of either 'young' or 'mature' lagomorphs were found between males and female ferrets or between juveniles and adults. Young lagomorphs were recorded in the diet throughout the study period.

Table 3: *Categorisation of lagomorph prey into the size classes: 'young' (under 500 g) 'mature' (over 500 g) and 'unknown' (no claws or toebones present in scat to determine age of lagomorph prey) from male, female, juvenile and adult ferrets.*

	Young lagomorph	Mature lagomorph	Unknown age
Male ferrets (n=380)	47	36	297
Female ferrets (n=214)	28	20	166
Juvenile ferrets (n=207)	12	6	39
Adult ferrets (n=57)	24	19	164

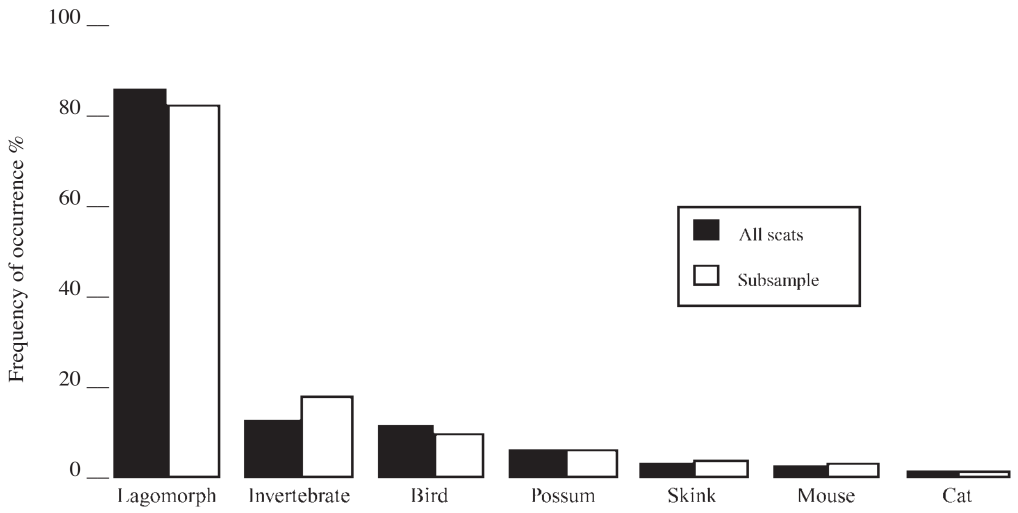

Figure 2: *Seasonal comparison of the percentage frequency of occurrence of all prey items. All scats included in analyses (*n*=904); spring (*n*=89), summer (*n*=314), autumn (*n*=314) and winter (*n*=172).*

Discussion

Ferret diet

Lagomorphs were the most common and staple prey of ferrets in this study, a result that is consistent with other diet studies from similar habitats in New Zealand (Pierce, 1987; Smith *et al.*, 1995; Alterio and Moller, 1997). Almost all the lagomorphs observed in the study area were rabbits. Accordingly, most of the lagomorph remains found in the scats would have been rabbit. Birds and invertebrates were the only other common prey items.

If I had not excluded scats from ferrets caught in live-traps on consecutive nights, large prey items would have been over-represented in the diet analysis. Alternatively excluding samples in this manner may under-estimate the contribution that large prey items make to the energetics of the study animal. This problem could be partly overcome by presenting the data as percentage contribution by weight. In terms of determining whether differences in diet exist between age and sex segments of the population it is appropriate to exclude samples which may record the presence of an individual prey item more than once, similarly this approach would apply if the research objective was to study predation rates.

Cat remains were found in nine of 904 ferret scats (1% frequency of occurrence). Pierce (1987) recorded the presence of remains from one cat in 635 scats. Ferrets will scavenge cat carcases; an adult cat was scavenged by a radio-collared female ferret during this study and a radio-collared male ferret scavenged a kitten (Ragg, *unpubl. data*). It is not known whether ferrets kill kittens. Adult cats and ferrets have been filmed feeding together at carrion (Ragg *unpubl. data*) and a ferret and a kitten were caught simultaneously in the same cage trap and both appeared fine.

Ferret hairs were found in 2.8% of scats. The usual practice in diet studies is to disregard the presence of hair from the study animal (Day, 1968; Roser and Lavers, 1976), but recently ferrets have been identified as being cannibalistic (Ragg *et al.*, *unpubl. data*) and therefore ferret hair may be also acquired from scavenging. About one third of the ferret hairs found were in clumps suggesting a cannibalism rather than grooming or allogrooming origin.

Intraspecific and seasonal differences in ferret diet

Significant sex differences were observed; females ate more invertebrates and birds than male ferrets. Similarly, female ferrets ate more non-lagomorph prey items than males. This is the first study to report significant sex differences in the absence of prey perturbations except for Roser and Lavers (1976) who found that more mice were consumed by female ferrets compared with males in winter. Body size is the obvious difference between mature male and female ferrets so it is likely that there is a relationship between sexual dimorphism and diet.

Seasonal differences in the diet of ferrets probably reflects variations in the relative abundance of the different prey species. For example, proportionally fewer rabbits were consumed in winter when rabbit numbers naturally decline (Gibb and Williams, 1995). Manipulation of rabbit numbers does result in prey switching by ferrets (Pierce, 1987; Norbury and Heyward, 1996). These studies suggest that the abundance and availability of rabbits determine to some extent the frequency of occurrence of other prey items in the diet. Lagomorph availability may influence the seasonal trends in the consumption of non-lagomorph prey items along with the relative availability of those prey items. In the present study, more skinks and birds were eaten in autumn and winter when lagomorph consumption was lowest. Other factors such as changes in seasonal mortality rates of prey species may also influence consumption rates, especially for food items commonly consumed as carrion, for example; possums. Before strong conclusions can be drawn about the determinants of the differential consumption rates of the various prey items, monitoring seasonal abundance of prey items, coupled with experimental manipulation of rabbit populations across seasons and over different lagomorph densities is required.

The only age effects detected (apart for the tendency for adults to eat more birds) were found in the summer months when juveniles ate more lagomorph prey. Rabbit control in the summer months may have different effects on juvenile and adult ferrets. If juvenile ferrets do have a higher dependence on rabbits then this may partly explain the lower rate of recruitment of juvenile ferrets into the population after rabbit control (Norbury and Heyward, 1996).

Implications for conservation and Tb mitigation

The present study can not offer a direct explanation for why male ferrets have a higher prevalence of tuberculosis as the observed dietary differences were that females were more likely to consume greater numbers of non-lagomorph prey items. The source of tuberculosis for ferrets has not been identified although possums and hedgehogs (*Erinaceus* *europeaus* Barrett-Hamilton) are considered to be sources (Lugton *et al*., 1997b). No sex or age differences in the consumption of these prey items were observed in this study. Diet may interact with other aspects of ferret ecology to produce the Tb epidemiology observed. Manipulations of prey populations are needed to identify which species contribute to the incidence of disease in ferrets.

If rabbit availability is affecting the consumption rate of other species because of ferret diet switching, then consideration should be given to timing of rabbit control operations when threatened species are not at seasonal population highs.

Although this study found significant sex differences in diet, large sample sizes were needed to detect them. This means that different management for males and female ferrets is probably not warranted and the real determinant of predation impact is likely to be absolute abundance of ferrets. This study confirmed the overwhelming importance of lagomorphs in both male and female diet and even though sex differences were found in the consumption of other prey items, they still made up a relatively small percentage of the diet. For example although females ate twice as many birds as males, birds only accounted for 14% of female ferret diet. The contribution of non-lagomorph prey to ferret diet would have been even less if the diet was described by percentage contribution by weight.

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