Microhabitat selection by feral ferrets (*Mustela furo*) in a pastoral habitat, East Otago, New Zealand

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Abstract: The spatial distribution of feral ferret (*Mustela furo*) activity and denning were studied using ink-print tracking tunnels and radio-tracking within pastoral farmland containing a mosaic of grazed (developed and semi-developed) and ungrazed pasture, scrub, tree plantation and scrubby fence lines at Palmerston, East Otago, South Island, New Zealand. Ferrets concentrated their activity in grazed areas but within these areas they were found more often where herbs, scrub and woody cover were present, and where there was an ecotone between pasture and vegetation cover. Ferrets were more likely to be present close to fence lines. When denning, ferrets selected areas with cover of all types and avoided open pasture areas. Ferrets particularly favoured man-made structures (woolsheds, haybarns, sheds etc.) for dens. The implications of these microhabitat selections by ferrets to wildlife conservation in New Zealand are discussed. Ferrets are a possible vector of bovine tuberculosis (*Mycobacterium bovis*). Ferrets may transmit tuberculosis to stock via contaminated food or latrines deposited outside den sites (68% of dens were accessible to stock). Concentration of ferret movements along pasture ecotones may be a factor facilitating tuberculosis transmission between possums (*Trichosurus vulpecula*) and ferrets, and between ferrets and stock.

Keywords: Den sites; disease transmission; ferret; microhabitat selection; *Mustela furo*; mustelid; pastoral habitat.

Introduction

Ferrets (*Mustela furo* L.) were introduced to New Zealand in the early 1880s to control rabbits (*Oryctolagus cuniculus* L.) and quickly established feral populations throughout the North and South Island. They can reach densities of 6 ferrets per km^2 (Cross *et al*., 1998). Although New Zealand has the largest population of feral ferrets in the world (Nowak and Paradiso, 1983), comparatively little is published about their ecology and population biology. The distribution and abundance of ferrets appears to be closely related to that of rabbits (Marshall, 1963), their main prey item. It is thought that ferrets achieve their highest abundance in pastoral habitats that are especially rabbit-prone.

Ferrets, along with weasels (*Mustela nivalis* Erxleben), stoats (*Mustela erminea* L.) and feral cats (*Felis catus* L.), prey upon many threatened endemic species (Murphy, 1996). Recently there has been much debate about whether the ferret is a vector of bovine tuberculosis (*Mycobacterium bovis* Karlson and Lessel) to farmed livestock in New Zealand after field surveys found high prevalence of tuberculosis infection in ferrets (Walker *et al*., 1993; Ragg *et al*., 1995).

Ferrets communicate with conspecifics by body odours and scent marks and they are thought to use a hinterland system where scents are deposited throughout their home ranges (Clapperton, 1989). Ferrets will also deposit scats on conspicuous objects, and form latrine heaps at the entrances of den sites. Understanding microhabitat use by ferrets may help to assess the risk of tuberculosis transmission risk from ferrets to stock, or generate hypotheses regarding how tuberculosis is transmitted (i.e., directly by contact with stock or indirectly though the contamination of pasture). An understanding of microhabitat use will also improve the efficacy of ferret control by guiding where best to place control stations (traps or poison).

A study of four radio-collared male ferrets at Macraes Flat, East Otago (Baker, 1989), asserted, but did not quantify, that ferrets preferred to move along habitat features such as fence lines, stock tracks and boundaries between tussock grassland and developed pasture. The ferrets rarely ventured out into the more open habitat (Baker, 1989). Recently in New Zealand, conservation managers have modified habitats in an attempt to reduce predation rates of ferrets, stoats and feral cats on endemic wildlife (Department of Conservation, 1991; Pascoe, 1995). These habitat modifications were attempted in order to decrease encounter rates of predators by altering their movements and thereby reducing their use of certain microhabitats used by threatened species. On the Otago Peninsula, for areas surrounding yellow-eyed penguin (*Megadyptes antipodes* Hombron and Jacquinot) colonies, the strategy has involved increasing vegetation cover by retiring pasture from livestock grazing. It was proposed that predators would avoid these 'vegetation buffers' because long rank grass would support fewer prey and act as a physical barrier, inhibiting movement (Department of Conservation, 1991). The opposite strategy has been implemented in the MacKenzie Basin, where lupin (*Lupinus polyphyllus* Lindley) and willows (*Salix fragilis* L.) were removed from braided river-beds to create more open habitat for the protection of black stilts (*Himantopus novaezealandiae* Gmelin) (Maloney, 1993; Pascoe, 1995). It was hypothesized that removal of this vegetation would reduce local rabbit abundance and consequently use of these areas by predators (Maloney, 1993).

The aim of this study was to provide more detailed information on ferret use of microhabitats in pastoral habitats containing a mosaic of developed pasture, scrub and trees. This information will assist tuberculosis mitigation and conservation interventions targeting ferrets.

Study area

Habitat use and movements of ferrets were studied using ink-print tracking tunnels on pastoral farmland at Pleasant Valley, near to Palmerston (45°S, 170°E), 51 km north of Dunedin, South Island, New Zealand (illustrated in Ragg, 1998). The study area was grazed by cattle (*Bos taurus* L.) and sheep (*Ovis aries* L.) and had a mixture of developed pasture, semi-developed pasture (typically tussock grassland (*Chionochloa* spp.)), oak (*Quercus* spp.) and pine (*Pinus radiata* D. Don) plantation. Gorse (*Ulex europeus* L.), broom (*Cytisus scoparius* L.) and matagouri (*Discaria toumatou* Raoul) were predominant in some gullies and over some semi-developed areas. Gorse was also commonly associated with fence lines. A part of the study area bordered the outskirts of Palmerston township.

Methods and Materials

Microhabitat selection as determined by tracking tunnels

Ink-print tracking tunnels (King and Edgar, 1977) were lengthened to 100 cm to ensure that an animal entering through the tunnel would leave more prints to aid identification. Each tracking tunnel consisted of an ink-pad in the middle of the tunnel with chemically treated papers on either side. A cube of beef was used as an attractant. One hundred and twenty-five tracking tunnels were placed at 200 m intervals on a grid throughout farmland. Tracking tunnels were checked weekly and rebaited. Papers were removed if they were marked or had prints and the ink replenished if necessary. The study commenced in late April 1996 and ran for 11 weeks until mid July 1996. Habitat measurements were taken in a 5 m radius around each tracking tunnel and determined (i) whether the area was grazed or ungrazed by stock, (ii) maximum and mean height of grass cover, (iii) presence or absence of 'herb' cover (non-woody plant species such as rushes, tussock and bracken), 'wood' cover (shrub species such as gorse, broom and matagouri) and 'canopy' cover (tree species such as pine and oak), (iv) distance to the nearest fence line, and (v) presence or absence of a forest - pasture ecotone within 50 m.

Prints on the tracking papers were identified by two persons in accordance with the key developed by Ratz (1997a). Any discrepancies were resolved by a third person and only double-confirmed prints were included in the analyses.

Simple and multiple logistic regression analyses were performed using the software package SAS™ (SAS Institute Inc., Cary NC, USA) to determine the effect that each vegetation variable had on the presence or absence of ferrets. Logistic regression fits linear logistic regression models for binary or ordinal response data by the method of maximum likelihood.

$$\pi = (\exp(ß_0+ß_1X_1+...+ß_pX_p)) / (1+\exp(ß_0+ß_1X_1+...+ß_pX_p))$$

where $ß_0$ is the intercept parameter and $ß_{1-p}$ = are the parameter estimates.

Seven of the variables were binary and were assigned 0 or 1 values (Table 1). Whether mice prints were present or not on tracking papers with ferret prints was also tested to determine if there was any association. The remaining variables (average height of grass cover, the mean height of grass cover and distance to the nearest fence) were continuous (i.e., measurable). As each tunnel was cleared 11 times during the study, the proportion of times each tunnel was tracked by a ferret was calculated and entered as the predicted variable (each tracking tunnel was used as the unit of replication). To test for a possible pseudo-replication influence, analyses were repeated treating each weekly clearance of the tracking tunnel as a single event (scored as 0 or 1) (i.e., each clearance of the tracking tunnels was used as the unit of replication).

Multivariate models were developed by trialing addition of variables one at a time that increased the χ^2 value by one degree of freedom. The first variable to be entered into the model was the one that was statistically significant with the highest χ^2 value; when more than one variable increased the significance of the model, the one with the next highest χ^2 value was added. The model that was considered to best describe the data was the one with the highest χ^2 value and where the expected values generated by the model were not significantly different from the observed values as determined by the Hosmer and Lemeshow Goodness-of-Fit test (Hosmer and Lemeshow, 1989).

Microhabitat selection as determined by den site location

Twenty-three ferrets were radio-collared for concurrent studies on spatial organisation (Ragg, 1997) and denning behaviour (Ragg, 1998). Ferrets were fitted with Stage 2 transmitters (SirTrack Ltd, Havelock North, NZ) with brass loop aerials from February to March of 1996. Some preliminary radio-tracking began in late February, but from April until early July 1996, ferrets were radio-tracked most days (Ragg, 1998). Ferrets were radio-tracked to den site (or to approximate location if active) using hand-held yagi antennae with Merlin 48 or Telonics TR4 receivers. Ferrets were located only during daylight hours (0900 h to 1800 h) when they were normally inactive. Den sites were marked with a cattle eartag, its position recorded by Global Satellite Positioning (GPS) and habitat measurements recorded.

Radio-collared ferrets were toe-clipped with an individually recognisable combination to attempt to gain individual activity data to supplement denning data for a concurrent study on spatial organisation (Ragg, 1997). An intramuscular injection of ketamine (20 mg) with xylazine (2 mg) was used to immobilise ferrets at a dose rate of approximately 50 mg/kg. Local™ (Lignocaine hydochloride), a local anaesthetic was injected above the toe before removal of the pad and claw at the joint. The skin was then sutured together. One or two toes were removed off each foot, with each corresponding front and hind foot receiving the same combination. Terramycin LA Injectable Solution™, a broad-spectrum antibiotic, was administered by intramuscular injection and ferrets were held for two nights before release. Ferrets were subsequently re-trapped to remove sutures and to re-administer antibiotic.

The immediate den habitat was classified into the following categories; (i) tree plantation, (ii) large gorse patches, (iii) tussock in rough tussock grassland (RTG), (iv) matagouri and gorse in RTG, (v) grass in RTG, (vi) open developed pasture, (vii) small gorse patches in open developed pasture, (viii) man-made structures and farmyards and (ix) other which included cleared tree plantation, crops, rank grass, water margins and rocks. Home range estimates were calculated using the minimum convex polygon method for each radio-collared ferret (Ragg, 1997) and mapped onto an aerial photograph of the study site. The percentage of each habitat type within each ferret home range (i.e., habitat availability) was estimated from the aerial photograph. Habitat availability values were then averaged for all ferrets to determine the availability of each habitat type at a population level.

Table 1. Single parameter logistic regression models of ferret presence as predicted by vegetation variables. Binary variables were assigned '1' for yes and '0' for no (for example; if herb cover was present within 5 m of a tracking tunnel site then a value of 1 was entered into logistic regression model analyses).

Parameter	*P* value	χ2+value	Parameter estimate ± 1SE	Odds ratio
Grazed by stock	0.0040	12.381	0.4945 ± 0.1436	1.640
Average height of grass (cm)	0.7509	-	-	-
Maximum height of grass (cm)	0.0530	3.743	0.0043 ± 0.0023	0.996
Herb cover present	0.0001	17.011	0.5026 ± 0.1215	1.653
Wood cover present	0.0001	34.809	0.7487 ± 0.1265	2.114
Canopy cover present	0.9882	-	-	-
Any cover present	0.0001	40.687	0.7446 ± 0.1187	2.105
Ecotone present within 50m	0.001	6.631	-0.0054 ± 0.0031	1.455
Distance to nearest fence (m)	0.0019	9.685	-0.0029 ± 0.0009	0.997
Mice prints present	0.4058	-	-	-

The Bonferroni analysis described by Neu *et al.* (1974) was used to test for denning habitat selection. In order to rank the denning habitats from most to least selected, the log-ratio of composition analysis as described by Aebischer *et al.* (1993) and Bradshaw *et al.* (1995) was used. Chi-square tests were used to determine whether ferrets denned more often in natural habitats or man-made structures and associated farmyard.

Results

Habitat selection by active ferrets determined by tracking tunnels

Papers collected from 1375 clearances of tunnels revealed ferret (n=477), stoat (n=23), hedgehog (*Erinaceus europaeus* L.) (n=51), rat (*Rattus* spp.) (n=3), mouse (*Mus musculus* L.) (n=148) and bird prints (n=9). Forty papers revealed prints of inadequate quality, which precluded identification of the species. Over the 11 week study period, 34.7%, 1.6%, 3.7% and 10.8% of papers were tracked by ferrets, stoats, hedgehogs and mice, respectively. More than one identifiable species was identified from 7.7% of tracking tunnels papers. It was not possible to reliably identify toe-clip combinations or whether ferret prints were from toe-clipped animals.

Tunnels in sites grazed by stock, tunnels within five metres of any vegetation cover and tunnels within 50 m of pasture - forest ecotones were more likely to have ferret prints (Table 1). Tunnels further away from fences had fewer prints (Table 1).

The best multiple logistic regression model of ferret presence incorporated; 'presence of herb cover', 'presence of wood cover', 'distance to the nearest fence', 'whether grazing by stock occurred' and 'presence of an ecotone' (χ^2=96.08, 5 d.f., P<0.0001) (Table 2, Figure 1). This model was found to have a significant Hosmer and Lemeshow Goodness of Fit test statistic (χ^2=19.53, 8 d.f., P=0.0123) indicating that the model did not fit the data well. Therefore interactions between the predictor variables were also screened and interactions were found between several variables (Table 2). The model including these interactions (χ^2=117.59, 8 d.f., P<0.0001) had a non-significant Hosmer and Lemeshow Goodness-of-Fit test statistic (χ^2=6.60, 7 d.f., P=0.4715).

When the analyses were repeated using each weekly clearance of the tracking tunnel as the unit of replication, a model containing the same predictor variables as in Table 2 resulted.

Habitat selection by denning ferrets determined by radio-tracking

Ferrets were radio-tracked to 203 dens but 58 den sites could not be approached closely because of dense vegetation and the risk of destroying the immediate den habitat or unacceptable disturbance to the ferret. Of the

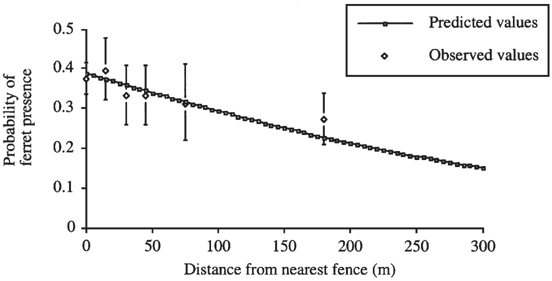

Figure 1. The probability of ferret presence as predicted by the logistic regression model including the variables: presence of wood cover, presence of herb cover, distance to the nearest fence, whether grazing occurred or not and whether an ecotone was present or not. The observed values are presented with 95% binomial confidence intervals.

Table 2. The best fit multiple logistic regression model of ferret presence as predicted by microhabitat and landscape features including interactions between variables.

Variable	Parameter estimate ± 1SE	*P* value	Odds ratio
Intercept	-1.1667 ± 0.1778	0.0001	
Presence of wood cover (PWC)	0.4067 ± 0.3169	0.1993	1.502
Presence of herb cover (PHC)	0.3393 ± 0.1537	0.0273	1.404
Distance to nearest fence (m) (F)	-0.0042 ± 0.0015	0.0065	0.996
Grazed (G)	0.2843 ± 0.1804	0.1149	1.329
Presence of an ecotone	0.5405 ± 0.1582	0.0006	1.717
PHC * F	0.0058 ± 0.002	0.0045	1.006
PWC * G	0.9615 ± 0.3543	0.0067	2.616
PWC * F	-0.0067 ± 0.0021	0.0018	0.993

Table 3. Habitat availability and use by 23 ferrets for denning at Palmerston expressed as proportions. The upper and lower Bonferroni confidence intervals for denning use are provided.

Habitat type	Availability of habitat	Denning use	Lower CI of use	Upper CI of use	Conclusion
Tree plantation	0.087	0.16	0.1209	0.1990	Selected
Large gorse patches	0.035	0.109	0.0758	0.1422	Selected
Matagouri & gorse in RTG	0.038	0.076	0.0477	0.1042	Selected
Gorse patches in OP	0.002	0.083	0.0536	0.1124	Selected
Human structures & farmyard	0.009	0.359	0.3079	0.4101	Selected
'Other'	0.058	0.077	0.0486	0.1054	Random
Tussock in RTG	0.04	0.016	0.0026	0.0294	Avoided
Grass in RTG	0.143	0.003	0.0000	0.0088	Avoided
Open developed pasture (OP)	0.588	0.118	0.0836	0.1524	Avoided

145 remaining den sites from which data were collected, 58 (40%) had latrine heaps immediately outside the den and food remains were found at or near to the den site in 56 instances, 13 of which were carrion carcasses, usually sheep. One hundred and twenty-five den sites (68.3%) were considered accessible to stock and 58 were not considered accessible (this data was not collected for 20 den sites).

The ferrets selectively used five of the nine habitat types for denning (Table 3). Random use was found for the grouped category 'other' which included rank grass, water margins, rocks, areas of cleared pine plantation and crops. The other three habitats were avoided.

The log-ratio analysis of composition ranked the denning habitats in the following order from the most selected to the least selected: man-made structures and farmyard > small gorse patches in open developed pasture > matagouri and small gorse patches in rough tussock grassland > large gorse patches > tree plantation > 'other' > tussock in rough tussock grassland > open developed pasture > grass in rough tussock grassland.

Even though less than one per cent of habitat within ferret home ranges was comprised of man-made structures and associated farmyard, ferrets denned significantly more in this habitat type than in all the naturally occurring habitats (χ^2=297, 1 d.f., P=0.0001). As significance (P<0.05) occurred for 17 of the 21 ferrets (with the deviations from the expected in the same direction) the data were pooled. This test was not applicable for two ferrets as they had no man-made structures in their described home range.

Discussion

Habitat selection by active ferrets

When assessing habitat selection by using tracking tunnels, the result is likely to be conservative because tunnels in highly favoured microhabitats may have been tracked by more than one ferret. It is not possible to determine how many different individuals tracked a single tunnel and some heavily tracked papers were observed in this study. Tracking tunnels were used as an index of ferret abundance in the different habitat types assuming equal levels of activity in the different habitats.

Toe-clip combinations could not be identified because of the high proportion of unclipped ferrets present in the study area and uncertainty about whether a partial print was from a toe-clipped animal or just a poor quality print. Toe-clipping ferrets for individual identification purposes was not considered a reliable or worthwhile technique given the effort required to toe-clip animals, the stress to the animals and the inability to identify prints from toeclipped animals.

The significant factor in ferrets using grazed areas more than ungrazed areas may be the fact that in this study, the ungrazed areas were typically small and fragmented (i.e., roadside verge) while grazed areas were typically large, continuous stretches of habitat (i.e., pasture). This result does not necessarily indicate that ferrets prefer short grass. Infact, as the maximum height of the grass increased, ferrets were more likely to be present (P=0.05). In other studies, abundance of lagomorphs, rodents and birds has been found to be higher in long rank grass areas (Alterio, 1994; Moller *et al.*, 1998) which may attract ferrets. In the MacKenzie Basin, both Pierce (1987) and Pascoe (1995) found that ferrets hunted more frequently in areas with increasing vegetation cover that supported higher numbers of rabbits. Other mustelid species have been found to use more extensively those habitats that have a higher abundance of prey (Erlinge, 1977; Pounds, 1981). Pascoe (1995) suggested that rabbits were using cover (rank grass, matagouri, sweet briar and gorse) as protection while foraging at night. Given that ferrets in the present study concentrated their activity and denning in areas with greater vegetation cover, it is not surprising that Alterio *et al.* (1998) and Ratz (1997b) found that ferrets used ungrazed vegetation buffer zones more extensively than grazed areas on the Otago Peninsula.

Ferrets used areas with 'herb' and 'wood' cover significantly more than areas without this type of cover. The presence or otherwise of canopy cover had no effect on ferret presence suggesting that different types of ground cover were most important. Polecats (*Mustela putorius* L.) have been shown to prefer habitats with vegetation cover (Weber, 1989a) and in enclosure experiments have demonstrated a finely scaled preference for those microhabitats offering the greatest protection from sight (Weber, 1988). Ferrets were more likely to be present close to fence lines and this result is likely to be an interaction with cover as fence lines are often associated with species such as gorse and broom. Such interactions between both 'herb' cover and 'wood' cover and distance to the nearest fence line were found in the multiple logistic regression model. The tracking tunnels that were close to ecotones were significantly more likely to be tracked by a ferret.

Habitat selection by denning ferrets

All habitat types associated with cover were selected for denning whilst the habitat types without cover were avoided. Rabbit holes were the most common den site for ferrets at this study site (Ragg, 1998). It is therefore likely that ferrets are attracted to cover because rabbits are hunted mostly below ground (Gibb *et al*., 1978) and rabbits (and their holes) are often associated with vegetation cover (Alterio, 1994; Pascoe, 1995).

Ferrets selected man-made structures and farmyard more often than any other denning habitat. A radio-tracking study of polecats during winter in Wales found that agricultural premises were the most preferred of all habitats utilised (Birks, 1998). Grain stored in buildings undoubtedly promoted rodent abundance and polecat scats collected from these places indicated that rats (*Rattus* spp.) dominated the polecat's diet (Birks, 1998). Polecats were probably present in these areas because of a high concentration of prey. Although grain is relatively rarely fed to stock in New Zealand, rodent abundance is still likely to be relatively higher around haybarns and woolsheds and could therefore be an attractant to ferrets. Alternatively, these farmyard structures may offer a desirable denning environment for ferrets. In Switzerland, warm denning sites are essential during the winter and buildings are considered an important resource for polecats; so much so that the northern distribution of polecats in Switzerland may be affected by the availability of suitable buildings for denning (Weber, 1989b)

Implications for conservation and predator control.

The ungrazed areas in this study are not comparable to the large ungrazed zones surrounding yellow-eyed penguin breeding areas, therefore the results of this study are not necessarily inconsistent with the findings of Alterio *et al*. (1998) that predators selected long grass over pasture. A more detailed study of ferret movement, probably using spool and line tracking, may resolve habitat differences more precisely. The most reliable way to determine the efficacy of rank grass in preventing predation will be comparisons of movements before and after habitat manipulations. Changes in the use of critical areas containing threatened species can then be tested while the spatial scale and mosaic of habitats surrounding the areas remain unaltered. In the absence of such before and after studies, the different results of this study and those of Alterio *et al*. (1998) indicate a need for caution in concluding whether long grass buffer zones increase or decrease predation of threatened species. Much may depend on the spatial scales of the habitat involved and the distribution of prey within the area.

Traps and bait stations are likely to have higher encounter rates with ferrets if placed along forest-pasture margins. If such ecotones are not present then placement alongside areas of vegetation cover will increase the probability of interception. Given that ferrets often den in rabbit holes, control stations placed in areas where rabbits reside may also yield favourable results. As ferrets commonly use farmyard buildings, then control stations set around these areas are also likely to have higher encounter rates.

Implications for tuberculosis transmission

The badger (*Meles meles* L.) is believed to be the main wildlife vector of tuberculosis to cattle in the United Kingdom and Ireland (Dunnet *et al*., 1986; O'Connor and O'Malley, 1989). Although the route of transmission between badgers and cattle has not been determined, it is hypothesised that cattle may be infected while grazing pasture contaminated by sputum, urine and faeces of an infected badger (Muirhead *et al*., 1974). A similar disease transmission mechanism may operate between cattle and ferrets, although transmission by pasture grazing is thought to be of lesser importance in New Zealand due to the short survival time of bacilli exposed to sunlight on open pasture (Jackson *et al*., 1995).

Stock could contact ferret products by consuming hay that ferrets have denned in or by grazing around ferret den sites. Benham and Broom (1991) found that most cattle avoided badger excreta at latrines but a small number of individuals were apparently unselective and grazed through the latrine areas. Even if most cattle avoid grazing around badger latrines, *M. bovis* may be inhaled by cattle when cattle sniff the contaminated area (Brown, 1993). In the present study, latrines were found at 40% of identified ferret den sites and 68% of them were accessible to stock, therefore it may be possible that tuberculosis is transmitted from ferrets to stock this way.

It has been hypothesised that forest-pasture margins play an important role in transmission of tuberculosis between cattle and possums (*Trichosurus vulpecula* Kerr) because of the positive relationship between the prevalence of tuberculosis infection in possums and possum density (Coleman *et al*., 1980, 1994), and because possums frequently cross this ecotone (Green and Coleman, 1986). Our study found that ferret movement was also concentrated at ecotones. This may result in higher contact rates of ferrets with sources of tuberculosis infection, either through environmental contamination, other tuberculous prey or carrion that are similarly concentrated, or infected possums. If ferrets, like possums, can effectively transmit infection to stock, then the observed ecotone effect may exacerbate transmission rates from ferrets to stock.

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