

Summer/autumn movements, mortality rates and density of feral ferrets (*Mustela furo*) at a farmland site in North Canterbury, New Zealand

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Abstract: For two summer/autumn periods (1999, 2000), we studied the movements and survival of feral ferrets (*Mustela furo* L.) at a site in North Canterbury that had been previously subjected to intensive control of ferrets. Movement distances of juvenile ferrets from the place of initial to final capture were generally low (median = 1.2 km) though variable [$\bar{x}=2.5 \pm 1.0$ (\pm S.E.M.), range 0.1–21.7 km]. The estimated instantaneous mortality rate of juvenile ferrets was high ($\bar{x} = 0.8 \text{ yr}^{-1}$), though imprecise (95% C.I. 0.4–1.8 yr^{-1}), as was that of adult ferrets ($\bar{x} = 1.1 \text{ yr}^{-1}$, 95% C.I. 0.3–4.5 yr^{-1}). Summer/autumn home ranges of adult ferrets in North Canterbury were larger than estimates from comparable studies. The density of ferrets during May was 1.7 km^{-2} in the first year and 2.5 km^{-2} in the second year. This corresponded with a trend for juvenile movements to increase, and juvenile survival rates to decrease. Our results suggest that formal studies to determine whether movements and survival of juvenile ferrets are density-dependent are warranted.

Keywords: abundance; dispersal; feral ferret; home range; mortality; *Mustela furo*; radio tracking; range length.

Introduction

Feral ferrets (*Mustela furo* L.) are considered to be pests in New Zealand because they prey on native wildlife (McLennan *et al.*, 1996) and may be an important host for *Mycobacterium bovis* (bovine tuberculosis) (Ragg *et al.*, 1995; Caley, 1998). Control of ferret populations is undertaken to reduce predation and the abundance of *M. bovis*-infected ferrets, and in an attempt to stop the geographic spread of *M. bovis*-infected ferret populations. At present it is unclear what effect “buffers” of reduced ferret density have on reducing the dispersal and spread of juvenile ferrets, and how important immigration is in maintaining ferret populations. Hypotheses abound on the proximal mechanism(s) for natal dispersal, and can broadly be categorised as density-independent (dispersal is innate), density-dependent (dispersal increases with increasing density) and inversely density-dependent (dispersal decreases with decreasing density). Dobson and Jones (1985) concluded that no single hypothesis adequately explains all the observed patterns. For example, a relationship between density and dispersal has often been suggested for small mammals (Caughley 1980;

Gaines and McGlenaghan, 1980), however Cowan *et al.* (1996, 1997) found dispersal of juvenile brushtail possums (*Trichosurus vulpecula* Kerr) was not influenced by density-dependent factors at the natal site, nor did poison buffers or reduced density entice possums to stop dispersing en route (Cowan and Rhodes, 1993). In an extensive review of population regulation in mammals, Wolff (1997) hypothesised that dispersal should be density-independent in nonterritorial species, and inversely density-dependent in territorial species (meaning that the emigration rate should decrease as the population approaches carrying capacity). Moors and Lavers (1981) reported feral ferrets, particularly males, to exhibit intrasexual territoriality. However, further studies (Norbury *et al.*, 1998; Ragg, 1997; Ragg, 1998) have not shown any territorial behaviour in feral ferrets inhabiting pastoral and semi-arid habitats of the South Island. Hence based on the density-independent hypothesis of Wolff (1997), we would expect little effect of density on emigration rate of juvenile ferrets.

The role of immigration/emigration in influencing population dynamics has been subject to recent theoretical analysis (Dias, 1996), and has been shown

to have practical application to our understanding of the population dynamics of some small mammal populations (Efford, 1998). Movement of individuals is also postulated to have a significant influence on the dynamics of disease, such as the case for *M. bovis* infection in badgers (*Meles meles* L.) (Rogers *et al.*, 1998) and brushtail possums (Barlow, 1993). Little published data exist on the movement behaviour of juvenile ferrets in New Zealand. Norbury *et al.* (1998) did not distinguish between age classes in their study of ferret movements. This lack of data limits understanding of the influence of juvenile emigration/immigration on population dynamics, and how to restrict the movements of ferrets for disease management. This study, therefore, aimed to describe movements of juvenile ferrets from a farmland site in North Canterbury where the ferret population was recovering after four years of sustained control. The study also estimated the instantaneous mortality rate and population density of these ferrets, as these data are needed for modelling *M. bovis* infection in feral ferrets, and in the case of instantaneous mortality rate, are not yet reported in the literature.

Methods

Study area

The study was centred on c. 4000 ha of the Scargill Valley, North Canterbury (42°56'S, 172°57'E). The predominant land use is sheep/beef farming on a mix of alluvial flats, rolling limestone hills and steep hill country. The vegetation of the flatter land is dominated by introduced pasture species. Willows (*Salix spp.*) and cabbage trees (*Cordyline australis* Forst. f.) line the watercourses. There are small areas of farm forestry (mainly *Pinus radiata* D. Don) throughout the site. Vegetation in the gullies and steeper hill country is dominated by native tussock (*Chionochloa* spp.), mānuka (*Leptospermum scoparium* J. R. & G. Forst) and to a lesser extent kānuka [*Kunzea ericoides* (A. Rich.) J. Thompson], matagouri (*Discaria toumatou* Raoul), and bush lawyer (*Rubus* spp.).

History of ferret control at Scargill Valley

Ferret control started on the Scargill Valley site in December 1994 using Victor 1½ soft-catch leg-hold traps, baited with rabbit (*Oryctolagus cuniculus* L.) meat, and spaced at c. 200 m intervals. The site was subsequently trapped using a similar method during May, August and December 1995, February–May, July, and December 1996, February and May 1997, and February and May 1998. In total, 779 ferrets were removed in 20 760 trap-nights of trapping. An index of

ferret abundance based on the mean proportion of traps catching ferrets averaged over the first 5 nights of trapping [corrected for non-target captures and sprung traps as suggested by Nelson and Clark (1973)] decreased from 7.8% in May 1995 to 1.8% in May 1998. Comprehensive details of the control undertaken during this period are presented by Caley *et al.* (1998) (available on request from PC).

Radio-collaring and tracking of ferrets

During January 1999 and January 2000, ferrets were captured using wire cage traps (Grieve Wirework, Christchurch, N.Z.) or plastic cantilever live traps (Michael Holden, Amberley, N.Z.) baited with fresh rabbit meat. The traps were set on a reasonably closely spaced (c. 200 m) grid, ensuring that juvenile ferrets were caught soon after emergence from the natal dens whilst they were still dependent on their mothers, and before they had entered the dispersal phase (Lavers and Clapperton, 1990). Trapping was started during mid-December in 1998 but few, if any ferrets emerged until mid-January 1999, hence trapping was started on 10 January in 2000. Ferrets were restrained in a “crush bag” whilst being weighed, sexed, ear tagged in both ears (Size #1 Monel, National Band and Tag Co.) and having radio-collars fitted. We used mortality transmitters (Sirtrack Ltd, Havelock North, New Zealand) that had a life of seven months and a pulse rate that doubled after 7 h of inactivity. Transmitters weighed 19–20 g, which is about 4% of the smallest sized juvenile radio-collared (530 g). Based on visual assessment of age (size, pelage colour, presence of teats), we collared 16 juveniles and 3 adults in 1999, and 20 juveniles and 5 adults in 2000.

Radio-collared ferrets were located during daylight hours from a motorcycle or on foot using a hand-held antenna and portable receiver. Attempts were made to locate ferrets weekly during February, March and April of both years. All confirmed surviving radio-collared ferrets were located and killed during the first week of May each year. The age of all ferrets whose bodies were recovered was checked by counting cementum annuli in sections of the lower canine tooth following the methods of Grue and Jensen (1979). Ferrets that could not be located from the ground and were not trapped during 2000 were subsequently searched for by radio-tracking from a helicopter. All fieldwork procedures were approved by the Landcare Research Animal Ethics Committee.

Monitoring rabbit abundance

An index of rabbit abundance was obtained from spotlight counts of rabbits seen on three permanently marked transects (transect lengths 12, 13 and 22 km).

Transect routes were chosen to give even coverage of three of the six farms within the study area where ferret trapping occurred. Observers riding motorcycles counted all rabbits seen in a strip transect illuminated on either side of the route using a 55–100W spotlight. The speed of travel was varied to enable all rabbits to be counted, and typically averaged about 6 kmph over the length of the transect. Spotlight counts of rabbits relevant to the current study occurred during October 1998, October 1999, and July 2000. Data was expressed as rabbits seen per kilometre of transect.

Analysis of ferret movements

The summer/autumn movement distances of juvenile ferrets were calculated as the straight-line distance between the first and last capture locations. This obviously fails to take into account the actual distance travelled, which may be much greater if an indirect path is chosen. As juvenile ferrets had left the natal den when captured, the initial capture location is only an approximation to the location of the natal den. Two sets of data on juvenile ferrets were analysed. The first data set aimed to examine dispersal distances, and only included radio-collared juvenile ferrets that survived for a period of 90 days or more. This arbitrary time period was chosen as it incorporated the late summer/autumn period when ferrets were expected to undergo dispersal, based on trapping observations during previous years from the Scargill Valley site. The second data set included movement distances of all juvenile ferrets, regardless of whether or not the animal was killed less than 90 days after being radio-collared. This data set was used to provide a general description of the movements of juvenile ferrets by fitting an exponential model to the observed distances moved, following Buechner (1987).

For adult ferrets, we calculated the home-range length (maximum distance between locations) and minimum-area convex polygon (MCP) measure of home-range size (Mohr, 1947; Southwood, 1966). The MCP method has several disadvantages in that calculated range size is strongly influenced by peripheral fixes, and the range area can include areas that are never visited (Harris *et al.*, 1990). However, it does enable comparisons with other studies of ferret home range (e.g., Norbury *et al.*, 1998), and it is robust compared with other techniques when there are few fixes (Harris *et al.*, 1990). Clearly, we did not estimate the definitive home-range size of ferrets [indeed there is ongoing debate whether such a measure actually exists – see Gautestad and Mysterud (1995)], but rather, we estimated summer/autumn (January–May) home-range areas and lengths. As we only located ferrets in their denning locations, and did not follow them at night, our estimates of home-range size are

clearly underestimates. A minimum of five fixes was arbitrarily chosen before a MCP was calculated for any individual ferret. MCP's were calculated using the software SPLUS (Mathsoft, Seattle, Washington), assuming no error in each fix location.

Estimating ferret abundance and density

The absolute abundance of ferrets was estimated from trapping undertaken during the first week of May in 1999 and 2000, using the Petersen Method (Krebs, 1989), modified for small samples as recommended by Seber (1982). The same radio-collared animals as those used in the dispersal/survival study were used to estimate the marked fraction of the population in each year. Trapping in both years consisted of a loosely spaced (c. 200 m) grid of traps over the study site. As with previous control, Victor 1¹/₂ soft-catch traps were used and baited with fresh rabbit meat. During each day of trapping, the number of radio-collared ferrets (juveniles and adults) at risk of being captured (i.e., inside the trapping grid) was ascertained by an observer independent of the people servicing the traps. Radio-collared ferrets were deemed to have been at risk of being trapped if at any time during the trapping period they were located within the trapping grid, or sequential locations indicated that they must have traversed the grid. The effective trapping grid for each year was estimated by extending the minimum area convex polygon by half the estimated home-range length of a ferret as estimated over the period of trapping (Kenward, 1987). As the number of radio-collared ferrets was small, with consequent imprecision in the Petersen Estimates, Zippin's Removal Estimator (Zippin, 1958) was additionally used to obtain indices of abundance in each year. The Removal Estimator was calculated for the first 5 nights trapping only, and the index expressed as number of trappable ferrets per trap. Feral cat (*Felis catus* L.) and stoats (*Mustela erminea* L.) incidentally caught in traps were killed.

Estimating mortality rates

The time from initial capture to natural death or right-censoring (i.e., time when animals were killed by farmers or survived to the end of the experiment each year) was recorded for each individual. Mortality of animals killed by farmers was considered to be unnatural, hence these observations were recorded as right-censored. The instantaneous mortality rate, or equivalently the instantaneous death rate (see McCallum, 2000), from the time of radio-collaring was calculated assuming a constant underlying hazard rate with censoring. For this exponential survival model (Lee, 1992), the estimated further life expectancy is simply the reciprocal of the instantaneous mortality

rate (Crawley, 1993). Estimating b was achieved by fitting a log linear hazard model to the observed survival times using the generalised linear modelling package GLIM (Crawley, 1993), with maturity (juvenile, adult) and year fitted as factors. More complex survival models (e.g., age-specific models) were not explored as the data sets were small, and the duration of the study relatively short, encompassing only one season.

Results

Fate of juvenile ferrets

From 22 December 1998 to 21 January 1999, 16 juvenile ferrets (6 ♂'s, 10 ♀'s) were radio-collared. Three of these were killed by farmers, two died of natural causes and 10 survived to the completion of the study (May 1999). The signal from one (a female first collared on 22 December 98) was last heard on 28 January 1999 and it remained unaccounted for. During 14–21 January 2000, 20 juvenile ferrets (7 ♂'s, 13 ♀'s) were radio-collared. Four of these died from natural causes, three lost their collars, and 11 survived to the completion of the study (May 2000). The signals from two, a male and female collared on 15 and 16 January respectively, were last heard on 20 and 2 February 2000 respectively, and they remained unaccounted for (despite extensive helicopter searches). Canine teeth were recovered for section from 26 ferrets visually classified as juveniles and four ferrets classified as adults. No cementum annuli were present in any of the 26 juvenile canine teeth, whilst all four adult canine teeth had at least one cementum annulus. As ferrets are strongly seasonal breeders, with births occurring during spring, these data confirm our initial visual estimation of maturity as cementum bands are laid down starting during early winter (late May), with distinct bands usually visible by August (Lisa McElrea, Landcare Research, Dunedin, N.Z., *pers. comm.*). We are confident that the juvenile ferrets were captured shortly (within days) after emergence and close (within 200 m) to their natal den as the grid of traps lay empty (of juvenile ferrets) for a considerable period of time before suddenly starting to catch a group of juvenile ferrets associated with an adult female, whom were captured in traps tightly clustered together.

Ferret abundance

The population density of ferrets (all ages) increased by 47% between 1999 and 2000 based on changes in the Petersen Estimate, and by 100% based on changes in the Zippin Removal index (Table 1), suggesting the population was recovering after the cessation of

Table 1. Summary of population densities as estimated by the Petersen estimate for ferrets of all ages, and summer/autumn movements of juvenile feral ferrets in the Scargill Valley area, North Canterbury, New Zealand. Ranges of values in parentheses are 95% Confidence Intervals. Errors represent standard errors of the mean (S.E.M.).

Year	Ferret density (km ⁻²)	Zippin removal index (trappable ferrets trap ⁻¹)	Mean juvenile movement distance (km ± S.E.)
1999	1.7 (1.5–1.9)	0.4	1.0 ± 0.16 range 0.4–2.4 (n = 11)
2000	2.5 (1.9–3.1)	0.8	4.1 ± 1.8 range 0.1–21.7 (n = 11)
Both	2.1	0.6	2.5 ± 1.0 range 0.1–21.7 (n = 22)

intensive control. During 1999, 45 ferrets (22 juvenile ♂'s, 3 adult ♂'s, 18 juvenile ♀'s, 2 adult ♀'s), 22 cats and 8 stoats were removed from the site as part of censusing, as were 56 ferrets (24 juvenile ♂'s, 28 juvenile ♀'s, 4 adult ♀'s), 19 cats and 10 stoats in 2000.

Rabbit abundance

Counts of rabbits on spotlight transects were 9.4 ± 2.8 rabbits km⁻¹ during October 1998, 14.4 ± 4.1 rabbits km⁻¹ during October 1999, and 6.6 ± 1.0 rabbits km⁻¹ during July 2000.

Movements

For the radio-collared juvenile ferrets that survived for 90 days or more, median distances moved between initial and final capture locations were low in both 1999 (median = 0.9 km, range 0.4–2.4 km, n=11), and 2000 (median = 1.7 km, range 0.1–21.7 km, n=11). For the years combined, the median distance moved was 1.2 km. Mean movements of juveniles did not differ between the sexes [2.6 km (males) vs 2.5 km (females), $F_{1,18} = 0.0$, $P = 0.98$] or year [1.0 km (1999) vs 4.1 km (2000), $F_{1,18} = 1.8$, $P = 0.19$]. The individual juvenile that moved 21.7 km during 2000 was a female. This ferret was last located in the study site on 1 February 2000 (when presumably it started dispersing), before being caught and killed by a farmer in early May 2000. The next largest movement was that of a juvenile male, which had moved 9.5 km when caught and killed by a farmer after the completion of the study. It was last located in the study site on 8 February 2000. For all juvenile ferrets whose fate was known (including those

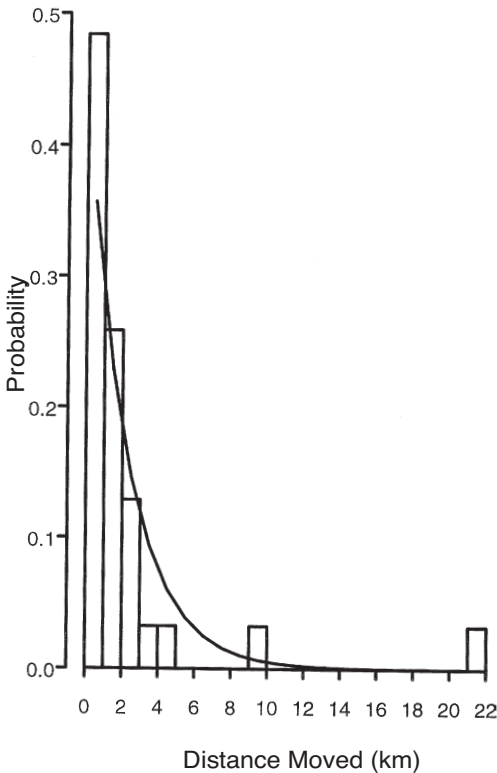


Figure 1. Probability distribution for distances moved between initial capture location and final summer/autumn location of 31 juvenile ferrets captured from a farmland site in Canterbury, New Zealand, during 1999 and 2000. Bars represent 1.0 km intervals. Fitted curve is the exponential distribution $f(d) = 1/k \cdot e^{-d/k}$, where $k = 2.2$ km (the mean distance moved) and d is the observed distance.

Table 2. Summary of instantaneous mortality rates of feral ferrets in the Scargill Valley area, North Canterbury, New Zealand. Ranges of values in parentheses are 95% Confidence Intervals.

Year	Instantaneous adult mortality rate (yr ⁻¹)	Instantaneous juvenile mortality rate (yr ⁻¹)
1999	0.5 (0.1–2.0) (n = 3)	0.3 (0.1–1.2) (n = 16)
2000	2.5 (0.6–10.0) (n = 5)	1.4 (0.3–6.5) (n = 20)
Both Years	1.1 (0.3–4.5) (n = 8)	0.8 (0.4–1.8) (n = 36)

dying less than 90 days after being collared), the vast majority of ferrets moved less than 1.5 km, and 90% moved less than 5 km. An exponential model provided a reasonable fit to the data ($\chi^2 = 3.6$, d.f. = 3, $P = 0.3$) (Fig. 1).

Only one adult male ferret was tracked sufficiently to estimate its summer/autumn home range ($\bar{x} = 7.6$ km²) (number of fixes = 5), whereas the mean summer/autumn home range for five adult females was 2.3 ± 1.1 km² (\pm S.E.) (mean fixes per individual = 13). Mean summer/autumn home-range lengths were 4.0 ± 0.2 km (\pm S.E.) for the two adult males and 2.1 ± 0.6 km (\pm S.E.) for the five adult females. The paucity of data negated estimating adult movements for individual years.

Mortality rates

Per capita instantaneous mortality rates were high in both years, and were highest during the year of highest density, although the estimates are rather imprecise (Table 2). The mean instantaneous mortality rate for juvenile ferrets of 0.8 yr^{-1} corresponds to a life expectancy of 1.3 years, and a yearly survival probability of 0.55.

Discussion

Movements

Summer/autumn movements of juvenile ferrets recorded in this study were lower than in a study of juvenile ferrets in braided riverbeds in the Mackenzie Basin, where the median dispersal distance was 5.0 km (A. Byrom, Landcare Research, Lincoln, N.Z., *pers. comm.*). As usually occurs in this type of study, average and median dispersal distances were probably underestimated, as the ferrets that disperse the greatest distances are probably the hardest to locate and monitor. However, it would be erroneous to assume that the ferrets whose signal was lost actually dispersed from the study site, as some radio-collars recovered during the trapping sessions had failed. Clearly a proportion of both male and female juvenile ferrets disperse large distances, and if infected with *M. bovis* before dispersing, may transport the infection to areas where wildlife populations are currently uninfected. However, the likelihood of these infected immigrants transmitting infection to ferrets and/or possums and causing new reservoirs of *M. bovis* infection is still open to debate (Ragg *et al.*, 1995; Ragg 1998; Caley, 1998; Qureshi *et al.*, 2000).

Dispersal, defined as the number of territories or home ranges crossed, appears as a measure in a variety of studies of dispersal movements and provides a

convenient cross-study comparison (Buechner, 1987). From this definition, it appears that very few juvenile ferrets in the present study undertook true dispersal, as most ferrets did not completely leave their natal home range, particularly during 1999. During 2000, there was a trend for more ferrets to move larger distances, correlating with an increase in density following the cessation of intensive control. One explanation for this is that dispersal of juvenile ferrets is a density-dependent process [c.f. the density-independent prediction of Wolff (1997)]. We stress that this is a *post hoc* observation, and needs to be tested before gaining any credence.

In contrast to the small juvenile movements, the summer/autumn home-range size of adult ferrets in this study was large compared with estimates for ferrets in the Mackenzie Basin (Norbury *et al.*, 1998) and all other estimates from unpublished studies in New Zealand. This occurred despite the small number of fixes per individual and inevitable underestimation of home range size in our study. Our data set is small, however the summer/autumn home range of the one adult male tracked was two-fold greater than the largest recorded by Norbury *et al.* (1998) over a considerably longer period. Clearly the movements of ferrets differ substantially between sites, and this has considerable implications for site-based management of ferrets. Both the required size of ferret control operations to remove resident ferrets, and the widths of depopulated buffer zones around control operations for minimising immigration of juveniles will vary between sites. Determination of whether intraspecific variation in the movements of ferrets can be predicted based on variables such as body mass and abundance, as demonstrated for feral pigs (*Sus scrofa* L.) by Saunders and McLeod (1999), may be worthwhile. For example, Ragg (1997) reported home-range sizes less than half those of our study in a site where the abundance of ferrets was subsequently estimated to be c. 6.0 ferrets km⁻² (Cross *et al.* 1998), about twice the density reported here.

Mortality

As expected based on the observed age structure of feral ferret populations (P. Caley, *unpubl.*), the instantaneous mortality rates for juveniles and adults were high, and there was a suggestion that it was influenced by density. The estimates of mortality from the current study assume a constant mortality rate year-round (not tested for here), and hence should be treated very cautiously when extrapolating to other time periods. A. Byrom (*pers. comm.*) reported significantly higher survival rates of ferrets from sites where population density was being reduced by active management.

In this study we estimated the instantaneous mortality rate post-emergence from the natal den up until May of each year. We did not test for differences in movements and mortality rates between the two years (and densities), as we did not have an a priori hypothesis that there would be between-year differences. In addition, the sample sizes in our study were small, the parameter estimates are imprecise and hence tests would have low power and consequent utility. However, this study suggests that the hypotheses that dispersal and survival of juvenile ferrets are density-dependent warrant formal testing. This would elucidate how best to manage ferret populations to control abundance and dispersal.

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