Habitat use and preference by polecats (*Mustela putorius* L.) in a Mediterranean agricultural landscape

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Abstract

An investigation is reported on the use of and preference for riparian vegetation, road verges, ponds and farms by polecats *Mustela putorius* L. living in a fragmented cultivated area. Eighteen polecats of both sexes were marked with radio-collars and monitored for 2–18 months each. Individuals were monitored with single nightly radio-locations, and during 12- and 24-h continuous sessions. Sex and seasonal variations in the density of key habitat features within home ranges were analysed. In order to measure the seasonal strength of attraction to key habitat features, the average distance to these features of observed trajectories, and of corresponding Monte-Carlo simulations, was compared. Polecats positively selected riparian vegetation within their home range throughout the year. Female home ranges contained more farms and ponds than those of adult males in the breeding season. Males expanded their home ranges in the breeding season, and the strength of attraction to riparian vegetation and ponds increased accordingly. The remnants of riparian vegetation apparently acted as a key habitat feature providing food and cover. Furthermore, these linear and interconnected landscape elements can facilitate the long-range movements involved in the search for mates.

Introduction

The European polecat *Mustela putorius* L. is among the least-known European mesopredators. The majority of the studies on this species have been conducted on life-history traits and diet, and have relied on trapping, track counts or scat collection (review in Blandford, 1987). A few investigations have involved an extensive use of radio-telemetry, and even less contain a quantification of habitat use and preference. According to these studies, in northern and central Europe polecats can exploit riverine, marsh, woody and cultivated habitats ranging from lowland to mountain areas (Weber, 1989*a*; Jedrzejewski, Jedrzejewska & Brzezinski, 1993; Lodé, 1993*a*, 1994). Nothing is known about habitat use and preference by polecats in fragmented, cultivated areas in the Mediterranean region.

The persistence of animal species in agricultural land is related to ecological heterogeneity at multiple scales (Benton, Vickery & Wilson, 2003). A key component of this heterogeneity is the non-cropped habitat, including field margins, hedges, ponds and ditches. The non-cropped habitat of farmland is capable of maintaining the biodiversity of a variety of organisms because it can provide abundant food through the edge effect, allows one to forage close to cover (Macdonald, 1995) and enhances connectivity

(Noss & Harris, 1986; Hobbs, 1992). Bird and mammal species prefer natural and semi-natural vegetation over the surrounding cropped open areas (e.g. Doncaster, Rondinini & Johnson, 2001; Rondinini & Boitani, 2002; Vickery, Carter & Fuller, 2002). In British cultivated areas polecats prefer agricultural premises, but also hedgerows and wetlands, over the other available habitat (Birks, 1998).

Here we report on an analysis of habitat preference by polecats in an agricultural, fragmented rugged area in central Italy. We focused on four types of habitat features: riparian vegetation, farms, road verges and ponds, as they represented the only potential habitat resources in the matrix of inhospitable cultivated land. We quantified habitat use based on distance of radio-locations to habitat features, and estimated availability using Monte-Carlo simulations based on the real trajectories (Doncaster *et al.*, 2001; Rondinini & Doncaster, 2002). The method is more robust against spatial errors than traditional (area-based) methods, and provides a continuous measure of the intensity of individual attraction/repulsion towards habitat features. We used this measure in order to test (1) whether observed use of habitat features departed from a random expectation, and (2) as males roamed in search of females in the breeding season, whether habitat preference in males differed between the breeding and the non-breeding season.

Methods

Study area and radio-telemetry

We carried out the study in the Riserva Naturale Lago di Penne, a natural reserve in the Apennine Mountains in Abruzzo, central Italy. Climate in the area is mesomediterranean, with a mean annual temperature of 14 °C. The hilly landscape (about 450 m a.s.l.) is dominated by large patches of arable land, and the remnant natural vegetation (*Populus* spp., *Salix* spp., *Quercus pubescens*, *Quercus cerris*, *Rubus* spp.) is confined to small strips along the three streams and the main ditches. Human activity is intensive, with farms and roads evenly scattered throughout the area.

We digitized a land-use map of the study area [the minimum convex polygon (MCP) encompassing all locations of the monitored individuals: *c*. 220 km^2] based on 1:10 000 aerial photos (Compagnia generale Riprese aeree, Parma, Italy, 1982) and on field surveys. Five habitat categories were considered: arable land; riparian vegetation (along the three streams and the main ditches); large asphalt roads (> 5 m wide), which were usually bordered by a vegetated verge; farms and other buildings; and ponds. We then converted the land-use map to an image with a pixel size of 50 m, equal to the accuracy of the vast majority of the radio-locations. We also derived four distance maps containing, for each grid cell, the distance to the closest pixel of riparian vegetation, road, farm and pond, respectively. All geographical analyses were conducted using Arc Info 8.3 (Esri Inc., Redlands, CA, USA).

From October 1995 to August 1999 we captured 20 male and eight female polecats, in box traps baited with an egg or dead frozen chick. Each individual was anaesthetized with Ketamine (0.2 cm^3 kg^{-1}), sexed, aged by tooth wear as yearling or adult, measured and fitted with a radio-collar (Telonics mod. 080, mod. CHP-2H; Televilt mod. TXT-1, TXT-2). Removal of radio-collars at the end of the study was unfeasible because of the very low recapture rate, but radio-collars were fitted loosely to avoid hurting the animals. As a result *c*. 35% of the polecats lost their collars in the monitoring period: this is a minimum estimate, because the same may have happened to other polecats after the signal transmission ceased. We located radio-tagged animals using a receiver and an H hand-held or a yagi car-mounted antenna. We estimated the accuracy of radio-locations at the beginning of the research by locating hidden transmitters in blind tests. The accuracy of locations obtained using an on-foot homing technique (93.3%) was ≤ 50 m, while locations collected with triangulation techniques (6.7%) had an accuracy ≤ 100 m. We collected animal locations using two sampling strategies: (1) single fixes every 7–10 h and (2) continuous 12–24 h monitoring sessions in which the animal was located every 15 min.

Analysis sample

Of the 28 captured polecats, 12 males and six females were monitored for at least 2 months and were located a total of 9227 times (on average 513 ± 118 SE locations in 183 ± 34 days per individual). We used this sample in order to estimate the size of individual home ranges (MCP), the composition of habitat within home ranges, and sex and seasonal differences in these variables. We identified two seasons: the breeding season, corresponding to spring and summer (from the beginning of March to the end of August); the non-breeding season, corresponding to autumn and winter (from the beginning of September to the end of February).

Individual trajectories were monitored in 51 continuous radio-tracking sessions on a subsample of 10 males and five females (on average 3.4 ± 1.0 sessions per individual) during which 4080 locations were collected. We used this subsample in order to quantify the average individual distance to key habitat features.

Four males and three females were radio-tracked in both the breeding and the non-breeding season. The analysis of variance (ANOVA) design used to investigate the preference for habitat features within home ranges requires that different subjects be sampled in different seasons in order to avoid pseudo-replication. We therefore removed the data on one of the two seasons for each of these individuals, according to the following rules: (1) tend to balance the ANOVA design; (2) remove the data based on the smaller number of locations. As this reduced the number of available females to three and two in the breeding and non-breeding season, respectively, we reported the results for females but performed the ANOVA on 10 males only (five in each season).

Two of the males were also monitored when they were yearlings. As their exploratory behaviour differed markedly from that of the adults, we used only their locations as adults in statistical analyses, although we also report the descriptive statistics as yearlings.

All statistical analyses were performed using Statistica 5.1 (StatSoft, Tulsa, OK, USA).

Sex and seasonal difference in size and habitat composition of home ranges

We estimated seasonal home ranges as the MCPs encompassing all individual locations collected in each season. From the land-use map we estimated the density of each of the key habitat features (proportion of riparian vegetation, number of ponds per hectare, number of farms per hectare and metres of road per hectare) within individual MCPs. We evaluated sex and seasonal differences in home range size, and in density of each of the four key habitat features, using a two-way ANOVA with the following design:

$$\text{Response} = \text{Sex} | \text{Season}$$

Distributions of the variables that we analysed did not significantly depart from normality (Shapiro–Wilk *W*-test) or homogeneity of variances (Levene's test).

Preference for habitat features within home ranges

For each observed trajectory we simulated 499 random walks from the same starting point, with the same number of steps and with the same frequency distribution of distances between consecutive points as the observed trajectory. The component of randomness was only in the direction taken from one location to the next, and in the order of consecutive distances. We then calculated the distance of each observed and simulated location to the closest target habitat feature (riparian vegetation, road, farm and pond). The distribution of observed and simulated distances therefore represents an estimation of habitat use and availability, respectively. The protocol is the same as described in Doncaster *et al.* (2001) and allows one (1) to test the hypothesis that polecats tended to move closer to the target features than random expectation and (2) to seek seasonal differences in the strength of attraction towards features.

In order to evaluate the statistical significance of the preference for habitat features, we averaged distances to habitat features within each monitoring session, and then among sessions for the individuals sampled for more than one trajectory. As in the previous analysis of habitat preference, four habitat features were considered: riparian vegetation, road, farm and pond. We then used average distances as response variables in a two-way split-plot ANOVA. The ANOVA model was

$$\text{Distance} = \text{Season}|\text{Subject}(\text{type of location})$$

where type of location is either observed or simulated.

Results

Size of home ranges

Polecats in the study area occupied a seasonal mean MCP of $598.5\,\text{ha} \pm 132.9$ SE. Mean male home ranges were significantly larger than those of females ($820.2\,\text{ha} \pm 164.8$, $n = 12$, and $155.1\,\text{ha} \pm 41.3$, $n = 6$, respectively; $F_{1,14} = 35.82$, $P < 0.001$). The size of individual MCP was larger in the breeding season ($F_{1,14} = 23.68$, $P < 0.001$) for both sexes (Table 1). This effect was more marked for males, as indicated by the significant interaction sex × season ($F_{1,14} = 16.26$, $P < 0.005$).

Table 1 Minimum convex polygon (MCP) home range size (ha) in the breeding and non-breeding season, given as mean (SE)

	Breeding		Non-breeding	
	n	MCP	*n*	MCP
M	6	1314.6 (138.1)	6	325.7 (52.1)
F	3	201.4 (71.0)	3	108.8 (36.7)
YM	–	–	2	987.9 (298.5)

M, males; F, females; YM, yearling males; *n,* number of individuals.

Two yearling males had non-breeding MCPs about three times larger than adult males (Table 1). They were possibly exploring or dispersing from their natal home range.

Habitat composition of home ranges

On average, $13.3 \pm 3.9\%$ of a polecat home range was covered by riparian vegetation, with no significant difference between sexes or seasons (Fig. 1a).

Polecat home ranges contained 0.04 ± 0.01 ponds ha^{-1}, the figure being significantly larger in females than in males ($F_{1,14} = 9.84$, $P < 0.01$, $n = 18$). The significant interaction sex × season ($F_{1,14} = 9.71$, $P < 0.05$, $n = 18$, Fig. 1b) was driven by the female home ranges containing more ponds in the breeding season.

The mean density of farms within individual MCPs was 0.18 ± 0.04 ha^{-1} and the home ranges of females contained more farms than those of males ($F_{1,14} = 5.40$, $P < 0.05$, $n = 18$). Even though the difference between sexes was larger in the breeding season, as for density of ponds, we found no significant effect of the interaction sex × season (Fig. 1c).

The amount of roads within home ranges was equal to 9 ± 1 m ha^{-1} with no significant effect of sex, season or their interaction (Fig. 1d).

Preference for habitat features within home ranges

The mean observed distance to riparian vegetation was below 30 m for both sexes in both seasons, 6–19 times smaller than for the other habitat features subjected to analysis (range 176–579 m). The figure was slightly larger for the two yearlings in the non-breeding season (see Table 2 for details).

The ANOVA on male polecats showed that they moved on average closer to the riparian vegetation than expected by chance (main effect of type of location: $F_{1,8} = 80.74$, $P < 0.001$, $n = 10$). Moreover, season and its interaction with type of location (Fig. 2a) had a significant effect on distance to riparian vegetation ($F_{1,8} = 12.99$, $P < 0.01$, $n = 10$; $F_{1,8} = 14.56$, $P < 0.01$, $n = 10$, respectively), indicating a stronger preference for this type of habitat during the breeding season. While the observed distance remained approximately constant between seasons, the significance of this interaction depended on the increase of the simulated distance during breeding (Fig. 2b).

Although there was no significant difference between observed and expected distances to ponds, nor a main effect of season on this distance, the interaction type of location × season was significant ($F_{1,8} = 5.48$, $P < 0.05$, $n = 10$, Fig. 2b), indicating a preference for moving and staying near these potential resources during the breeding season. No main effect of type of location or season, or their interaction, was detected for distance to roads and distance to farms, respectively, indicating that these habitat features were used according to availability in both seasons (Fig. 2c and d).
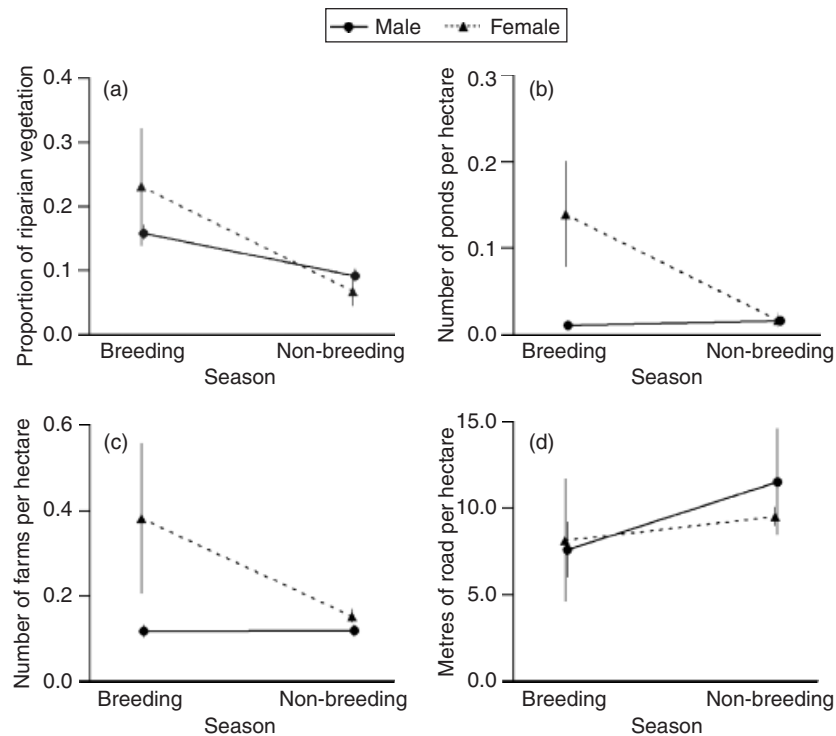
Figure 1 Sex and seasonal differences in density of key habitat features within individual minimum convex polygons (mean ± SE).

Table 2 Observed distance (m) to key habitat features during the breeding and non-breeding season, given as mean (SE)

	Breeding					Non-breeding				
	n	Rip.	Pond	Farm	Road	n	Rip.	Pond	Farm	Road
M	5	24 (8)	430 (140)	282 (30)	579 (274)	5	16 (5)	553 (163)	176 (25)	294 (60)
F	3	17 (16)	502 (135)	109 (11)	256 (38)	2	14 (14)	512 (312)	878 (45)	417 (206)
YM	–	–	–	–	–	2	41.2 (28.7)	397 (132)	187 (26)	256.4 (4.2)

M, males; F, females; YM, yearling males; n, number of individuals; Rip., riparian vegetation.

Discussion

Our study showed that in a fragmented agricultural landscape polecats were attracted to riparian vegetation within their home ranges all over the year. Home ranges of adult females contained farms and ponds at a higher density than those of adult males in the breeding season, when males expanded their home ranges, probably roaming in search of females to mate with. Furthermore, the strength of attraction of adult males to riparian vegetation, and to ponds, increased in the breeding season accordingly. Road verges were used proportionately to availability by both sexes all over the year.

The preference we observed for riparian vegetation is common among mustelids inhabiting highly fragmented landscapes (e.g. American marten: Hargis, Bissonnette & Turner, 1999; skunk: Lariviere & Messier, 2000; badger and beech marten: Virgos, 2001). Additional support to such

selective patterns is provided by a study by Forsey & Baggs (2001), who noticed that Newfoundland martens immediately shifted towards remnant riparian vegetation after prescribed forest cuttings. The need for cover in polecats has been reported by Weber (1989a), who suggested that the probability of not being detected at a small distance could drive the species' habitat choice. In both clear-cut forests and agricultural areas, linear elements of riparian vegetation can ensure connectivity across the landscape.

Preference for riparian habitat by polecats seems to be a trait of the species' life history and is not restricted to fragmented landscapes. In fact, it has been reported in forests in Poland and Russia, where riparian habitats were embedded within a heterogeneous landscape composed of mature pristine forests (Danilov & Rusakov, 1969, in Brzezinski, Jedrzejewski & Jedrzejewska, 1992; Lodé, 1994). Although the definition of home range is itself a major problem in animal ecology (Garshelis, 2000; Powell,
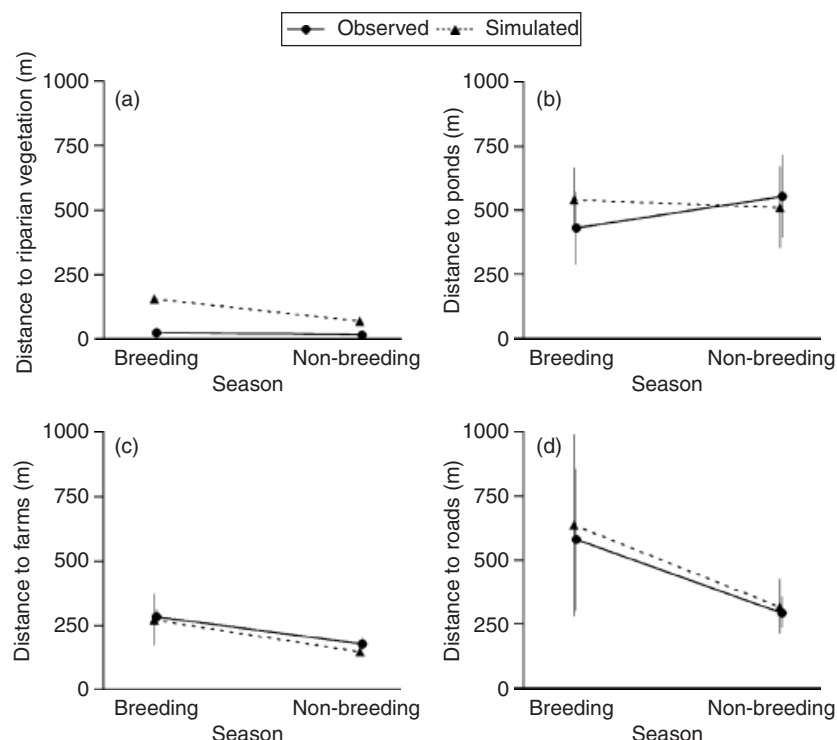
Figure 2 Seasonal differences in distance to key habitat features of observed and simulated male locations (mean ± SE).

2000), it is worthwhile noticing that during winter our polecats occupied an average MCP 300 ha in size, similar to that reported from Poland (200 ha, Brzezinski *et al.*, 1992) and Russia (100–2500 ha, Danilov & Rusakov, 1969). By the same token, we hypothesize that the type of matrix surrounding the riparian habitat selected by polecats (forest in Poland and Russia, cropland in our study area) may not heavily affect their movements.

In most species, habitat preference patterns during foraging reflect two constraints: to obtain food and to avoid predation (Lima & Dill, 1990). Rodents and anurans are reported as being the main prey of polecats (Blandford, 1987; Jedrzejewski, Jedrzejewska & Szymura, 1989; Weber, 1989*b*,*c*; Lodé, 1990, 1993*b*, 1996, 1997, 1999; Jedrzejewski *et al.*, 1993). During the study period, riparian habitats offered a higher availability of small rodents compared with other types of habitat within the area (our unpublished data based on trapping transects). Frog *Rana* 'kl' *esculenta* and toad *Bufo bufo* populations were monitored in the study area in the same years (Ferri, 2000). Anurans were abundant from March to June, when they formed breeding congregations along traits of the rivers, ditches and ponds. Although the amphibian habitat preference in the area during winter is poorly known, it seems possible that they could hibernate in the proximity of the riparian vegetation (Ferri, 2000) as it has been reported elsewhere (Matthews & Pope, 1999). From a preliminary analysis of scats collected during this study, we found traces of anuran bones even in December. Polecats are well adapted in capturing anurans in all seasons, as they are capable of excavating them from the mud (Weber, 1989*b*; Jedrzejewski *et al.*, 1993).

Our analysis evidenced an increased attraction of adult males towards riparian vegetation and ponds during the breeding season. Other authors reported a seasonal shift in habitat preference by polecats due to changes in local availability of prey (Lodé, 1990, 1994) or as a consequence of severe weather (Weber, 1989*a*; Jedrzejewski *et al.*, 1993). As we did not detect major shifts in habitat preference by potential prey or extreme climatic conditions, we hypothesize that the increased attraction of adult males towards streams and ditches reflected the use of these features as linear corridors facilitating movements in search of females to mate with. The enhanced need for cover during long-distance displacements has in fact been reported for many species. In deforested areas, riparian vegetation has been reported as a crucial habitat in affecting the movements of small mammals (Mauritzen *et al.*, 1999; de Sao *et al.*, 2000) and herpetofaunal species (Burbrink, Phillips & Heske, 1998; Maisonneuve & Rioux, 2001). Riparian zones are also used by wildlife as migration routes (Thomas, Maser & Rodiek, 1979) and corridors (Gregory *et al.*, 1991).

Pond and farm densities were higher in female than in male home ranges, especially in the breeding season. This could possibly be related to an increased need for food and cover by pregnant and lactating females, which has been widely reported for mustelids (Zalewski, 1997; Gough & Rushton, 2000). The use of farms as denning sites has also been reported in other mustelids, including skunks (Lariviere & Messier, 1998) and beech martens (Genovesi & Boitani, 1997).

The mean distance to ponds that we observed in this study is large compared with the distance to other habitat

features potentially capable of providing food and cover. However, we suggest that the importance of ponds for polecats could be underestimated for two reasons. Ponds are point, unevenly distributed, rare elements (93 in total in the study area). They were overall used for limited amounts of time; however, habitats that are used infrequently may be more important than suggested by the time spent there, if they provide key resources (Geffen *et al.*, 1992; Powell, 1994; Garshelis, 2000). Moreover, it is possible that the inclusion map of more freshwater elements relevant to amphibian ecology in the land-use, such as ephemeral ponds (Gibbs, 1998; Semlitsch, 2000) or deep stagnating confluences between ditches, would give more insights on the fine-grained habitat preference operated by polecats.

Beech martens are abundant in the study area, and show a strong attraction for the residual semi-natural vegetation along rivers and ditches (Rondinini & Boitani, 2002). Although the observed syntopy between polecats and beech martens has also been reported by Lodé (1991) in France, it is noteworthy that here the fragmentation of habitat forced both species in the few remnants of riparian vegetation. We therefore hypothesize that the two species can coexist in the same remnants of usable habitat because of segregation along other axes of the ecological niche including circadian rhythms (Marcelli, Fusillo & Boitani, 2003), use of space (comparison of results from this study and that of Rondinini & Boitani, 2002) and diet (Baghli, Engel & Verhagen, 2002).

Acknowledgements

References

Baghli, A., Engel, E. & Verhagen, R. (2002). Feeding habits and trophic niche overlap of two sympatric Mustelidae, the polecat *Mustela putorius* and the beech marten *Martes foina*. *Zeitschrift für Jagdwissenschaft* **48**, 217–225.

Benton, T.G., Vickery, J.A. & Wilson, J.D. (2003). Farmland biodiversity: is habitat heterogeneity the key? *Trends Ecol. Evol.* **18**, 182–188.

Birks, J.D.S. (1998). Secondary rodenticide poisoning risk arising from winter farmyard use by European polecat *Mustela putorius*. *Biol. Conserv.* **85**, 233–240.

Blandford, P.R.S. (1987). Biology of the polecat *Mustela putorius*: a literature review. *Mamm. Rev.* **17**, 155–198.

Brzezinski, M., Jedrzejewski, W. & Jedrzejewska, B. (1992). Winter home ranges and movements of polecats *Mustela putorius* in Bialowieza Primeval Forest, Poland. *Acta Theriol.* **37**, 181–191.

Burbrink, F.T., Phillips, C.A. & Heske, E.J. (1998). A riparian zone in southern Illinois as potential dispersal corridor for reptiles and amphibians. *Biol. Conserv.* **86**, 107–115.

Doncaster, C.P., Rondinini, C. & Johnson, P.C.D. (2001). Field test for environmental correlates of dispersal in hedgehogs *Erinaceus europaeus*. *J. Anim. Ecol.* **70**, 33–46.

Ferri, V. (2000). La gestione degli anfibi e rettili nella riserva. In *Piano di assetto naturalistico della riserva naturale regionale Lago di Penne*: 103–122. Di Fabrizio, F. (Ed.). Penne: COGECSTRE.

Forsey, E.S. & Baggs, E.M. (2001). Winter activity of mammals in riparian zones and adjacent forest prior to and following clear-cutting at Copper Lake, Newfoundland, Canada. *Forest Ecol. Mgmt.* **145**, 163–171.

Garshelis, D.L. (2000). Delusions in habitat evaluation: measuring use, selection, and importance. In *Research techniques in animal ecology*: 611–644. Boitani, L. & Fuller, T.K. (Eds). New York: Columbia University Press.

Geffen, E., Hefner, R., Macdonald, D.W. & Ucko, M. (1992). Habitat selection and home range in the Blandford's fox, *Vulpes cana*: compatibility with the resource dispersion hypotheses. *Oecologia* **9**, 75–81.

Genovesi, P. & Boitani, L. (1997). Day resting sites of the stone marten. *Hystrix* **9**, 75–78.

Gibbs, J.P. (1998). Distribution of woodland amphibians along a forest fragmentation gradient. *Landscape Ecol.* **13**, 263–268.

Gough, M.C. & Rushton, S.P. (2000). The application of GIS-modelling to mustelid landscape ecology. *Mamm. Rev.* **30**, 197–216.

Gregory, S.V., Swanson, F.J., McKee, W.A. & Cummings, K.W. (1991). An ecosystem perspective of riparian zones. *Bioscience* **41**, 540–551.

Hargis, C.D., Bissonnette, J.A. & Turner, D.L. (1999). The influence of forest fragmentation and landscape pattern on American martens. *J. Appl. Ecol.* **36**, 157–172.

Hobbs, R.J. (1992). The role of corridors in conservation: solution or bandwagon? *Trends Ecol. Evol.* **7**, 389–392.

Jedrzejewski, W., Jedrzejewska, B. & Brzezinski, M. (1993). Winter habitat selection and feeding habits of polecats (*Mustela putorius*) in the Bialowieza National Park, Poland. *Z. Saugetierkd.* **58**, 75–83.

Jedrzejewski, W., Jedrzejewska, B. & Szymura, A. (1989). Food niche overlap in a winter community of predators in the Bialowieza Primeval Forest, Poland. *Acta Theriol.* **34**, 487–496.

Lariviere, S. & Messier, F. (1998). Denning ecology of the striped skunk in Canadian prairies: implications for waterfowl nest predation. *J. Appl. Ecol.* **35**, 207–213.

Lariviere, S. & Messier, F. (2000). Habitat selection and use of edges by striped skunks in the Canadian prairies. *Can. J. Zool.* **78**, 366–372.

Lima, S.L. & Dill, L.M. (1990). Behavioral decisions made under the risk of predation: a review and prospectus. *Can. J. Zool.* **68**, 619–640.

Lodé, T. (1990). Le régime alimentaire d'un petit carnivore, le Putois (*Mustela putorius*) dans l'ouest de la France. *Gibier Faune Sauvage* **7**, 193–203.

Lodé, T. (1991). Exploitation des milieux et organization de l'espace chez deux mustélidés européens: la Fouine et le Putois. *Vie Milieu* **41**, 29–38.

Lodé, T. (1993*a*). Stratégie d'utilisation de l'espace chez le Putois européen *Mustela putorius* L. dans l'ouest de la France. *Rev. Ecol. (Terre vie)* **48**, 305–322.

Lodé, T. (1993*b*). Diet composition and habitat use of sympatric polecat and American mink in western France. *Acta Theriol.* **38**, 161–166.

Lodé, T. (1994). Environmental factors influencing habitat exploitation by the polecat *Mustela putorius* in western France. *J. Zool. (Lond.)* **234**, 75–88.

Lodé, T. (1996). Polecat predation on frogs and toads at breeding sites in western France. *Ethol. Ecol. Evol.* **8**, 115–124.

Lodé, T. (1997). Trophic status and feeding habits of the European polecat *Mustela putorius* L., 1758. *Mamm. Rev.* **27**, 177–184.

Lodé, T. (1999). Time budget as related to feeding tactics of European polecat *Mustela putorius*. *Behav. Proc.* **47**, 11–18.

Macdonald, D.W. (1995). *European mammals: evolution and behaviour*. Oxford: Harper Collins.

Maisonneuve, C. & Rioux, S. (2001). Importance of riparian habitats for small mammals and herpetofaunal communities in agricultural landscapes of southern Québec. *Agr. Ecosyst. Environ.* **83**, 165–175.

Marcelli, M., Fusillo, R. & Boitani, L. (2003). Sexual segregation in the activity patterns of European polecats (*Mustela putorius*). *J. Zool. (Lond.)* **261**, 249–255.

Matthews, K.R. & Pope, K.L. (1999). A telemetric study of the movement patterns and habitat use of *Rana muscosa*, the mountain yellow-legged frog in a high-elevation basin in Kings Canyon National Park, California. *J. Herpetol.* **33**, 615–624.

Mauritzen, M., Bergers, P.J.M., Andreassen, H.P., Bussink, H. & Barendese, R. (1999). Root vole movement patterns: do ditches function as habitat corridors? *J. Appl. Ecol.* **36**, 409–421.

Noss, R.F. & Harris, L.D. (1986). Nodes, networks, and MUMs: preserving diversity at all scales. *Environ. Mgmt.* **10**, 299–309.

Powell, R.A. (1994). Effects of scale on habitat selection and foraging behavior of fishers in winter. *J. Mammal.* **75**, 349–356.

Powell, R.A. (2000). Animal home ranges and territories and home range estimators. In *Research techniques in animal ecology*: 65–110. Boitani, L. & Fuller, T.K. (Eds). New York: Columbia University Press.

Rondinini, C. & Boitani, L. (2002). Habitat use by beech martens in a fragmented landscape. *Ecography* **25**, 254–264.

Rondinini, C. & Doncaster, C.P. (2002). Roads as barriers to movement for hedgehogs. *Funct. Ecol.* **16**, 504–509.

de Sao, J.A., Rebelo, P., Prudentio, J., Ramalhinho, M.G. & Mathias, M. (2000). A comunidade de pequenos mamiferos associada a Ribeira dos Castelhanos (Herdade da Ribeira Abaixo, Gradola). *Rev. Biol. (Lisboa)* **18**, 83–95.

Semlitsch, R.D. (2000). Principles for management of aquatic-breeding amphibians. *J. Wildl. Mgmt.* **64**, 615–631.

Thomas, J.W., Maser, C. & Rodiek, J E. (1979). Riparian zones. In *Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington*: 40–47. Thomas, J.W. (Ed.). Washington D.C.: USDA Agricultural Handbook 553.

Vickery, J.A., Carter, N. & Fuller, R.J. (2002). The potential value of managed field margins as foraging habitat for farmland birds in the UK. *Agri. Ecosyst. Environ.* **89**, 41–52.

Virgos, E. (2001). Relative value of riparian woodlands in landscapes dominated with different forest cover for medium-sized Iberian carnivores. *Biodiv. Conserv.* **10**, 1039–1049.

Weber, D. (1989*a*). The ecological significance of resting sites and the seasonal habitat change in polecats (*Mustela putorius*). *J. Zool. (Lond.)* **217**, 629–638.

Weber, D. (1989*b*). Foraging in polecats (*Mustela putorius* L.) of Switzerland: the case of a specialist anuran predator. *Z. Säugetierkd.* **54**, 377–392.

Weber, D. (1989*c*). The diet of polecats (*Mustela putorius* L.) in Switzerland. *Z. Säugetierkd.* **54**, 157–171.

Zalewski, A. (1997). Factors affecting selection of resting site type by pine marten in primeval deciduous forests (Bialowieza National Park, Poland). *Acta Theriol.* **42**, 271–288.