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Landscape features in the habitat selection of European mink (*Mustela lutreola*) in south-western Europe

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Abstract

Habitat change is one of the main factors influencing the decline of the western population of European mink *Mustela lutreola*, but data on habitat selection are scarce. Landscape features influencing selection of habitat and resting sites of male European mink were studied using radio-tracking. None of the habitat descriptors accounted for the habitat selection of European mink during their activity periods. On the other hand, resting site selection was correlated with the presence of bramble patches. Intensive use of bramble patches is explained as a consequence of the need of mink for protection against predators. Moreover, the high availability of bramble patches provides the mink with easy resting sites.

Key words: European mink, *Mustela lutreola*, denning behaviour, bramble thickets, semi-aquatic carnivore, riverbank management, conservation, south-western Europe

INTRODUCTION

The European mink *Mustela lutreola* is a riparian mustelid native to the European continent whose distribution range has suffered a noticeable reduction over the last century. Whilst it has been present from the Pechora River basin in the east to the Iberian Peninsula, and from the tundra near Arcanghel to the Caucasus (Youngman, 1982), only two major populations have been reported in the second half of the 20th century (Youngman, 1982). One nucleus in Eastern Europe, where several sub-populations have been documented, has experienced further geographical range reduction. A second population can be found in Western Europe, which seems to be expanding southwards, whilst mink have disappeared from the northern part of its previous range (Youngman, 1982; Romanowsky, 1990; Palazón & Rúiz-Olmo, 1992; Tumanov, 1992; Maran & Henttonen, 1995; Maizeret *et al.*, 1998; Maran, Kruuk *et al.*, 1998; Sidorovich, 2000).

Although several factors have been conjured up to explain the shrinking range of European mink, habitat loss and degradation has been singled out as one of the most important factors for the decline of the species (Maran & Henttonen, 1995; Sidorovich, Savchenko & Bundy, 1995; Tumanov, 1996; Maran, Macdonald *et al.*, 1998; Lodé, Cornier & Le Jacques, 2001). Colonization by the American mink has also been postulated for the disappearance of the native mink in the eastern area, mainly as a result of aggressive physical interactions between the species (Maran, Macdonald *et al.*, 1998; Sidorovich, Kruuk & Macdonald, 1999; Sidorovich, 2000; Macdonald *et al.*, 2002). Nevertheless, the validity of this argument to explain mink distribution in the western nucleus has been recently questioned (Lodé *et al.*, 2001). In other studies, the potential hybridization with polecat (Davison, Birks, Griffiths *et al.*, 1999; Davison, Birks, Maran *et al.*, 2000) and the effects of isolation on genetic variability of populations (Lodé, 1999) have been suggested as underlying the regression of the species.

To our knowledge, no in-depth study has been conducted into the habitat selection of the European mink even though habitat change alone may have an important bearing on the current distribution and the decline of the species. Hitherto, only Lodé *et al.* (2001) has studied the relationship between habitat change and the regression of the European mink. Their findings suggest that the conjunction of intensive trapping, alteration of water quality and habitat modification were the critical factors explaining the decline of European mink in north-western France (Lodé *et al.*, 2001; Lodé, 2002).

Knowledge of the habitat use, especially of resting sites, of a species is paramount for its conservation. Indeed, it has been suggested that availability of suitable resting places may be a crucial factor in determining

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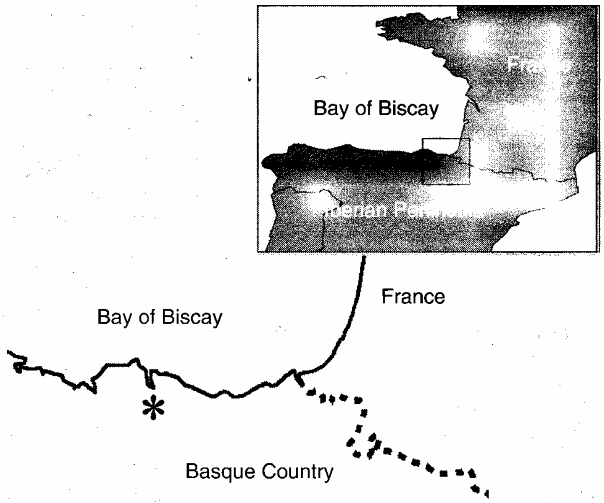

Fig. 1. Study area location.

the distribution and abundance of semi-aquatic mammals (Gerell, 1970; Birks & Linn, 1982; Weber, 1989; Dunstone, 1993; Halliwell & Macdonald, 1996; Stevens, Ashwood & Sleeman, 1997). However, available data on habitat use and resting sites of European mink are usually descriptive and vague.

The aim of this work was to determine the landscape features determining habitat selection by riparian European mink, with special stress on resting site selection. In addition, the possible implications of the observed habitat selection pattern for the conservation of this species are discussed.

STUDY AREA

The study was conducted at the Urdaibai Biosphere Reserve, Basque Country (south-west Europe) (Fig. 1). The Urdaibai Biosphere Reserve spreads over a whole basin (230 km^2); altitude ranges from 0 to 900 m. Climate is oceanic, annual rainfall ranges between 1200 and 1600 mm, and January and July average temperatures are 6 and 18 °C, respectively. Winters are mild and there is no effective snow cover.

The landscape is hilly and rugged; 61% of the land is forested, mainly with *Pinus radiata* and *Eucalyptus globulus* plantations. Native holm oak *Quercus ilex* forests are also common in rocky outcrops. Meadows and estuarine habitat occupy 34% of the area; the remaining 5% is an urban area with *c.* 45 000 inhabitants. The Oka, the main river and its tributaries show low pollution levels except near the main towns, where levels of nutrients and heavy metals are high (Department of Environment and Land Ordination, 2001). Upper parts of the streams are the least modified, and they usually have alder *Alnus glutinosa* and willow *Salix atrocinerea* gallery forests. Middle parts of rivers are most diverse, including well-preserved stretches as well as patches with exotic plantations and disturbed areas with heliophytic formations. Finally, the lower parts are the most modified, forested areas are rarer and, with the exception of some scarce well-preserved stretches, river bank vegetation is mainly composed of brambles *Rubus* sp. or it is absent (Navarro, 1980).

MATERIALS AND METHODS

Animals were live-trapped in single-entry cage traps (25 × 25 × 45 cm). Trapping sessions were carried out in streams from February 1999 to January 2000. After immobilization with 0.8 mg of Zooletil (Virbac, Carros, France) per 100 g of animal weight, animals were collared with radio-transmitters (Biotrack, Dorset, U.K.). Used radio-collars weighed *c.* 13 g (i.e. < 2% of animal mass), had an expected medium life of 6–7 months and their emission range was between 150 and 151 MHz. After radio-collaring, mink were released in concealed areas (bramble patches) and observed until they woke up and fled. During all the handling, mink were kept warm using rags to prevent hypothermia. Six adult males (M1–M6) were caught. No other stream-dwelling mustelid but European mink was caught (Zabala *et al.*, 2001). M4 died after capture and therefore, was not considered for analysis (Zabala *et al.*, 2001; Garin, Zuberogoitia *et al.*, 2002). A hand-held 3-element Yagi antenna and TRX-1000S receiver (Wildlife Materials Inc., Carbondale, U.S.A.) were deployed, usually on foot. Fixes were achieved by homing-in (White & Garrot, 1990) and located on a map to the nearest 100 m, to minimize cartographic error (Mech, 1986), and later transferred into a geographic information system (GIS). Animals were classified as either active or inactive according to the level of variations in radio signal strength (Kenward, 1987). M1 and M2 were tracked for 3 months, M5 and M6 for 6 months, and M3 for 7 consecutive months; tracking periods and home-range size are detailed elsewhere (Garin, Zuberogoitia *et al.*, 2002). M1 included marshes within his home range and was discarded because of the different landscape features defining his range. To avoid bias owing to data correlation, only 1 fix during the daytime rest and 1 at night, when mink become active, were considered for analysis (Aebischer, Robertson & Kenward, 1993). The daytime location was taken between 2 h after dawn and 2 h before dusk, whilst the night location was taken at least 1 h after the start of the activity period. Linear home ranges were calculated as metres of waterway used by mink with 95% of the locations (White & Garrot, 1990; Palazón & Rúiz-Olmo, 1993; Garin, Zuberogoitia *et al.*, 2002).

A set of 9 variables was selected describing habitat features and anthropogenic level (Table 1). These variables were chosen because they can potentially influence the habitat selection of small carnivores (Weber, 1989; Brainerd *et al.*, 1995; Genovesi & Boitani, 1997; Zalewski, 1997*a*,*b*). It has been stated that European mink prefer well-preserved streams with a high degree of forest cover (Youngman, 1982; Palazón, 1998; Sidorovich & Macdonald, 2001). Therefore, variables were also considered that described the forest cover and species diversity of the river shore. Finally, since anthropic

Table 1. Variables describing European mink *Mustela lutreola* habitat: bramble (*Rubus* spp.) cover, degree of bramble cover on the riverbank; riparian forest, degree of forest cover on the riverbank; forest cover, degree of forest area inside the polygon; cover of main species, degree of diversity in the polygon; river, characteristics of the river stretch in the polygon; main use, use given to land inside the polygon; meadows, grasslands as well as small crop cultures; road and path, paved roads and forest paths (m) included in the polygon, respectively; buildings, number of buildings that fall totally or mainly inside the polygon

Variable	Category (%)
Bramble cover	0–25
	26–50
	51–75
	76–100
Riparian forest	0–25
	26–50
	51–75
	76–100
Forest cover	0–33
	3.4–66
	67–100
Cover of main species	0–40
	41–100
River	Streams
	Stem river
Main use	Urban
	Meadows
	Forest cultures
	Autochthonous forests
	Others
Road	0
	1–150
	> 150
Path	0
	1–50
	> 50
Buildings	0
	1
	2
	3 or more

pressures are considered the main factor for European mink decline in neighbouring French study areas (Lodé *et al.*, 2001), variables were included that described the degree of human disturbance.

On the other hand, taking into account the riparian behaviour of mink and that 100% of their dens will occur within 25 m of a stream (Youngman, 1982; Dunstone, 1993; Palazón, 1998; Stevens *et al.*, 1997; Garin, Zuberogoitia *et al.*, 2002), a buffer area of 25 m was set at each side of river stretches within the home range of mink. Subsequently, it was subdivided into polygons of 100 m long each. The variables, bramble cover and riparian forest, were estimated in the field for each polygon. Values for the other variables were obtained with the aid of a GIS.

First, a principal components analysis (PCA) was performed as an exploratory tool to reject covariables (Kelt, Meserve & Lang, 1994; Morrison, Marcot & Mannan, 1998). The PCA identified variables that helped distinguish the plots (Morrison *et al.*, 1998). Components of the PCA with eigenvalues > 1 were retained for ecological evaluation (Kelt *et al.*, 1994; Morrison *et al.*, 1998). Afterwards, components with eigenvalues > 1 were tested against presence of mink using Spearman's correlation (Morrison *et al.*, 1998; Zar, 1999). Finally, to determine which variables controlled the resting site selection of the studied mink, a logistic regression analysis (LRA) was performed with the components that were correlated with mink presence after running Spearman's correlations (Morrison *et al.*, 1998). The LRA is a multivariate analysis that allows the inclusion of categorical variables (Ferrán, 1996). For the LRA, 20 polygons were randomly selected plus 8 more for each variable in the analysis, following the recommendations of Morrison *et al.* (1998). In total, 75 polygons were used for the LRA. The dependent variable was the presence/absence of mink, and independent variables were those selected by the PCA. The number of polygons with presence of mink in the 75 polygon sample used in the LRA was similar to that of the polygons where mink was never detected. Note that every polygon, both presence and absence polygons, were picked up within home ranges of mink. Therefore, after the classification of Johnson (1980) the habitat selection tested is third-order selection, or relative use of habitats within the home range (Johnson, 1980; Garshelis, 2000). The stepwise method is an exploratory tool that allows identification of the best predictors from the pool of potentially useful parameters (Ferrán, 1996). In this approach, variables are entered into the LRA individually provided that they fulfil certain requirements. The selection of variables ends when no further increase in the accuracy of the model can be achieved.

Afterwards, selection of classes within determinant variables after the LRA was tested using the χ^2 test corrected with Bonferroni's inequality (Manly, McDonald & Thomas, 1993), and electivity was assessed using Jacobs' index (Krebs, 1989); α value was 0.05 in all cases.

RESULTS

A total of 407 polygons within mink home ranges was characterized, and inactive mink were recorded 141 times in 83 of them. Resting sites were used twice (range 1–10 times). Mink used an average of 21 (range 16–29) different resting sites during the tracking period, and a media of 4.21 different resting sites per month (range 3.1–5.3); 91.3% of resting sites were located beneath bramble thickets. Other structures such as branch heaps or tree roots were used occasionally. Active mink were recorded 90 times in 69 different polygons. At night, most polygons were used only once (range 1–3 times, average 1.3). Each mink was located in an average of 17 different polygons at night (range 16–21).

The PCA classified nine components. The eigenvalue of the two first components was > 1 and explained 35% and 14% of the variation, respectively. Spearman's correlation was performed with these two components (Table 2) and activity and inactivity data. The first component was

Table 2. Composition of components of the PCA with eigenvalues > 1.0

	Composition of components	
	1	2
Bramble cover	−0.550	
Riparian forest	0.601	−0.312
Buildings	−0.481	
Road		0.704
Paths		
River		−0.711
Main use	0.886	
Forest cover	0.891	
FCCP	0.769	

Table 4. Resting site selection of male European mink *Mustela lutreola* assessed through the Jacobs' index

Variable	Class	Jacobs
Bramble cover	0–25%	−0.6620[a]
	26–50%	−0.3988[a]
	51–75%	0.1741
	76–100%	0.5423[a]
Main use	Urban	0.0911
	Meadows	0.1874[a]
	Forest cultures	−0.4614[a]
	Autochthonous forests	−0.0904
	Others	−0.6107[a]

[a] Values that reached statistical significance using Bonferroni's inequality.

correlated with both activity and inactivity data (activity: $r_s = -0.113$, $P < 0.023$; inactivity: $r_s = -0.26$, $P < 0.001$), whilst the second one was correlated with none (night: $r_s = -0.076$, $P < 0.128$; daytime: $r_s = -0.055$, $P < 0.266$). Therefore, LRA was performed (forward, Wald statistic) with the variables of the first component. For this purpose, a total of 75 polygons was randomly selected, following the recommendations of Morrison *et al.* (1998). No variable reached statistical significance during the activity period. On the other hand, the LRA selected two variables for the inactivity period: bramble cover and main use (Table 3). Only bramble cover reached statistical significance. However, the correlation between bramble cover and presence of mink during the inactivity period was low (6%). Therefore, although there is a close relationship between selected resting sites and bramble cover, the degree of bramble cover is not a good predictor of the presence of mink. Mink selected riverbanks with dense bramble patches in meadows, and avoided those with low cover of brambles or those located in forest and in the 'others' class (Table 4).

DISCUSSION

European mink at the Urdaibai Biosphere Reserve selected resting sites according to the availability of dense bramble patches. Small carnivores are susceptible to harassment and predation by larger members of their guild (Youngman, 1982; Lindström *et al.*, 1995; Maran, Macdonald *et al.*, 1998; Palomares & Caro, 1999; Sidorovich, Kruuk *et al.*, 1999; Sidorovich, Macdonald *et al.*, 2000), and especially by humans and their pets (Arambarri, Rodríguez & Belamendía, 1997; Palazón, 1998; Zabala *et al.*, 2001). Dense bramble patches provide not only thermal insulation but protect European mink effectively from humans and most carnivores. Mink are probably safer there than in burrows, because most of the animals listed above are capable of digging to chase mink inside burrows whilst they can hardly enter dense bramble thickets. The sole exception would be the American mink, which has a similar body size and, therefore, is capable of chasing European mink through brambles. However, as European mink flee when harassed by American mink (Sidorovich, Kruuk *et al.*, 1999), it would be easier to run away from a bramble patch than from an underground burrow when caught by surprise. Also, digging is an energetically demanding activity that is not likely to be carried out in all types of substrates (Neal & Cheeseman, 1996). Therefore, burrowing would not allow mink to use many resting sites and could constrain the size of home ranges (Garin, Zuberogoitia *et al.*, 2002).

Although the European mink has been reported to use bramble patches as resting sites more often than other semi-aquatic carnivores (Weber, 1989; Palazón, 1998; Stevens *et al.*, 1997), reported frequencies of bramble thicket use are not as exclusive as at the Urdaibai Biosphere Reserve (Table 5). The high number of resting sites used by mink and the low degree of fidelity shown at these sites are a consequence of the low energy cost of denning in bramble and the high availability of bramble patches (185 polygons out of 409 had > 50% of the shore covered by bramble). This also explains the low correlation between bramble patches and presence of mink. Therefore, although bramble cover is closely related to the resting habits of mink, it is not a good predictor of the presence of this species. On the other hand, as mink do not invest time or energy on burrowing, they can change dens

Table 3. Results of the LRA and predictive value of the models

Selected variable		Wald	Degrees of freedom	P	r	Predicts Presence (%)	Predicts Absence (%)	Predicts Total (%)
Activity	Bramble cover	3.2554	3	0.3539	0.000	67.65	100	85.33
Rest	Main use	10.9325	5	0.0527	0.0957	66.67	80.49	74.32
	Bramble cover	9.12.2021	3	0.0067	0.2467			

Table 5. Burrows of various mink species, after several studies. Figures are percentages with the exception of Gerell (1970) who does not provide numeric values. Sidorovich & Macdonald (2001) only gave data for use of beaver burrows, other values remaining uncertain

Species	Dense vegetation (Bramble)	Between roots	Holes/fissures/ burrows	Others	Reference
M. lutreola	56.1	14.6	19.5	9.8	Palazón, 1998
M. lutreola	22.2	0	28.8	49	Ceña *et al.*, 1999
M. lutreola	?	?	56	?	Sidorovich & Macdonald, 2001
M. lutreola	91.3	0	1	7.7	This paper
M. vison	7	42	44	7	Dunstone, 1993
M. vison	0	Most common	Second place	0	Gerell, 1970
M. vison	13	57	0	30	Stevens *et al.*, 1997
M. putorius	0	8	18.75	73.25	Weber, 1989
M. putorius	0	100	0	0	Brzezinski, Jedrzejewski & Jedrzejewska, 1992

often without sustaining severe energy cost. Furthermore, the European mink is known to show active bouts during diurnal resting periods (Palazón, 1998; Garin, Aihartza *et al.*, 2002), presumably to forage. As many rodents are active at daytime (Lodé, 1995), mink may feed safely on them within bramble patches.

Resting site selection by small carnivores has been explained as the effect of three non-mutually exclusive factors: protection against predators, thermal insulation and proximity to preferred feeding areas (Weber, 1989; Dunstone, 1993; Brainerd *et al.*, 1995; Lindström *et al.*, 1995; Halliwell & Macdonald, 1996; Genovesi & Boitani, 1997; Zalewski, 1997*a*,*b*; Larivière & Messier, 1998). The importance of protection against predators is stressed by our results, whilst the influence of the other two factors is difficult to determine. Thermal regulation plays an important role in resting place selection of small carnivores (Weber, 1989; Lindström *et al.*, 1995; Zalewski, 1997*a*). This holds true especially for semi-aquatic species, which tend to lose more heat owing to the enhanced conductivity of water (Chanin, 1993; Kruuk, 1995). Bramble patches on the ground provide poorer thermal insulation than burrows or other structures (Weber, 1989; Brainerd *et al.*, 1995; Zalewski, 1997*a*,*b*). The importance of thermal insulation on the selection of resting site changes seasonally, being paramount in winter, having little importance in spring and almost none in summer (Zalewski, 1997*a*,*b*). The mild winters and warm temperatures year round at the Udaibai Biosphere Reserve (minimum absolute value during the study period was −8 °C, and coldest temperatures averaged 2.4 °C) probably allow mink to use bramble patches without severe energy cost.

Although there are no data available on the diet of the European mink in the study area, Palazón (1998) reported that small mammals (mainly *Apodemus sylvaticus*), fish and birds contributed to mink diet in this order of importance. Diet studies from other areas also reported small mammals as an important part of the diet (*Microtus* spp., *Arvicola terrestris*, *Apodemus* spp. and *Clethrionomys glareolus*) (Sidorovich, 1992; Maran, Kruuk *et al.*, 1998). One of the main habitat requirements of those small mammals is the availability of dense vegetation patches such as bramble patches (Castién & Mendiola, 1989; Escala *et al.*, 1997; Ouin *et al.*, 2000). Considering that rodents mainly consume green parts of plants and fruits, and that some species thrive in agricultural areas (Castién & Mendiola, 1989; Garde & Escala, 2000), it can be assumed that their abundance will be higher in agricultural areas such as those included in the meadows category in our study area. Therefore, the selection of areas with dense bramble cover on meadows might be explained by their proximity to preferred feeding areas, such as has been shown for other species such as American mink, polecat or pine marten (Weber, 1989; Dunstone, 1993; Brainerd *et al.*, 1995).

Mink did not show any habitat preference during their activity periods. This could be a consequence of a lack in habitat preferences. Alternatively, mink may actually have habitat preferences during their foraging bouts, but our set of variables was not adequate to describe them. One such factor could be food availability. Indeed, activity and habitat selection of semi-aquatic carnivores are known to be related to prey availability and to change seasonally in relation to prey activity (Lodé, 1994, 1995, 2000; Bonesi, Dunstone & O'Connell, 2000). Nevertheless, precise data on mink diet as well as on food supply are lacking at the study area, and thus, the importance of those factors cannot be assessed.

Resting site availability is of importance for the ecology and distribution of semi-aquatic carnivores (Gerell, 1970; Birks & Linn, 1982; Weber, 1989; Dunstone, 1993; Halliwell & Macdonald, 1996; Stevens *et al.*, 1997). Moreover, an animal may not use a resource if the risk associated with its use exceeds the gains. Therefore, a high availability of resting sites may enhance efficiency in the exploitation of the home range. Some food resources exploited by mustelids are distributed in patches, their availability being different along the home range (Macdonald, 1983; Lodé, 1994; Halliwell & Macdonald, 1996; Bonesi *et al.*, 2000). Moreover, individuals use different parts of their home range in relation to their food availability (Macdonald, 1983; Lodé, 1993; 1994; 1995; 2000; Halliwell & Macdonald, 1996; Bonesi *et al.*, 2000). Extensive bramble cover at the Urdaibai Biosphere Reserve may provide safe places almost across the whole of the mink's home range, thus favouring the efficient use of most food patches.

Furthermore, resource concentrated in patches with no bramble thicket or similar structures providing mink with safe areas to move, hunt, handle prey and rest, might not be actually available, as the risk of using them may exceed the possible benefits.

Lodé *et al.* (2001), suggested that changes in water quality and habitat alteration are among the main factors influencing the decline of European mink in the western population. In this sense, the survival chances of the mink may be affected by the depletion of the vegetation cover used for resting, even though quality of water is improved. Therefore, efforts made to improve water quality could achieve limited success unless efforts are made to preserve and restore riverbanks. Riverbank management experiments and policies are needed to understand the importance of cover availability for European mink and to guarantee conservation of this elusive carnivore.

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