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Factors affecting occupancy by the European mink in south-western Europe

Facteurs affectant l'habitat du vison en Europe sud-occidentale

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Abstract

The European mink is an endangered species in need of urgent conservation efforts, but whose decline and habitat requirements are only poorly known. In this study we developed a model for mink distribution in Biscay to catalogue variables influencing its presence/absence. Sites were described in terms of vegetation parameters, water quality, riverbank alteration, anthropogenic structures and American mink presence. Logistic regression analysis was used to identify ruling variables and synergies. The model extracted two variables of high significance: water quality and riverbank alteration. European mink was absent from polluted waters and canalised streams. The absence is explained by a decrease in prey availability. In the case of water pollution, bioaccumulation is considered to have a deleterious effect on the presence of the species. In the case of canalisation, the lack of adequate shelter areas and especially the depletion of food resources are also likely to play an important role explaining the absence of the species. Finally, the possible barrier effect of canalisation for European mink and its consequences are also discussed. For the remaining variables, only those describing habitat use by European mink within its home range seemed to have a little influence on the presence of the species. The presence of American mink was a poor predictor of the absence of its European counterpart. Based on the results, we suggest that improved riverbank management policies are needed to ensure the future of European mink in the area. Species introduction and reintroduction programs should consider our habitat model when searching for suitable areas for the species. Further research is also needed on the effect of diverse types of water pollution on European mink.

Keywords: American mink, *Mustela vison*; competition; conservation; European mink, *Mustela lutreola*; fragmentation; habitat; management; water quality.

Résumé

Le vison européen est une espèce protégée qui nécessite une conservation urgente mais dont les raisons de sa disparition et ses exigences biotiques sont très peu connues. Dans la présente étude, nous avons développé un modèle pour l'étude de la distribution du vison à Biscay dans le but de cataloguer les variables qui influencent sa présence ou son absence. Les sites ont été décrits sur la base des paramètres de la végétation, de la qualité de l'eau, de l'altération des berges de rivières, de l'influence de la présence humaine et de celle du vison américain. Nous avons ensuite réalisé une analyse de régression logique qui nous a permis déterminer les mécanismes de variation et les synergies. Deux variables se sont révélées fortement significatives: la qualité de l'eau et l'altération des berges de rivières. Le vison européen a été absent dans les sites à eaux polluées et à rivières canalisées. Cette absence a été justifiée par la faible disponibilité des aliments dans ces sites. Le cas d'une pollution des eaux due à une bioaccumulation est considéré comme pouvant avoir un effet négatif sur le nombre d'espèces présentes. Dans les cas des canalisations, le manque d'abris et l'épuisement des ressources alimentaires pourraient probablement être un facteur important dans l'explication de l'absence des espèces. Finalement, la possibilité de l'effet de barrière de la canalisation sur le vison et ses conséquences ont également été discutées. En ce qui concerne les autres variables, seules celles qui décrivent le vison européen le long d'un gradient d'utilisation de l'habitat semblent avoir une faible influence sur la présence des espèces. La présence du vison américain s'est révélé être un mauvais indicateur de l'absence de son analogue européen. Nos résultats suggèrent qu'une amélioration de la gestion de l'aménagement des rivières est nécessaire afin d'assurer la conservation du vison européen dans la zone d'étude. Les programmes d'introduction et de réintroduction du vison européen devraient considérer notre modèle d'habitat dans la recherche d'un espace convenable pour les espèces. En outre, des recherches ultérieures sont nécessaires afin de déterminer les effets des différents types de pollution de l'eau sur le vison européen.

Mots cles: compétition; conservation; fragmentation; gestion; habitat; qualité de l'eau; vison américain, *Mustela vison*; vison européen, *Mustela lutreola*.

Introduction

The European mink *Mustela lutreola* Linnaeus is a riparian mustelid native to the continent. It has experienced severe regression, resulting in two major population nuclei (Youngman 1982; Macdonald et al. 2002). Although no single factor has been identified as being responsible for the decline in the whole area, habitat loss and degradation and interspecific relationships with the American mink *Mustela vison* Schreber are usually pointed out as possible causes (Maran and Henttonen 1995; Macdonald et al. 2002). Potential hybridisation with polecats (Davison et al. 1999, 2000) and the effects of isolation on genetic variability of populations (Lodé 1999; Michaux et al. 2004) have also been considered among other minor hypotheses. Several conservation plans have been drawn up as a consequence of this drastic regression, including captive breeding programs and reintroduction trials on islands (Maran 1996; Macdonald et al. 2002).

Although habitat loss and degradation are considered two of the main causes of decline in most studies, these effects have been poorly studied (Maran and Henttonen 1995; Macdonald et al. 2002). In some areas they have been regarded as important causes of population decline in the past, but not currently (Macdonald et al. 2002). This is quite surprising, since changes in habitat quality are the main threat to world biodiversity, including carnivores (Wilcove et al. 1998; Sunquist and Sunquist 2001). The decline in European mink has mainly been studied in the eastern part of its range, where the American mink has been suggested as the reason for the disappearance of native mink from some areas, a hypothesis based on aggressive physical interactions observed in captivity-held experiments (Sidorovich et al. 1999; Macdonald et al. 2002). Interestingly, the only work conducted in the western part of its range reviewed the decline of the species in north-western France in the last decades of the 20th century and concluded that a combination of intensive trapping, changes in water quality and habitat alteration were critical for the decline in the area (Lodé et al. 2001). Moreover, Lodé (2002) states that trapping should not be a cause of decline at present owing to the current protection status of European mink.

Knowledge of the habitat requirements of a species is of paramount importance for its conservation. Overlooking key variables can lead to inadequate definitions of the problems, inadequate solutions, and continued losses (Clark et al. 2001). Habitat use and selection are the result of several processes that take place at different scales. Johnson (1980) defined four orders of habitat selection, ranging from the selection of a large geographical area to microhabitat selection. Interestingly, the same species may select different features at different scales or orders (Johnson 1980; Garshelis 2000). Johnson's second-order habitat selection (selection of the home range site in the available area) provides a good insight into the factors ruling the presence/absence of a species, and indeed has been used to describe distribution patterns of carnivores and other species at intermediate spatial scales (Carroll et al. 1999; Madsen and Prang 2001; Manel et al. 2001; Schadt et al. 2002). Moreover, the use of adequate statistical techniques may help in understanding regression causes with a focus on the possible incidence of synergies.

The aim of this paper is to study occupancy at the home range level of the European mink through a reliable statistical procedure to develop a predictive model of the factors responsible for the presence/absence of the species and therefore of its current regression, including possible synergies. The results should represent a basic tool for forthcoming introductions and reintroductions of the species, as well as stream management and improvements.

Materials and methods

Study area

The study was conducted in Biscay, Basque Country (SW Europe). Biscay is 2236 km^2 and its population is approximately 1.2 million inhabitants. The landscape is hilly and rugged, and altitudes range from 0 to 1475 m a.s.l. (Gorbea Peak). The climate is oceanic, with annual rainfall ranging between 1200 and 2200 mm, and annual average temperatures varying from 18.3°C to 12°C. Winters are mild and there is no summer drought. There are several short, small and fast-flowing catchments running into the Bay of Biscay. Streams show different degrees of pollution, ranging from heavily polluted to clean waters. Major infrastructures such as roads and villages run along valleys and some riverbanks have been altered and partially canalised. The upper parts of the streams are the least modified of all, and usually there are gallery forests of alder (*Alnus glutinosa*) and willow (*Salix* sp.) on the banks. The middle parts of the rivers are the most diverse, including well-preserved stretches, stretches forested with exotic plantations, disturbed areas with heliophytic formations, and canalised stretches. Finally, the lower parts are the most modified, rarely showing forested areas and, with the exception of some scarce well-preserved stretches, riverbank vegetation is mainly composed of brambles (*Rubus* sp.) or is absent (Navarro 1980). Several lower reaches are canalised. In the urban areas, land is mostly devoted to forest cultures, mainly exotic *Pinus radiata* and *Eucalyptus globulus*, which occupy more than half of the surface of Biscay (Department of Environment and Land Ordination 2001).

The European mink is known to inhabit Biscay since 1960, occupying most of the area and with only small gaps in its distribution (Rodríguez de Ondarra 1963; Zabala and Zuberogoitia 2003a). On the other hand, some American mink are known to be present in the area, mostly escapes from fur farms, with the oldest report of a feral American mink dating back to 1993 (Zuberogoitia and Zabala 2003b).

European mink distribution

To determine the distribution of the European mink, we conducted an extensive live-trapping survey over the whole area, with over 3500 trap-nights in major catchments of the study area. Traps were set in trapping stations of 4–6 traps and kept operative for 5 days. Trapping stations were at least 3 km apart and regularly distributed along the main streams and the principal tributaries. Trapping was conducted throughout the whole area in winter 2004–2005 because this season of the year provides the highest number of captures (Zabala et al. 2001).

We also gathered all records of European mink available for the previous 3 years (2001–2004), chiefly from other extensive distribution studies, local studies, radiotracking data and road kills, which were used to check and complete the distribution pattern. Finally, to double check the presence/absence data, we conducted an extensive sign survey simultaneous to the trapping. We considered the European mink as absent from catchments where no mink was trapped, no previous data on mink presence were available and where no signs of mink were observed. On the other hand, we considered the European mink as resident in catchments where we captured mink or at least other data (previous captures, road kill eradication of troublesome animals, reliable sightings) were available for the area.

Sample unit design

Since riparian mink activities are closely related to streams (Dunstone 1993; Garin et al. 2002a), a buffer area of 25 m was identified on both sides of river stretches, which were then subdivided into polygons of 100 m long to create homogeneous sample units (Zabala et al. 2003). To ensure that areas characterised as positive from single data records were included in the actual European mink home ranges (i.e., to avoid bias due to possible gaps in distribution areas), we created a confidence range based on knowledge of the ecology of the species from one of the catchments considered (Garin et al. 2002a,b; Zabala et al. 2001, 2003; Zabala and Zuberogoitia 2003b,c). For this purpose, we assumed that European mink activities are randomly distributed along the home range (Zabala and Zuberogoitia 2003c). Then we randomly selected a set of points within known home ranges (Garin et al. 2002a; Zabala et al. 2003) and compared a set of distances (100, 200, 300, 400, 500 m, and so on) measured upstream and downstream from the randomly selected points with the distances actually included in the home range. Thus, we defined the confidence interval for the distance that can be considered as included in the home range of an animal measured upstream and downstream from a random location. This comparison showed that distances of 500 m on both sides could be considered as included in the home range, because there were no statistical differences among the comparisons (Table 1). Therefore, we characterised 500 m upstream and downstream of the 13 European mink capture points for a total of 130 units for which the presence of European mink was indicated. In the same way, we identified 23 points regularly distributed along the seven catchments without European mink and created 230 sample units. In total, we created 360 sample units that were equally distributed across the whole area along the main rivers and large tributaries. Third-order streams were not considered (i.e., neither as positive nor as negative data sources) for the study because they are steep, torrential and of scarce entity (Elosegi et al. 2002).

Variable selection

To characterise the polygons, we selected a set of eight variables describing vegetation, impact of human activities and other factors that have been suggested as possible causes of the decline of the European mink (Table 2). From a set that can potentially influence the habitat selection of small carnivores, we considered those retained for analysis in a previous work after running exploratory analyses at other habitat-use order, *sensu* Johnson (1980) (Zabala et al. 2003). On the other hand, since human activities are considered the main factor for European mink decline in neighbouring French study areas (Lodé et al. 2001; Lodé 2002), mainly through water pollution and habitat loss, we included descriptors of the degree of water pollution and riverbank alteration. Finally, considering that interactions with the alien American mink have been proposed as the main cause for the current decline in Eastern Europe (Sidorovich et al. 1999; Macdonald et al. 2002), we also included the presence of American mink as a variable.

The variables bramble cover, riparian forest and riverbank alteration were estimated in the field for each polygon. Riverbank alteration was classified as five categories. The first two are representative of well-preserved streams; the category “altered” included rivers with a certain degree of intervention, but in which the natural substratum has not been changed and vegetation is still present. Streams that had been canalised, with building of an artificial bed of rocks that allows a certain degree of vegetation growth, were classified as canalised, as well as rivers that were contained within concrete walls, but including some metres of natural shore. Finally, streams running along concrete canals were classified as aggressively canalised. The presence of American mink was ascertained from captures obtained during the extensive live-trapping study conducted for this work and data published by Zuberogoitia and Zabala (2003a). For each catchment, the American mink was recorded as present where there were captures, established populations and/or breeding individuals. American mink were considered rare in catchments where there are sporadic data on the species, probably dispersive individuals, and absent in catchments where there were no captures and no records of presence for the previous 5 years (1999–2004). Data on water pollution were provided by the Department of Environment and Land Ordination of the Basque Government. Owing to the characteristics of streams, data from sampling at a single point in time

Table 1 Comparison with Wilcoxon’s text and Student’s t-test for matched samples between distances measured upstream and downstream from a random point inside European mink home ranges and actual distances included in the home range.

Distance (m)	500	1000	1500	2000	2500
Wilcoxon’s z	-1.6	-2.37	-2.8085	-3.1	-3.412
Significance	0.11	0.02	0.005	0.001	0.001
Student’s t	-1.7	-2.8	-3.8	-4.6	-6.1
Significance	0.1	0.01	0.001	0.001	0.001

Table 2 Variables describing stretches.

Variable	Category
Bramble cover	0–25%
	26–50%
	51–75%
	76–100%
Riparian forest	0–25%
	26–50%
	51–75%
	76–100%
Forest cover	0–25%
	26–50%
	51–75%
	76–100%
Riverbank alteration	Natural
	Slightly altered
	Altered
	Canalised
	Aggressively canalised
American mink	Absent
	Rare
	Present
Pollution	Clean waters (>120)
	Unpolluted waters (101–120)
	Critical quality (signs of pollution) (61–100)
	Polluted waters (36–60)
	Very polluted waters (15–35)
	Extremely polluted waters (<15)

Bramble cover indicates the degree of bramble cover on the riverbank. Riparian forest indicates the degree of forest cover in the riverbank. Forest cover indicates the forested area inside the polygon. Riverbank alteration indicates the degree of human intervention on the riverbank in the polygon. Presence of the American mink was treated as "present" when stable populations were known in the area, "rare" when individuals were sporadically detected in the area, and "absent" when no American mink was detected in the area in the previous five years. Pollution indicates the water quality according to BMWP categories, with BMWP scores in parentheses. Road and Buildings variables were not categorical, but considered as the total length of paved roads inside the polygon in metres, and the number of buildings that fell totally or for the most part inside the polygon.

should not be considered as representative of the year-round conditions (Elosegi et al. 2002). Thus, we used Biological Monitoring Working Party scores adapted for Spain (BMWP′) that do not represent the status of the river during the sampling period, but rather the overall status of the watercourse. BMWP scores were summarised into six categories. Values for the remaining variables were obtained with the aid of a geographic information system.

Statistical analyses

To determine which variables explained the presence of the European mink, we performed logistic regression (LR) with all variables using the forward Wald stepwise method (Morrison et al. 1998), which is a type of multivariate analysis that allows the inclusion of both categorical and parametric variables (Ferrán 1996). For LR we randomly selected 20 polygons plus 8–10 more for each variable in the analysis, following the recommendations of Morrison et al. (1998). In total, we used 108 polygons for LR, for which the dependent variable was the binary variable presence/absence of European mink. The number of polygons with presence of mink in the 108-polygon sample used in the LR was similar to that of the polygons from areas where European mink was absent (56 presence and 52 absence polygons). Polygons were randomly selected, extracting one from each catchment at a time to minimise problems of spatial pseudo-replication. The stepwise method is an exploratory tool that allows identification of the best predictors from a pool of potentially useful parameters (Ferrán 1996). In this approach, variables are entered into the LR individually, provided that they fulfil some requirements. The selection of variables ends when no further increase in the accuracy of the model can be achieved. The main drawback of presence-absence models used in ecology is that results are affected by the prevalence of the target species (Pearce and Ferrier 2000; Manel et al. 2001). To overcome problems based on reliance on the prediction success, understood as the performance of the model, the area under the curve (AUC) for the receiver operating characteristic (ROC) has been proposed as an alternative approach to measure discrimination capacity (Pearce and Ferrier 2000; Manel et al. 2001). AUCs measured for ROCs are independent of prevalence and highly significantly correlated with the easily computed Cohen's κ (Manel et al. 2001); therefore, we calculated Cohen's κ to evaluate the models.

The selection of categories within the variables produced by the LR was tested using the χ^2 test corrected with Bonferroni's inequality (Manly et al. 1993). Electivity was assessed using the Jacobs index (Krebs 1989), and the α value was 0.05 in all cases.

On the other hand, since there is always a certain degree of covariance among variables, a single datum could be explained by several variables categorised in the model. Therefore, in areas other than Biscay with different characteristics, some of our explanatory variables could be of little relevance or act at different levels. Thus, to assess the relative importance of the different hypotheses for regression of the autochthonous species in the study area, we constructed a table assessing the explanatory power of variables considered individually. We first performed LR with no variables and based on a constant that predicts that every datum will have a negative value (i.e., absence of mink) to assess the explanatory power of a model without variables or a constant-based model (CBM). Then we modified the LR requirements to include variables in the model regardless of their statistical significance and performed LR for variables that have been proposed as important for the presence-absence of the species (Maran and Henttonen 1995; Lodé et al. 2001; Lodé 2002; Macdonald et al. 2002; Zabala et al. 2003). For each LR, we considered the explanatory power of the target variable and calculated the increment in explanatory power relative to the CBM and Cohen's κ value as indicators of the performance of the variable. For this purpose, since the CBM considers every datum as negative and the proportion in the model of negative and positive data is balanced, we calculated the performance of the variable by subtracting the explanatory power of the CBM from that of the variable-based model and multiplying the output by two. We assumed that the variable correctly classifies positive and negative data, but only the change in positive data is observed owing to the characteristics of the CBM. Finally, we also considered the statistical significance of the variable and Cohen's κ for the model. When there was no significant relationship between the variable considered and the presence-absence of the European mink, Cohen's κ's values were not considered. Independent of the model for the study area considering every variable, the purpose of this last analysis is two-fold: first, it represents a tool to identify management practices, and second, it can help in assessing the importance of different variables in the decline of the species.

Results

We conducted more than 3500 trap-nights in streams of the study area, capturing 16 European mink in six different catchments and 18 American mink in three different catchments. In addition, we considered other 300 trap-nights from non-extensive studies, three European and three American mink road kills, and captures of four problematic American mink that were causing damage in poultry farms. Areas inside home ranges of the European mink were determined by radiotracking in three of the catchments, while areas in the other three catchments were obtained following the procedure described in materials and methods. The presence of European mink in catchments where no radiotracking was conducted has also been reported in previous studies (Palazón et al. 2002), so individuals were assumed to be residents. Seven catchments were considered not to harbour European mink because trapping yielded no results, there were no previous records of European mink, and we found no signs of mink presence during the track surveys.

LR created a two-step model (Table 3). Water pollution was included in the first, and riverbank alteration in the second. Both steps reached statistical significance for Cohen's κ, which showed an increase in values at each step (Table 3).

We analysed the influence of these two variables using the χ^2 test corrected with Bonferroni's inequality and via the Jacobs index. European mink were present in clean-water streams and absent from polluted streams (Table 4). No polygon with extremely polluted water was found within the home ranges of European mink, and thus could not be tested after Bonferroni's inequality, but this doubtless has biological significance. On the other hand, mink also avoided canalised streams, preferring natural or slightly altered waters (Table 4). Intermediate values for both categories were used when available.

Finally, among the series of LRs performed with single variables (Table 5), only the variables pollution, riverbank alteration, bramble cover and riparian forest were significantly related to the presence of the species. Of these, the first two had the best predictive performance and were included in the model. Other variables, such as American mink presence, did not reach statistical significance. In addition, the model performance tested with Cohen's κ was statistically significant in several cases, but not for forest cover, buildings, roads and American mink (Table 5), suggesting that these variable are of scarce importance in explaining the presence of European mink at the study scale.

Discussion

Our model explained the absence of European mink from catchments mainly on the basis of water pollution and the degree of canalisation. Both features imposed constraints on the presence of European mink, but the effect was not absolute, i.e., mink were also present in areas with some unfavourable features. The model did not con-

Table 3 Results of the linear regression and predictive value of the model at each step.

Step	Variables included	Wald	d.f.	p	Correctly predicts (%)			Cohen's κ	Approx. κ significance
					Presence	Absence	Total		
1	Pollution	24.173	5	0.001	76.4	88.7	82.4	0.649	0.001
2	Pollution	17.584	5	0.004	84.9	94.5	88.8	0.796	0.001
	Riverbank alteration	11.213	4	0.024					

Table 4 Variables influencing the presence of European mink assessed through the Jacobs index.

Variable	Category	Jacobs index
Water pollution	Clean waters	0.49*
	Unpolluted waters	0.25
	Critical quality (signs of pollution)	-0.07
	Polluted waters	-0.57*
	Very polluted waters	-0.62*
	Extremely polluted waters	-1.00
Riverbank alteration	Natural	0.37*
	Slightly altered	0.19
	Altered	-0.53*
	Canalised	-0.62*
	Aggressively canalised	-0.78*

*Values reached statistical significance after using Bonferroni's inequality (note that -1 Jacobs values cannot be tested with Bonferroni's inequality).

Table 5 Performance of several variables after running a single-variable linear regression.

Variable	Correctly predicts (%)	Increment In explanatory power (%)	Significance*	Cohen's κ	κ significance
Constant (model without variables)	50.9	0.0	0.847	0.219	0.310
Bramble cover	69.4	37.0	0.001	0.386	0.001
Riparian forest	65.7	29.6	0.012	0.310	0.001
Forest cover	55.6	9.4	0.401	0.105	0.245
Buildings	58.3	14.8	0.069	0.083	0.096
Roads	53.7	5.6	0.097	0.033	0.724
Riverbank alt.	78.7	55.6	0.001	0.572	0.001
American mink	51.9	2.0	0.935	0.025	0.728
Pollution	82.4	63.0	0.001	0.649	0.001

Values are approximate. *Statistical significance of the relationship between the variable considered and the presence-absence of European mink. Cohen's κ measures the probability of the model being a consequence of chance for variables not related to European mink presence; see the text for further details.

sider bramble cover, which was among the variables identified at the lowest order of selection (Zabala et al. 2003).

European mink were absent from every polluted water course, while they seemed to actively select clean waters. In some cases, European mink were present in stretches of polluted or even highly polluted waters, but such areas were always close to the river's mouth and thus are marginally represented in home ranges. A similar pattern was found by Lodé (2002) in France, where mink avoided poor-quality watercourses. Lodé (2002) suggested that prey loss and bioaccumulation may explain this distribution pattern. Indeed, the latter factor has been singled out as one of the possible causes of the regression of the species elsewhere (Maran and Henttonen 1995; Lodé et al. 2001; Lodé 2002). BMWP scores were designed to evaluate the degree of organic pollution. They show little sensitivity to seasonal effects, as opposed to other indexes, but reflect the effect of diverse types of pollution (Zamora-Muñoz et al. 1994; García-Criado et al. 1999; Clarke et al. 2002). Therefore, it is difficult to speculate which change or changes in water quality and food availability might actually represent the low BMWP scores and how they might affect European mink. López-Martin et al. (1994) found important quantities of polychlorinated biphenyl compounds in European mink tissues. Although we cannot reach definitive conclusions on the deleterious effects of pollution and which factors might be influencing the absence of European mink, we suggest that bioaccumulation might play an important role, as in other areas (Lodé 2002).

Regarding food, the diet of European mink is variable among study areas and poorly known in the Iberian Peninsula. However, Palazón et al. (2004) pointed out that fishes account for 30% and amphibians for 1.5%. Interestingly, amphibians are the main prey item of the European mink in Belarus, with an important presence of fish and crayfish (Sidorovich 2000). These prey species might be absent from areas with the worst BMWP values, as well as from areas with low BMWP scores. Lodé (2002) found that in France, the European mink occupied watercourses showing better fishing quality either in salmonid or cyprinid water courses. However, relationships between low BMWP scores and fish availability are difficult to assess. We propose that the effect of water pollution should be an important research topic for future studies on European mink conservation.

The second variable highlighted by the model is the degree of canalisation of watercourses. Again there was clear rejection of altered watercourses, while less managed ones were used according to availability. Canalisation negatively affects European mink in a variety of ways. Prey availability and accessibility to den and resting sites are basic requirements for European mink. Watercourse canalisation implies the complete destruction of riverbank vegetation and substitution of the riverbed geological substratum by hard materials such as concrete or rocks. Consequently, mink cannot burrow or use roots or dense riverbank bramble patches as den or resting sites. Moreover, high availability of such structures has been related to within-home range habitat use of the European mink, and to safe and efficient exploitation of resources (Zabala et al. 2003; Zabala and Zuberogoitia 2003b). Canalisation also implies a severe change in the riparian mosaic. By changing the riverbed natural substratum into concrete canals or flat bedrock systems, refugia for fish, crayfish and other prey are eliminated (Oliva-Paterna et al. 2003). The creation of artificial straight banks implies the destruction of bogs and pools at the riverbank and adjacent areas, which depletes suitable foraging and spawning areas for amphibians. Finally, removal of riverbank vegetation and isolation of the shores from the surrounding areas might drastically reduce rodent, bird and amphibian availability by the river side (Escala et al. 1997; Zuberogoitia and Torres 2002; Carter and Bright 2003). Thus, food and habitat availability for aquatic organisms becomes reduced. Although the mink diet is variable, it is likely that the species cannot thrive in areas with no aquatic food at all. If canalisation is combined with polluted watercourses, mink probably face both a lack of food and the adverse effects of bioaccumulation of toxicants, which may eventually drive the species out.

Although there were several polygons that included canalisations or altered riverbanks within European mink home ranges (Table 4), these areas were short in length and related to infrastructures such as bridges, roads, railways or buildings crossing or adjacent to streams. On the other hand, canalised areas where mink were absent were long stretches of as much as 5–6 km. Lodé (2002) considered that polluted watercourses may act as barriers for mink dispersal; however, provided that riverbank vegetation is preserved, polluted streams could act as valid corridors for dispersal of animals, though not as breeding or foraging areas. The effect of canalisation on habitat degradation is further increased by depleting refuges, as discussed above. Therefore canalised areas are not only not suitable for European mink, but probably also act as barriers for dispersion and create gaps in the distribution of the species. Finally, canalisation related to roadway crossings and similar structures within European mink home ranges probably also have a deleterious effect by enhancing the probability of road kills (Grogan et al. 2001). Taking into account that mink activities are linked to the linear nature of catchments (Youngman 1982; Garin et al. 2002a; Zabala et al. 2003) and that poor between-habitat connectivity precludes the dispersal of medium-sized carnivores (Ferreras 2001), it is reasonable to conclude that canalisation of rivers is a major threat to the persistence of the European mink.

Lodé et al. (2001) estimated the importance of several factors on the decline of European mink by analysing historical data, and their findings suggest that intensive trapping, changes in water quality and habitat alteration are the critical factors explaining the decline in northwestern France. Interestingly, the last two factors are the main explanatory causes for the current absence of European mink in catchments in Biscay, which might support our model. Therefore, regardless of their possible role as causes of historic declines, they seem to be the main factors causing the current decline in European mink populations in densely populated areas of Western Europe. On the other hand, Lodé et al. (2001), among others (Tumanov 1992), state that competition with American mink cannot be the main cause for the decline in France, disagreeing with the results of most studies conducted in Eastern Europe (Sidorovich et al. 1999; Macdonald et al. 2002). Interestingly, our model did not consider the presence of American mink as a predictor for the absence of its European counterpart (Table 3). Furthermore, American mink presence was one of the variables with the lowest performance in our series of exploratory LRs (Table 5), it was not related to the presence-absence of European mink, and the model based on this parameter did not reach statistical significance. Therefore, American mink should not be considered as the only major concern in the area. Moreover, after water pollution and habitat degradation it could be regarded as a second-order problem for the persistence of the native species at a catchment scale. However, this possibility still requires further analysis and studies in areas less modified than Biscay and at fine-grained scale, studying the effect of American over European mink where they coexist in the same catchment, where it could be a major threat. Notwithstanding, it is possible that the American mink takes advantage of weakened, upset or extirpated European mink populations to take over new areas. For instance, once habitat degradation has reduced European mink numbers, the American counterpart (with smaller home ranges producing denser populations and being more generalist regarding habitat and diet; Sidorovich 2000; Sidorovich et al. 1998, 2001) may take advantage of the narrower habitat requirements of the former to take over. However, a note of caution is needed here, since the consequences of the introduction of American mink may not have yet run their full course (Macdonald and Thom 2001).

Table 5 shows that of the variables not included in the model, bramble cover and riparian forest are the variables that best predict European mink presence. Interestingly, these are among the variables determining the next-lower order of habitat use for the European mink, i.e., within-home range habitat selection (Zabala et al. 2003; Zabala and Zuberogoitia 2003a). Logically, variables that determine a given habitat selection order also influence the habitat selection of related orders, although only at a second level of importance.

Rivers and river systems are ecosystems of paramount importance for humankind. In our study area, as in all of Western Europe, they are used for water, energy, food and transportation and also provide fertile soils, whilst they represent potential hazards such as flooding (Elosegi et al. 2002). Therefore, they are intensely managed ecosystems supporting increasing pressure. In these areas, the future of the endangered European mink is linked to proper management of the streams in which it dwells. This particularly involves water quality improvements and sensitive riverbank management and improvement. Introductions of the species to new areas had been tried, paying special attention to presence-absence of American mink (Maran 1996; Macdonald et al. 2002), several captive breeding programs have been launched, and some reintroductions are likely to take place in the near future. These and other conservation programs would benefit by considering empirical evidence discussed in this paper and in Zabala et al. (2003), because the final success of reintroduction projects depends mainly on the habitat quality of the release area (Breitenmoser et al. 2001).

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