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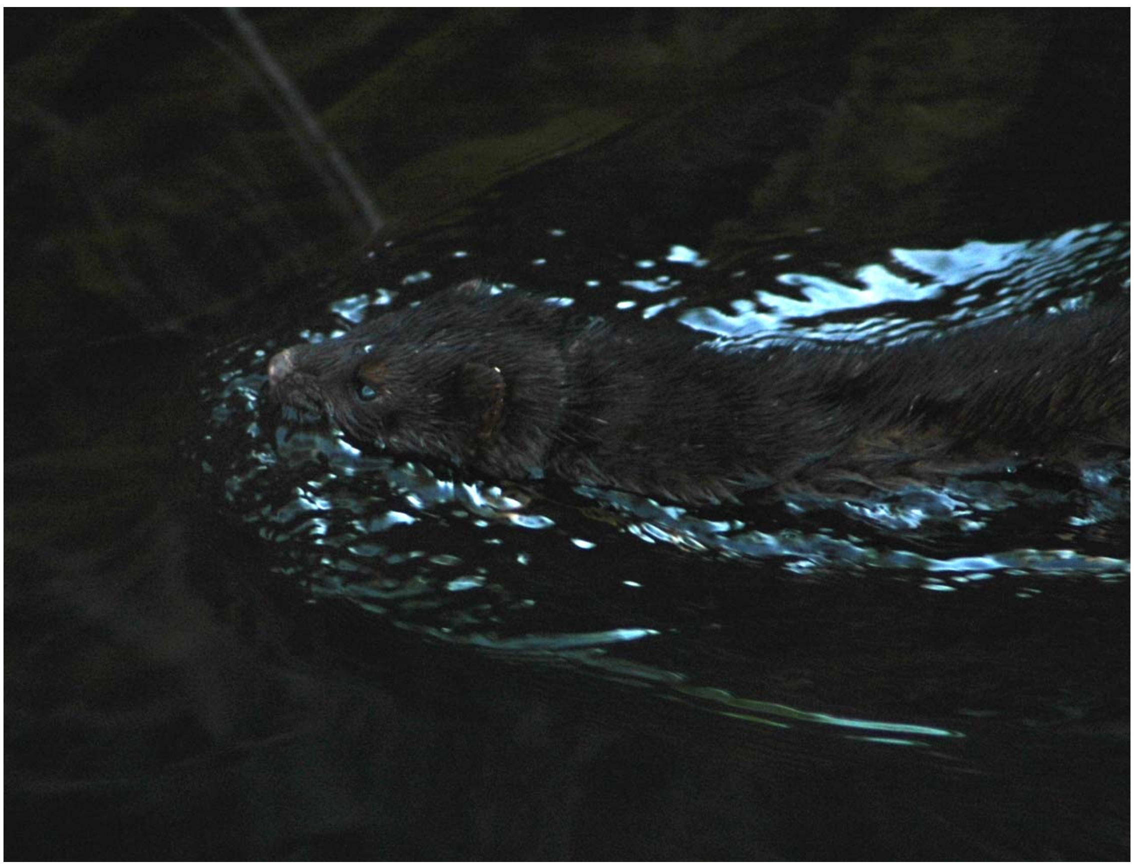
DISTRIBUTION AND SPATIAL ECOLOGY OF SEMI-AQUATIC MUSTELIDS (CARNIVORA: MUSTELIDAE) IN BISCAY.



Jabi ZABALA ALBIZUA.
Ph.D. THESIS.
Leioa March 2006

To A. A. E.

and Unkas,
and the unnamed others

Do not follow the tracks of the forbears
But search
What they searched after.

(Japanese Hai-ku)

INDEX

PROLOGUE

This work consists on a collection of published papers and others submitted for publication. The order in which they appear herein is neither the order in which they were published nor the one in which they were written. Therefore, there may be some evolution in the ideas or changes in terminology along the work that reflect changes in ideas and improvement in knowledge we had along the years of study. The papers are not the result of a research project but the outcome of different studies, many of them self-financed, directed towards concise goals of a research programm held in mind. Each chapter is, in some cases slightly modified, a fresh research paper, with the sole exception of chapter 2 in which I had merged two already published papers. Therefore, although they form a coherent and cohesive corpus, each chapter was thought to be independent, readable and understandable on its own. Because of it, I kept the format of a scientific article in each chapter, in spite of some having similar paragraphs in the introduction or common references in literature. Unfortunatelly, lack of funding and research support set aside many ideas that would have much improved this work and also the knowledge of the studied species and opportunities for theyr management and conservation.

This PhD deals with ecological aspects of semi aquatic mustelids in Biscay. The guild of semi aquatic mustelids was originally composed by three species the otter (*Lutra lutra*), the European polecat (*Mustela putorius*) and the European mink (*Mustela lutreola*). The otter disappeared in the 80's from the Biscayan rivers and, in turn, the American mink (*Mustela vison*) was introduced. So there is no chapter devoted to otters whereas many deal with American mink. In the first chapter we review the distribution of European mink in Europe based on published records and we give our interpretation of the data, and in the second we study with more detail the distribution of both mink species in Biscay. Chapters 3, 4 and 5 are devoted to habitat issues of European mink at different scales. Chapters 6 and 8 are studies on habitat of American mink while chapter 7 is a study of spacing patterns and intersexual competition. Chapter 9 is a GIS based model of fragmentation and dispersion of European mink populations in Biscay, and a model of American mink expansion. Finally, the last chapter, chapter 10, is a brief study of polecat's habitat in the area analysing the scanty data of the species available.

CHAPTER 1*

Changes in the distribution of the European mink (*Mustela lutreola*) with special regard to south-western Europe.

ABSTRACT

Since most works on distribution of European mink in the Iberian Peninsula have been published in local papers or remain as unpublished reports, it is difficult to determine the current distribution of the European mink and to assess historical changes on its distribution. In this paper, we analyse data on the distribution of the European mink in the Iberian Peninsula and we conclude that, since it was first reported, the European mink has been slowly but steadily expanding its range across the Iberian Peninsula, mainly southwards but recently also eastwards and, possibly westwards.

* Originally Published as: Zabala, J., Zuberogoitia, I. and Martinez-Climent, J. A. 2004. The historical and current distribution of the Iberian population of the European mink (*Mustela lutreola*). Lutra 47 (2): 101-112.

INTRODUCTION

The European mink (*Mustela lutreola*) is a riparian mustelid native to the European continent that once inhabited the most part of Europe (Youngman 1982). During the second half of the 20th century its distribution range shrank severely, and mink disappeared from most of its range (Youngman 1982, Maran and Henttonen 1995, Romanowsky 1990, Maran et al. 1998b, Sidorovich 2000). As a result of this decline, there are two major populational nuclei nowadays: one in the East (Maran and Henttonen 1995, Tumanov 1992), and another in the West.

In the Eastern part of its range mink have disappeared from most countries in the last decades, and in areas were it is still present its population continues to decline (Maran and Henttonen 1995, Maran et al. 1998b). Even if no single factor has been identified as responsible for the decline, recent studies point out the American mink as responsible for the decline of its European counterpart, at least in some regions (Maran et al. 1998a, b, Sidorovich 2000, Sidorovich et al. 2000).

The situation is quite different for the western population. Mink disappeared from Brittany and Pays de Loire (France) in 20 years, between 1977 and 1997 (Lodé et al. 2001). Nowadays, the European mink still occupies the south of the country, approximately half of the area occupied before 1997. The underlying cause to the decline seems to be the anthropic pressure upon the species. (Maizeret et al. 1998, Lodé et al. 2001). On the other hand, the situation of the south-western population is intriguing because the species seems to be expanding southwards. Nevertheless, data are inconclusive (Maran and Henttonen 1995, Palazón and Rúiz-Olmo 1992, Torres and Zuberogoitia 1997, Macdonald et al. 2002).

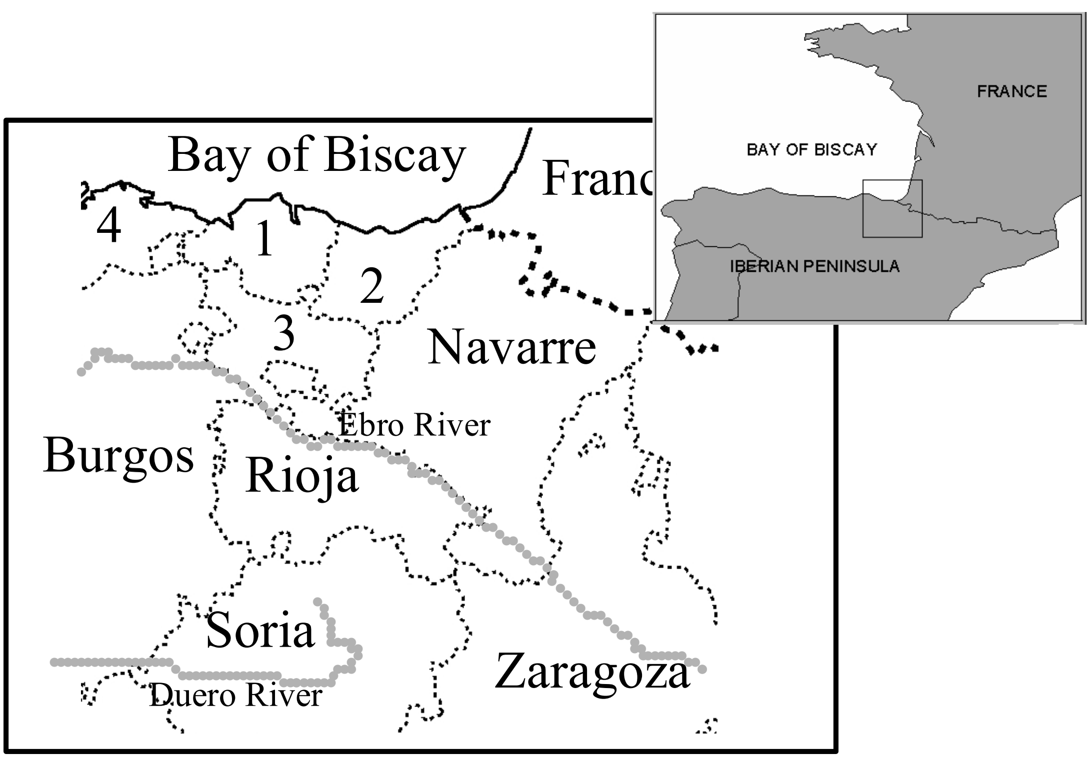
Most studies on the status and distribution of the European mink in the Iberian Peninsula focus on small regions, are published in local journals or remain as unpublished reports. Therefore, the current distribution, status and trends are difficult to assess. This has lead to confusion and in some cases to misunderstandings both in local and international publications, with some papers presenting “wrong” data.

In this paper we review the available information on the European mink in the Iberian Peninsula. The aim of the paper is to assess distributional changes of the European mink in the Iberian Peninsula, population trends, and the origin of the species in this area. Two alternative hypotheses are considered: 1. the European mink has reached the Iberian Peninsula in the 20th century, and 2. it has always been part of the Iberian fauna, but went unnoticed until the last century, when increased interest among researchers prompted the collection of new records.

MATERIALS & METHODS

This study reports on data from the northern Iberian Peninsula (figure 1). In the regions of Biscay, Gipuzkoa, Cantabria and north-western Navarre, the climate is oceanic. Annual rainfall ranges between 1200 and 2200 mm, winters are mild and there is no aestival drought. In those regions streams are short, small and fast flowing, running into the Bay of Biscay (Flores 1989, Walter 1997).

Figure 1: Map of the study area including the major rivers. 1 Biscay, 2 Gipuzkoa, 3 Araba and 4 Cantabria.



The climate of the southern regions (Soria, Rioja and Southern Navarre and Burgos) is Mediterranean. Winters are rainy and summers dry, and there is a marked contrast between winter and summer temperatures. In this area streams run towards two majors rivers: the Ebro, which flows eastwards to the Mediterranean Sea, and the Duero, which flows westwards to the Atlantic Ocean. Some small streams may disappear due to the summer drought (Walter 1997).

We consulted a total of 22 works dealing with the distribution of European mink on the Iberian Peninsula, mostly international and local papers or books not widely available. Consulted works were: Rodríguez de Ondarra (1955, 1963), Puente (1956), Blas Aritio (1970), Senosiain and Donazar (1983), Castién and Mendiola (1985), Rúiz-Olmo and Palazón (1990), Palazón and Rúiz-Olmo (1992, 1997), Palazón (1993), Illana (1994), Torres and Zuberogoitia (1996, 1997), Arambarri et al. (1997), Ahiartza et al. (1999), Belamendia (2001), Ceña et al. (2001), Gonzalez-Estaeban et al. (2001), Palazón et al. (2002), Zabala et al. (2001), Zuberogoitia et al. (2001), Zabala and Zuberogoitia (2003a).

Table 1: Type of data considered reliable or not reliable.

Data source	Reliability
Trapping data	Reliable
Photographic data	Reliable
Road kills, hunted or stuffed animals	Reliable
Observations and presence reports	Depending on source: Scientists or naturalists of renown reliable. Others not reliable
Inquests	Not reliable
Indirect reports (not from the author)	Not reliable

These papers deal with different areas, at different scales and, often use different methods. Therefore, the discussion is coarse-grained in order to provide a general overview. We evaluated the reliability of each paper in relation to the methods used and the effort made to detect the species. In this sense, works were thoroughly revised and those based on live-trapping data, road kills, trigged cameras or similar techniques that involve the handling of the animal, or provide secure proof of its presence were considered. Works based on observations were only considered when these were made by professional researches or well known naturalists (Table 1). Other works were not considered, but nevertheless are discussed individually.

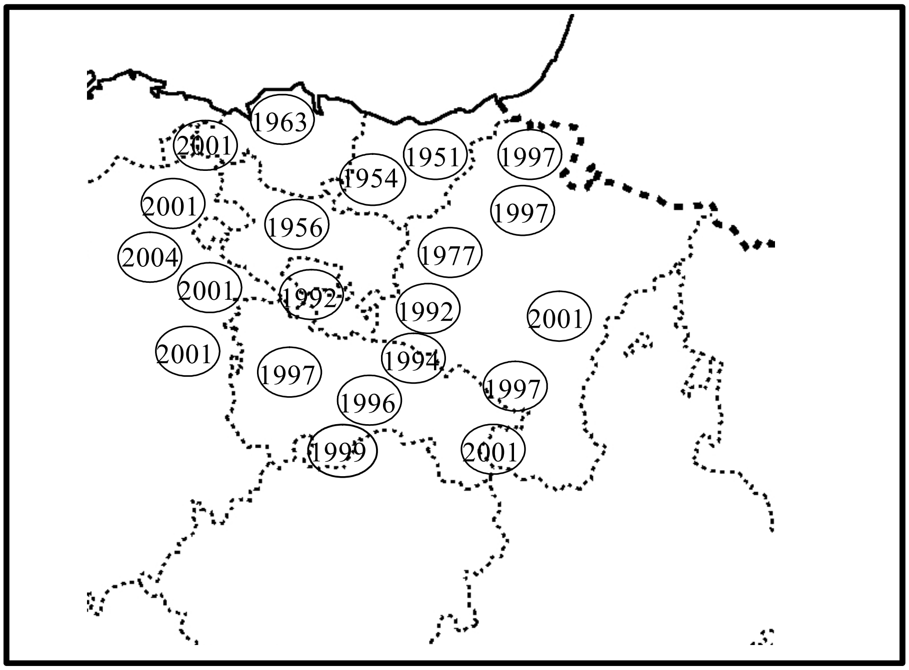
RESULTS

The first data of European mink in the Iberian Peninsula date back to 1951 (Rodríguez de Ondarra 1955). The author provides data of three mink captured between 1951 and 1952 at two locations in Gipuzkoa (figure 2). By 1956 the presence of the species into the nearby region of Araba is reported (Puente 1956). In 1963, new locations in Gipuzkoa and Araba are given, as well as the first data in two locations of Biscay and one in Navarre, near the border with Gipuzkoa (Rodríguez de Ondarra 1963). Senosiain and Donazar (1983) confirm the presence of the species southwards (Navarre) based on road-kills between 1977 and 1982. Castién and Mendiola (1985) report the presence of the populations observed in Gipuzkoa, oriental Biscay and central Araba. Presence of European mink in these areas is confirmed by several authors (Palazón and Rúiz-Olmo 1992, Palazón 1993, Illana 1994, Arambarri et al. 1997, Aihartza et al. 1999, Ceña et al. 2001, González-Esteban et al. 2001, Zabala et al. 2001, Zuberogoitia et al. 2001, Zabala and Zuberogoitia, 2003a).

Blas Aritio (1970) reports European mink in western Cantabria based on indirect data from trappers.

Palazón and Rúiz-Olmo (1992) report new European mink locations in Navarre, thus expanding its known range southwards, towards the Ebro River. Palazón (1993) shows similar results for the mink population in central Araba. By 1997, the presence of European mink in large areas of the Ebro River and La Rioja is documented (Torres and Zuberogoitia 1996, Arambarri et al. 1997, Palazón and Rúiz-Olmo 1997). Before 1994 the species was unknown in La Rioja, and during this year a trapping study revealed it in the area (Torres and Zuberogoitia 1996). A few years later, road kills and illegally shot individuals were reported (Torres and Zuberogoitia 1996). The last results show higher densities at those sites where the first mink were trapped (Ceña 2003).

Figure 2. Data for the Iberian Peninsula of first record of European mink in each area.



At the same time, in 1990 there is a single record of mink in Catalonia in the Ebro delta (Rúiz-Olmo and Palazón 1990), and by 1992 there are another two possible data, but the later are not sure (Palazón and Rúiz-Olmo 1992). This record is far away from the European mink's distribution area and has not been explained neither confirmed afterwards. The authors speculate about a possible long distance migration of a single mink or of some individuals (Rúiz-Olmo and Palazón 1990).

Finally, by 1999 the presence of the European mink in Burgos and Northern Soria as well as first data from the catchment of the Duero river are reported (Palazón et al. 2002).

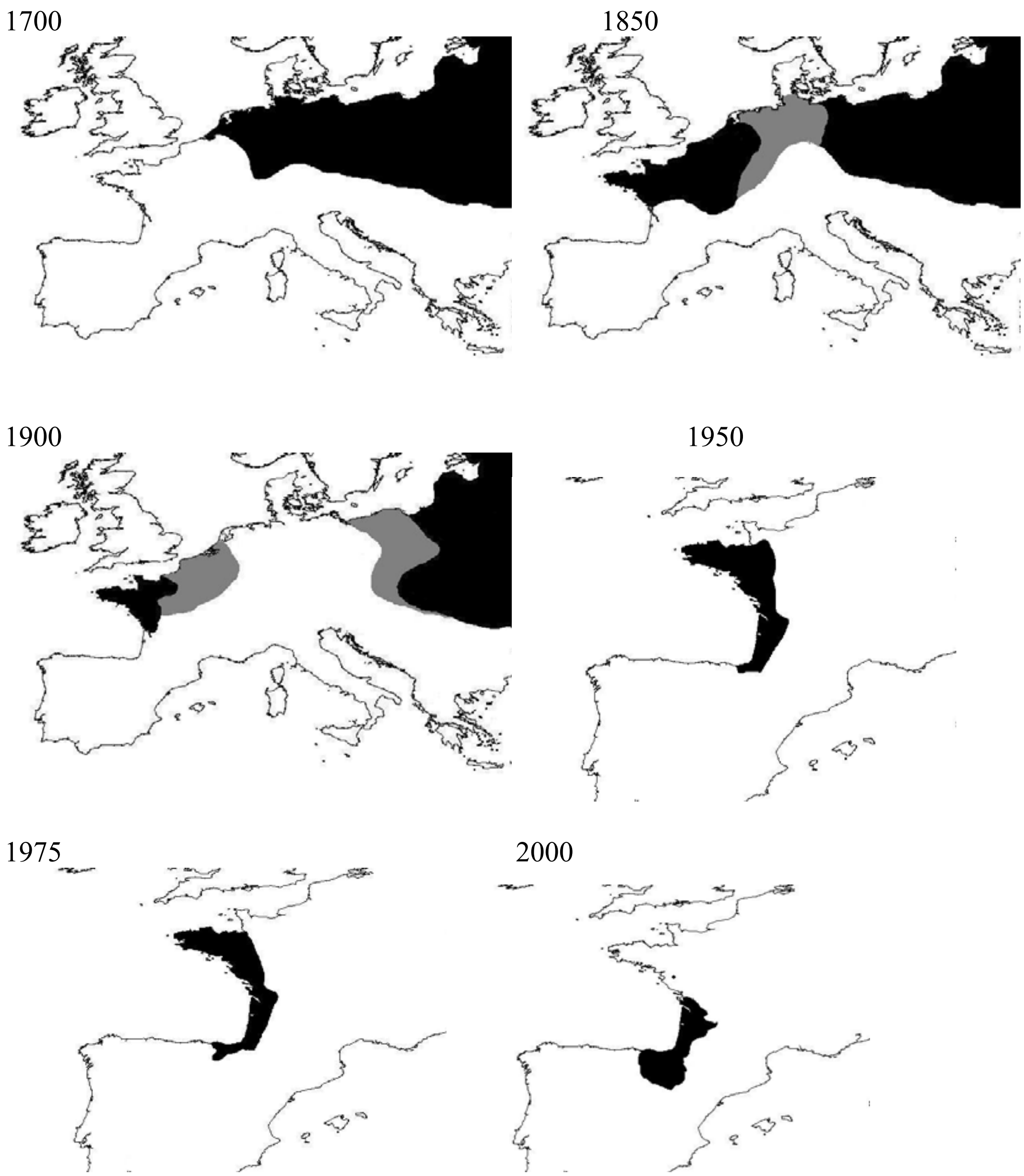
DISCUSSION

Did European mink colonise the Iberian Peninsula?

Although there is no scientific basis to reject none of the hypotheses on the historical distribution of European mink on the Iberian peninsula, the information considered suggests that the species first reached Iberia around 1950 (Zabala and Zuberogoitia, 2003b).

There are no records of European mink in the area before 1951, even though the presence of commercially valuable furbearers are among the first species to be recognised by local hunters, trappers and naturalists (Youngman 1982). Although there are no data available for the intensity of trapping in the past, it is known that it was quite common, practised not only by trappers but also by farmers, who regard most mustelids as pests. Indeed, the first European mink known in the study area was captured by a fur-trapper and it was submitted to naturalists for a thorough identification, because the species was unknown to trappers. It turned out to be unknown to naturalists as well (Elosegi pers. Com.). Subsequent reports of European mink are based on trapped and hunted individuals (Rodríguez de Ondarra 1955, 1963, Puente 1956, Blas Aritio 1970, Senosiain and Donazar 1983). In this way, Rodríguez de Ondarra (1963) gathered data about more than 35 mink captured between 1951 and 1958 in the Basque Country, which probably account for a small part of the total hunted. There are neither road kills nor other kind of "lateral" data before 1951, which are still nowadays a major source of information (see Belamendia 2001, Zabala and Zuberogoitia 2003a, Maizeret et al 2002) and no fur nor cranial sample of European mink is available from the study area before 1951. Moreover, during the late XIX and the early XX centuries the Iberian fauna attracted the attention of several naturalists who described many subspecies for the Iberian Peninsula, including two subspecies of stoats, two of weasels, one polecat, one stone marten, and several small mammals (see Garcia-Perea and Gisbert 1997). Thus, it is unlikely that the European mink went unnoticed. Besides, changes in the knowledge of the distribution of the species show a consistent pattern of expansion south-westwards matched with an extinction front in the east-north area (see Figure 3). Therefore, we suggest that the European mink reached the Iberian Peninsula in the late 1940's, as has been stated before by most authors (Rodríguez de Ondarra 1955, Youngman 1982, Senosiain and Donazar 1983, Aihartza et al. 1999, Zabala and Zuberogoitia 2003b). In addition, based on the same reasons and given the increased fieldwork effort from the 90's onwards, we consider that data of the first record of the species is, approximately, indicative of the time of colonisation of new areas by the species.

Figure 4. Changes in known European mink distribution. Black areas indicate known European mink presence, shaded areas indicate where mink was recorded as rare or disappearing at that time. Maps have been built after Youngman 1982, Saint-Girons 1994, Lodé et al. 2001, Maizeret et al. 2002, Palazón et al. 2002 and Zabala and Zuberogoitia 2003a.



Indications for an expanding population

The European mink has been slowly but steadily expanding southwards as shown by the fact that it was first reported in the area in 1951 (Rodríguez de Ondarra 1955) (figure 2). Eastward expansion is also supported by the colonisation of the Ebro River tributaries (Senosiain and Donazar 1983, Palazón and Rúiz-Olmo 1992, 1997). The European mink reached its western distribution limit by 1963 (Rodríguez de Ondarra 1963) and only recently there are indications of a further westward expansion (Zuberogoitia et al. 2001, Zabala and Zuberogoitia 2003a). Despite the introgression of some American mink populatuions (Ceña et al. 2001, Zuberogoitia et al. 2001, Palazón et al. 2002), the presence of European mink has been confirmed at coarse-grained spatial scales. Interestingly, the authors found a road killed European mink at Burgos in the summer of 2004 (Fig. 2), in an area where the species had not been previously detected in spite of the fact that trapping had been conducted there (for the last map on the species' distribution see Palazón et al. 2002). The only outlier in this distributional pattern is the record from Catalonia reported by Ruiz-Olmo and Palazón (1990), which is some 400 km away from its current distribution area. Bowman et al. (2002), suggest that the dispersal distance of mammals is isometric to the linear dimension of their home range multiplied by a constant that ranges from 7 to 40. The home ranges of male European mink in the study area are about 13 km wide (Garin et al. 2002), which would, according to the model of Bowman et al. (2002), enable dispersion distances of 90 – 520 km. Such distances cover the referred gap between the main areas and the Catalonia record. In fact, the authors themselves speculate with that possibility (Ruiz-Olmo and Palazón 1990, Palazón and Ruiz-Olmo 1997). Another problem regarding the distribution is the presence of European mink in Cantabria reported by Blas Aritio (1970). The trappers from the area recorded two types of polecat. One of these, which was considered by the referred author to be a European mink, had a darker coat. However, since the presence of mink there has not been confirmed neither by captures, road kills or examination of old material, and the author was based on indirect reports of trappers we do not consider these records as valid. Moreover, polecats are known to have a dark phenotype that is usually confused with the European mink's (Lodé et al. 2001), which seems to be common in the north of the Iberian Peninsula (Zuberogoitia et al. 2001).

Interestingly, in a recent genetic research on the species including populations from south-western Europe, Michaux et al. (2004) found very low intraspecific genetic variability in mtDNA for European mink, which is consistent with the hypothesis of an expanding population. Moreover, European mink from France and Spain lack almost completely in genetic variation, suggesting that the population was established by a few individuals, possibly even by a single female (Michaux et al. 2004). However, an early Holocene origin is also possible, with some long distance migrants from a refugium establishing the population (Michaux et al. 2004). Moreover, studies based on mtDNA and microsatellites concluded that there is a negligible genetic variability between the European mink populations from France and Spain, the most probable explanation being a severe bottleneck or the consequence of a founder effect. This is in agreement with the probable absence of mink in the area before the XIX century (Cabria et al. 2003, Gómez-Moliner et al. 2003).

The colonisation of the Iberian Peninsula in the late 1940's would coincide with, and possibly be a consequence of, a period of high population density in the neighbouring France, judging from the large number of specimens from France deposited in museums during that time (Youngman 1982).

Possible explanations

How can we explain the recorded population expansion on the Iberian Peninsula? Factors limiting a species' distribution may be abiotic or biotic, such as competition. Among the former it is difficult to single out one as responsible for the distribution, current or past, or for the changes in distribution. Indeed, the European mink distribution spreads currently across Eurosiberian and Mediterranean biogeographical areas of Europe, with very different in climate conditions (Walter 1997, Palazón et al. 2002). Among the biotic factors, whilst competition with the American mink is suggested as the cause for the decline in Eastern Europe (Macdonald et al. 2002), the suggested underlying cause in France seems to be the anthropic pressure upon the species. More precisely, the conjunction of intensive trapping, alteration of water quality and habitat modification (Lodé et al. 2001, Lodé 2002).

Besides, based on experiments conducted in captivity, interspecific relationships with polecat (*Mustela putorius*) have also been proposed (Schröpfer et al. 2001).

Data on water quality are scarce in the study area. It seems that there has been a slight improvement in the last years, at least in some areas, and there are also some policies favouring the use of natural fertilisers and regulating the use of pesticides, which could favour the presence of mink in some rivers. Having being just recently implemented, it is unlikely that they could had a major bearing in explaining the recent expansion of mink (Consejería de Agricultura, Ganadería y Desarrollo Rural de La Rioja 2000, Departamento de Ordenación del Territorio y Medio Ambiente del Gobierno Vasco 2001, Arluziaga 2002, Departamento de Agricultura, Ganadería y Alimentación del Gobierno de Navarra 2003). Nevertheless, changes in landscape and land use are known to influence the distribution of predators, especially of habitat specialists like the European mink, and intensification of agricultural practices is supposed to be one of the reasons for its historic and current decline (Lodé et al. 2001, Macdonald et al 2002, Robinson and Sutherland 2002, Schadt et al. 2002). In the Basque Country, agricultural practices have experienced a severe regression, especially during the 1980's and 1990's, in favour of forest cultures that currently occupy a 54% of the surface (Departamento de Ordenación del Territorio y Medio Ambiente del Gobierno Vasco 2001). However in a study on the habitat selection of the European mink conducted there, it was found that mink avoided forests and forest cultures, preferring meadows and small orchards (Zabala et al. 2003). In La Rioja, on the other hand, there are no clear tendencies in land use changes. There has been an expansion of agricultural lands and forest cultures since 1996 (of a 2% and 16% respectively), whilst meadows have been reduced by a 23% of their previous area (Consejería de Agricultura, Ganadería y Desarrollo Rural de La Rioja 2000). In Navarre, finally, there has been only minor changes. From 1991 to 2000, areas devoted to agriculture have been reduced by a 4%; meadows and pastures experienced a regression of a 9% and forest cultures expanded by a 1%. (Departamento de Agricultura, Ganadería y Alimentación del Gobierno de Navarra 2003). The overall pattern in land use is variable among areas (table 2), and its possible influence in the expansion of mink is difficult to assess. However, in areas where expansion seems to have occurred in the last decade, like Navarre and La Rioja, there has been no significant change in land uses. The only exception could be the reduction of pastures and meadows in La Rioja area (Consejería de Agricultura, Ganadería y Desarrollo Rural de La Rioja 2000), but no single study has pointed out possible benefits of the reduction of this habitat for the European mink. The few studies conducted hitherto on the habitat selection of the European mink stress the importance of some riverbank structures such as bramble thickets (Zabala et al. 2003, Zabala and Zuberogoitia 2003 c). Some changes in agricultural practices and intensity as a result of the abandonment of rural areas in the last decades may be an important cause favouring the expansion of the European mink in the Iberian Peninsula. Moreover, riverbank protection policies have been developed, with different intensity in different areas, which could affect the expansion of European mink. Another practice whose importance is difficult to assess, but undoubtedly has had an effect is the indiscriminate use of poisons that was also common in the past. This has been also pointed out as an important factor modelling the current distribution of some carnivores in the area (Aihartza et al. 1999). However, the law 4/1989 of the 27th of March of 1989 forbade these practices, and it is noticeable that, for instance in Araba, since 1988 there is no data on trapped, not live-trapped, individuals (Arambarri et al. 1997). Even if this last factor seems too weak to explain the expansion, it is likely, however, to have had at least some beneficial effects for the species.

Table 2: Percentage on main land uses in the main territories of the European mink distribution area (adapted from Consejería de Agricultura, Ganadería y Desarrollo Rural de La Rioja 2000, Departamento de Ordenación del Territorio y Medio Ambiente del Gobierno Vasco 2001, Departamento de Agricultura, Ganadería y Alimentación del Gobierno de Navarra 2003).

Land Use	Agriculture	Pastures & Meadows	Forests & Forest cultures	Others
Basque Country	14	19	54	13
Navarre	34	25	30	11
La Rioja	32	22	27	19

Finally, intragild effects can be discussed. There are some American mink populations in the Iberian Peninsula, the oldest of them dating back to the late 1950's or the early 1960's. By the 1990's American mink were present in several areas of the Iberian Peninsula, especially in the north, including areas already occupied by the European mink (Bravo and Bueno 1999, Zuberogoitia et al. 2001). Therefore the expansion of both species is synchronic and the observed pattern can not be a consequence of the presence/absence of the American mink, since there are areas relatively well preserved where both mink are absent. Moreover, the westernmost distribution area of the European mink in Biscay lies besides the well preserved streams of Cantabria were no mink is known, whilst both mink species are present in the less well preserved rivers of Biscay (Bravo 2002, Zabala and Zuberogoitia 2003a, Zuberogoitia and Zabala 2003). On the other hand, the American mink has been detected in some areas occupied by the European mink, and there seem to be local extinctions of the European mink (Ceña et al. 2001, Zuberogoitia et al. 2001, Palazón et al. 2002). Regarding polecats, little is known on their ecology in the Iberian Peninsula. However it is distributed across most of the European mink area and locally it may reach fair densities (Virgós 2002), Moreover some studies point out that this mustelid may not behave as semi-aquatic in the area (Zuberogoitia et al., 2000; Virgós 2002). Moreover, the polecat is common in the neighbouring French area, where it is regarded as a pest (Lodé et al. 2001), and it is not considered as a cause for the decline of the European mink there (Lodé et al. 2001). Finally, these two factors, and especially interspecific aggressive relationships with the American mink, could explain the regression, or rather the braking of the expansion rather than influence the expansion itself.

Conclusions

In conclusion, even if we can not definitively reject the hypothesis that the European mink is an old part of the West-European fauna, and probably we will never be able to do so, there are strong indications that the European mink is a recent arrival to the area. We can not currently present a conclusive cause or explanation for this phenomenon as none of the causes argued for its decline (or abiotic factors) changes markedly among the areas where the European mink is present/absent. Zabala and Zuberogoitia (2003a) state that the European mink extended recently its distribution westwards in Biscay, therefore the expansion could be still an ongoing process and this could be one reason for the absence of explanatory variables.

Further research:

Further research is needed in order to check for a possible expansion into nearby areas and determine which causes may have favoured such expansion. Among the needs for research, genetics might play an important role by determining the origin of the western population in space and time, and by confirming or rejecting the expansion proposed in this paper. Research on land uses and policies that could benefit the presence of European mink at landscape scale would help understand changes in the distribution. It would be interesting to determine the potential distribution area for the species, identifying areas liable to colonization, and check them periodically, especially in the borders of known distribution areas, to find out whether expansion is still going on. Finally, studies on mink pathologies could help understand the decline or the absence from some historically occupied and nowadays apparently suitable but unoccupied areas in Europe.

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CHAPTER 2†

Current and historical distribution of European mink (*Mustela luteola*) and the American mink (*Mustela vison*) in Biscay.

ABSTRACT

First records of European mink in Biscay date back to 1963. Since then its distribution underwent no important changes until recent colonisation of western Biscay. Recently, European mink surveys have been carried out in the Basque Country using line-trigged camera systems, and in Biscay using live-trapping. Results are contradictory suggesting respectively a reduction of the distribution in Biscay and an expansion westwards.However, this seems to be an artefact due to different performances of European mink detection techniques. In the same way, data of feral American mink date back to 1993 although first wild populations may have settled earlier. American mink is settled in three coastal catchments and expanding to adjacent ones. We provide a distribution map for the species considering every existing data, and we stress the need for a systematised methodology for European mink surveys.

† Adapted and updated from: Zabala, J. and Zuberogoitia, I. 2003. Current and historical distribution of European mink (*Mustela lutreola*) in Biscay. Evolution and comments of the results. Small Carnivore Conservation **28**: 4-6. & Zuberogoitia, I. and Zabala, J. 2003.Aproximación a la distribución del visón americano en Bizkaia. Galemys 15: 29-35.

INTRODUCTION

The European mink (*Mustela lutreola*) is a riparian mustelid native to the continent. Its distribution experienced a severe regression during the second half of the 20th century and disappeared from most countries (Youngman 1982, Maran and Henttonen 1995, Maran et al. 1998a). As a result of this decline, nowadays, there are two major populational nuclei: one in the East, (Maran and Henttonen 1995, Tumanov 1992), and other in the West. The eastern population is still in regression (Maran and Henttonen 1995, Maran et al. 1998b); mink has disappeared from some countries in the last decades, and it continues declining in areas where is still present (Romanowski 1990, Maran and Henttonen 1995, Maran et al. 1998b).

On the western population, the situation is different. In the north, the French population has disappeared from Brittany and Pays de Loire in 20 years, between 1977 and 1997 (Lodè et al. 2001). On the other hand, in the Iberian Peninsula the situation is intriguing since the species seems to be expanding southwards (Maran and Henttonen 1995, Palazón and Rúiz-Olmo 1992, Torres and Zuberogoitia 1997). Recently, some surveys have been carried out in the whole area occupied by the European mink, including Biscay.

On the other hand, the American mink (*Mustela vison*), is a semi aquatic mustelid native to North American that has been introduced in many areas for fur purposes (Dunstone 1993). By the late 50s some American mink farms were active in Segovia and Pontevedra (Palazón and Ruiz-Olmo 1997), and some 20 years latter first records of free ranging individuals were reported (Delibes and Amores 1978). Feral populations expanded as well as escapes from other fur farms gave rise to new nuclei spreading over areas of Castilla y León, Galicia, Portugal, Cantabria, Aragón, Castellón and Catalonia (Palazón and Ruiz-Olmo 1997).

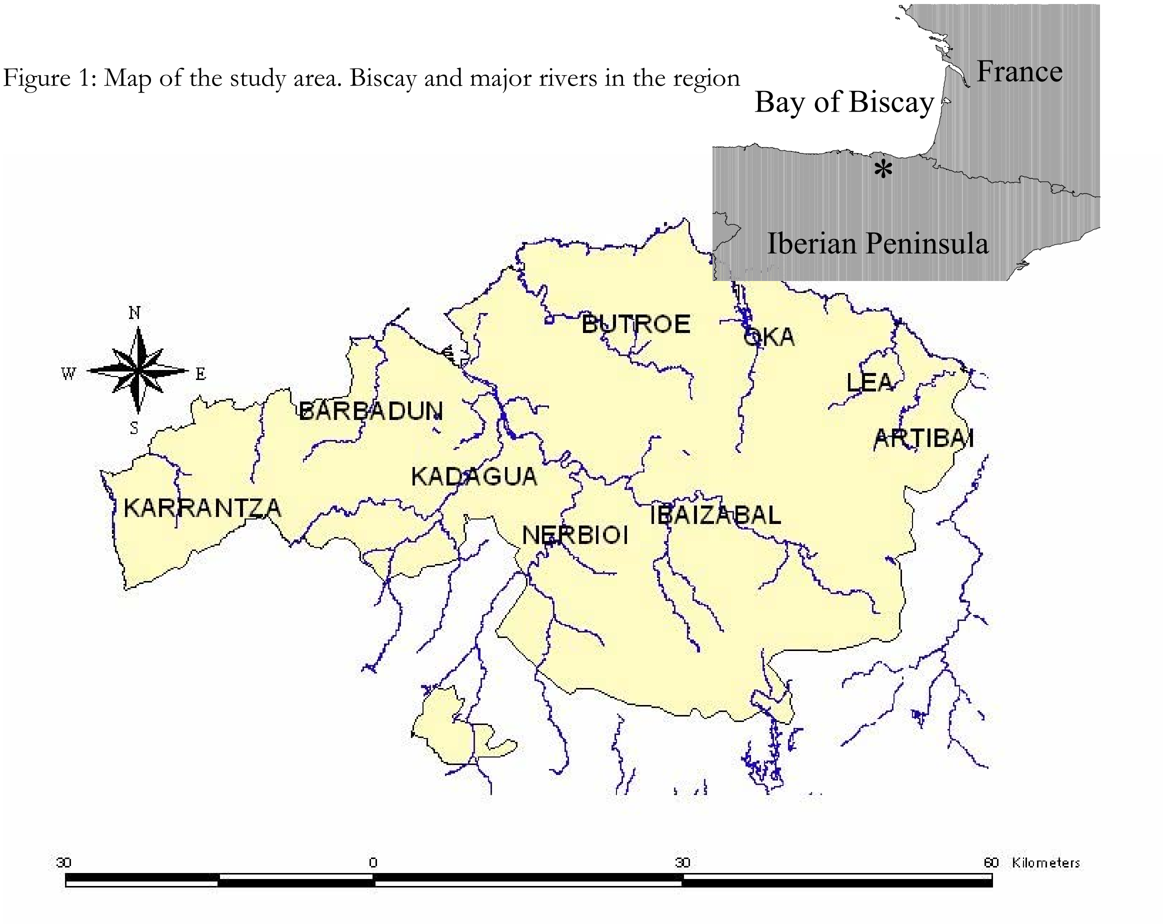
The first reliable report of American mink in Biscay is from the Butroe catchment and dates back to 1993, although it is very likely that the species had settled there for some years before (Zuberogoitia et al. 1997). From then onwards, there have been scattered records suggesting an expanding population (Aihartza et al. 1999, Zuberogoitia et al. 2001).

In this chapter we discuss the results of mink surveys for Biscay, present past data on the distribution of mink species in the area and discuss the current distribution and its historical evolution for both mink species.

STUDY AREA

Biscay, in the north of the Iberian Peninsula (Fig.1), has an area of 2236 km2 and a population of near 1 200 000 inhabitants. Altitudes range from 0 (by the sea shore) to 1475m (Gorbea peak). Climate is oceanic, annual rainfall ranges between 1200 and 2200 mm, and annual average temperatures range from 13.8ºC to 12ºC. (Flores 1989) winters are mild and there is not summer drought. Streams are short, small and fast flowing, running into the Bay of Biscay. All the major rivers, with the sole exception of the Butroe river (Fig 1), are polluted, specially the Nerbioi and Ibaizabal rivers (Departamento de Ordenación del Territorio y Medio Ambiente del Gobierno Vasco 2001). Springs, tributaries and small coastal streams show in general acceptable water conditions, however some of them are also polluted, especially those of Nerbioi and Ibaizabal rivers near the main population nuclei (Departamento de Ordenación del Territorio y Medio Ambiente del Gobierno Vasco 2001). Best water conditions are in small rivers in the Artibai-Oka area and westwards of the Kadagua river Departamento de Ordenación del Territorio y Medio Ambiente del Gobierno Vasco 2001).

Figure 1: Map of the study area. Biscay and major rivers in the region



METHODS

For assessing current and past distribution we used several methods. Firstly we reviewed previous works, either local or extensive, dealing with the presence, status and distribution of the species. For previous data we used the following sources:

1- Data from already published papers.
2- Data from live-trapping and torching studies conducted during carnivore surveys and studies at the Urkiola Natural Park, Urdaibai Biosphere Reserve and some local trappings conducted under environmental vigilance projects and for eradication and control of problematic individuals.
3- Data from animals collected at the Wildlife Rescue Centre of Biscay.
4- Road kills, animals killed by hunters, stuffed animals and corpses.

5- Sightings of animals. In this case only data from the research team and/or from renowned scientists or naturalist have been considered (see Table 1 in Chapter 1)

For the assessment of the current situation of the species we used results from the extensive live-trapping survey conducted by Zuberogoitia et al. (2005) and data from above referred sources dating back no more than 3 years.

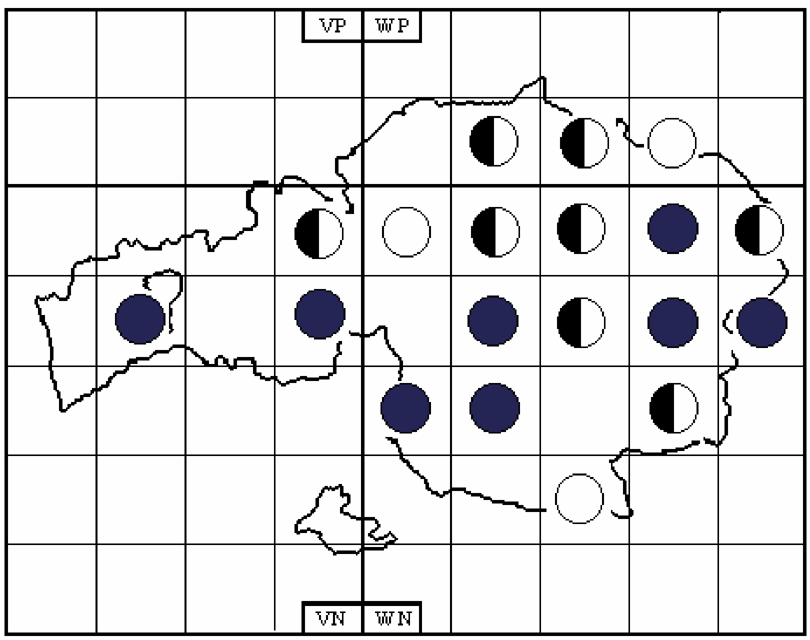
Well preserved stream from western Biscay.

RESULTS

European mink

The European mink was firstly reported in Biscay in 1963 (Rodiguez de Ondarra 1963), few years later of the first record of the species in the Iberian Peninsula (Rodriguez de Ondarra 1955). Afterwards, continuity of mink in Biscay area has been confirmed in several works (Castién and Mendiola 1985, Palazón and Ruiz-olmo 1997, Aihartza et al 1999, Zuberogoitia et al 2001) including the last survey carried out from February 1999 to December 2000 (Gonzalez-Esteban et al. 2001, Palazón et al. 2002). The species reached in Biscay from Gipuzkoa in the East, and by the time of its first report it had arrived the Northwest of the region, east of the Nerbioi river (Rodiguez de Ondarra 1963). Castién and Mendiola (1985) reported European mink to be present in five 10 x 10 km UTM squares, including the two already reported by Rodriguez de Ondarra (1963). In 1997 after an extensive study, Palazón and Ruiz-olmo (1997) cited European mink in 13 10 x 10 km UTM squares, two of them based in bibliographic data before 1980 and another one reported before 1980 and confirmed afterwards (Palazón and Ruiz-olmo 1997). Locations recorded spread over the catchments of the rivers Ibaizabal, Oka, Artibai and Butroe, and also some other minor rivers (Palazón and Ruiz-olmo 1997). In addition, they reported two bibliographical (before 1980) locations in a tributary of the Nerbioi and another one in the Nerbioi (after 1980), but none westwards of this river. Aihartza et al. (1999), as the result of field surveys carried out between 1990 and 1996, reported European mink in ten 10 x 10 km, including two new squares and the first location westwards of the Nerbioi river. Zuberogoitia et al. (2001) cited the species as present in the most of the region, but more common in the oriental area, they also include a new data westwards of the Nerbioi near the western edge of the region. Finally in the last survey carried out from February 1999 to December 2000, Gonzalez-Esteban et al. (2001) located a total of 8 European mink in five different 10 x 10 km UTM squares. Four of these locations are in the Artibai catchment, one in the Lea, two in the Oka catchment and the last one in the Ibaizabal catchment (Gonzalez-Esteban et al. 2001, Palazón et al. 2002). The authors concluded that the European mink maintains populations in the area of the Artibai and Oka rivers, and they also remarked the fact that European mink is absent from western Biscay, where the rivers are best preserved (Gonzalez-Esteban et al. 2001). From November 2004 to January 2005 Zuberogoitia et al. (2005) conducted and extensive live-trapping survey in Biscay, and found European mink in Lea, Artibai, Ibaizabal, Butroe and Kadagua, this last among the rivers from western Biscay. The Oka catchment was not surveyed during that study (Zuberogoitia et al. 2005).

Figure 2: Distribution of European mink in Biscay. Empty circles indicate bibliographic data, full circles indicate presence detected in the last three years, and divided circles indicate both bibliographic data and presence detected in the last three years.



American mink

Data on American mink are shown in table 1. From them it can be drawn that first feral populations of American mink in the area originated from escapes or releases from a fur farm that existed in the Butroe catchment.

A decade before the first record of feral American mink in the area, there was a escape of some 35 animals that very likely originated the population, the fur farm being closed shortly afterwards (Zuberogoitia et al. 2001). The seven first reports on American mink were in this catchemnt, and during this time there were many other unconfirmed data from the area.

Table 1. American mink repots form Biscay. Age and sex of the individual (if known), catchment and town where it was detected are detailed.

Year	Sex	Age	Data source	Catchment	Town
1993	Male	Young	Trapped	Butroe	Gatika
1994	Male	Adult	Killed by farmer	Butroe (Laukariz)	Mungia
1994	Female	Adult	Killed by farmer	Butroe (Laukariz)	Mungia
1994	Unknow	Unknow	Sighting	Butroe	Mungia
1994	Unknow	Unknow	Sighting	Butroe	Fruiz
1994	Unknow	Unknow	Sighting	Butroe	Fruiz
1994	Unknow	Unknow	Sighting	Butroe	Gatika
1994	Unknow	Unknow	Sighting	Butroe	Gatika
1995	Unknow	Unknow	Sighting	Oka	Muxika
1990-95	Male	Adult	stuffed	Butroe	Gamiz
1996	Male	Adult	Trapped	Nerbioi	Arrigorriaga
1996	Unknown	Unknown	Road killed	Asua	Lezama
2000	Male	Old	Trapped	Butroe	Maruri
2000	Male	Young	Killed by dog	Oka	Oiz (Mendata)
2002	Male	Young	Road killed	Artibai	Markina
2002	Unknown	Unknown	Road killed	Artibai	Markina
2002	Male	Young	Road killed	Ibaizabal	Zornotza (Euba)
2002	Unknown	Unknown	Sighting	Asua	Zamudio
2004	Female	Young	Trapped	Artibai	Berriatua
2004	Male	Adult	Trapped	Lea	Aulestia
2004	Male	Adult	Trapped	Butroe	Fruiz
2004	Male	Adult	Trapped	Butroe	Gamiz
2004	Female	Old	Trapped	Butroe	Arrieta
2004	Male	Young	Trapped	Butroe	Gatika
2004	Female	Young	Trapped	Butroe	Gatika
2004	Male	Old	Trapped	Butroe	Gatika
2004	Unknown	Unknown	Trapped	Zadorra	Otxandio
2005	Male	Old	Trapped	Butroe	Gamiz
2005	Female	Adult	Trapped	Butroe	gatita
2005	Female	Young	Trapped	Butroe	Gamiz
2005	Female	Adult	Trapped	Butroe	Mungia
2005	Female	Adult	Trapped	Butroe	Gatilka
2005	Male	Young	Trapped	Bolue	Getxo
2005	Female	Unknown	Trapped	Bolue	Getxo

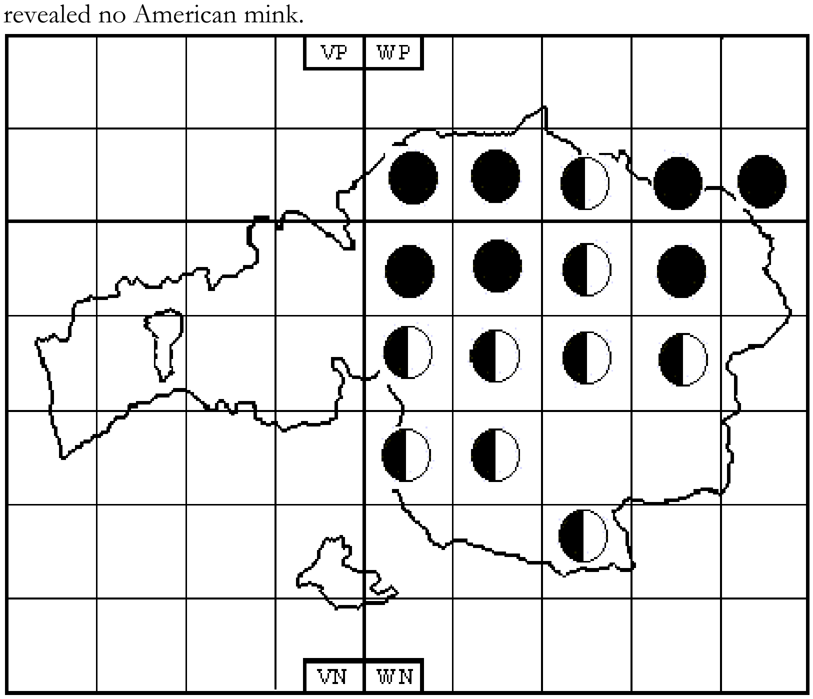
In 1995, first data are reported from the neighboring Oka cathment. However, in 1999-2000 during an intensive live-trapping survey only European mink was found in the Oka (Zabala et al. 2001), in spite of a dog-killed American mink being found in a mountain slope of the area.

In 1996 a mink was trapped in the Nerbioi, one of the main rivers of the area, but it seems to have been a dispersive individual because there are no other data from the area and recent trapping surveys in the area revealed no mink (Zuberogoitia et al. 2005). Also in 1996 an American mink was found in the Asua, a minor catchmnet between Nerbioi and Butroe, and more recent data suggest presence of American mink populations in the area.

In 2002 there were two reports from two different catchments, two mink in the Artibai catchments and another one in the Ibaizabal.

Finally, in 2004-05, during an extensive live-trapping survey Zuberogoitia et al. (2005) trapped American mink in three catchments; a dense population settled in the Butroe area and two other in the Artibai and Lea catchments (Fig 3).

Figure 3: Distribution of American mink in Biscay. Full circles indicate areas with already settled populations and divided circles indicate areas where presence has been detected but trapping revealed no American mink.



DISCUSSION

European mink

At first sight, it seems that the European mink spread rapidly over oriental and central Biscay after its arrival and maintained this distribution for a long period of time, without colonising the area westwards of the Nerbioi river. By the late 1990's there are two records of European mink westwards of the Nerbioi (Aihartza et al. 1999, Zuberogoitia et al. 2001), but definitive colonisation of the area has not been confirmed until 2004-2005, when Zuberogoitia et al. (2005) tracked two territorial males in the Kadagua catchment. A previous survey, carried out by Gonzalez-Esteban et al. (2001), suggested a reduction of the distribution of European mink, with the species confined to the north-east area. However, as stated by Gonzalez-Esteban et al. (2001), there were some methodological differences that prevent unconditional comparison among works.

Firstly, works of Castién and Mendiola (1985) and Palazón and Ruíz-Olmo (1997) are partially based on bibliographic data, dating back as far as 1963 (22 and 34 years respectively). Therefore, they are liable to provide elapsed and unreal data, artificially enlarging the actual distribution of the species.

Secondly, data for Biscay given by Palazón and Ruíz-Olmo (1997) and Aihartza et al. (1999) are not the result of a survey for European mink with an specific methodology, but based on different sources such as: live-trapping data, track searches, torching, enquires and road casualties and casual observations. Thus, there are liable to fail to detect mink in remote areas and areas of low human density.

Thirdly, the survey carried out by Gonzalez-Esteban et al. (2001), was conducted using photographic bait stations, more precisely the Line-Triggered Camera System described by Zielinski and Kucera (1995). There are some remarks that one should bear in mind about this method: Firstly, some studies found that this method is less efficient than other methods when detecting carnivores (Zielinski and Kucera 1995). Indeed, Gonzalez-Esteban et al. (2001) failed to detect European mink in areas where there were data on road kills, the species had been sighted and in a stream where European mink was being studied at the moment (Zuberogoitia et al. 2001, Garin et al. 2002a,b). Moreover, Gonzalez.-

Esteban et al. (2001) used the same method in order to detect European mink in Araba, a region adjacent to Biscay where simultaneously a live-trapping study was being carried out, and failed to detect the species in 14 squares where the live trapping method did (Gonzalez-Esteban et al. 2001, Palazón et al. 2002). On the other hand, they detected mink in a square where live trapping did not (Gonzalez-Esteban et al. 2001, Palazón et al. 2002). However, despite its lower performance, the method used by Gonzalez-Esteban et al. (2001) has several advantages like being cheaper and non intrusive with the species. Moreover, it does not suffer from the deleterious effects that live-trapping may have (Zabala et al. 2001).

Finally, the live trapping study conducted by Zuberogoitia et al. (2005) detected European mink in all areas where it had been previously reported plus two new areas, one of them with old data and the other suspected to host European mink. However, it failed to detect European mink in some area where there have been sightings and road kills, probably due to a medium intensity of the effort and low mink densities rather than to the absence of the species.

Hitherto, most studies have been conducted over long periods of time (a whole year or more), whilst small carnivores, including mink, have different degrees of activity and displacements throughout the year, are likely to be more attracted to bait in some seasons and their trappability also changes markedly throughout the year (Brzezinski et al. 1992, Zielinski and Kucera 1995, Zabala et al. 2001). Moreover, overall trapping success is related to trapping effort (Mcdonald and Harris 1999); therefore, some distributional studies, specially those based on trapping that do not include data from other sources, and/or have low trapping efforts are not reliable and probably only detect target species in areas with high densities.

In our opinion, the results of the last European mink surveys in Biscay have underrepresented the distribution of the species. Based on the results of the recent surveys, scientific research publications, road kills and sightings of the species, we give a more accurate distribution for the species in Biscay (Fig. 2).

As observed in Fig. 2, European mink in Biscay occupies almost the entire province, including several areas were it was not detected in the surveys. The current distribution is quite close to that reported in older works (Castién and Mendiola 1985, Palazón and Ruiz-olmo 1997, Aihartza et al 1999). A possible difference might be the colonisation of the area westwards of the Nerbioi river, where mink has been absent for many years. Indeed, besides data on two road kills (Zuberogoitia et al. 2001), there are data on mink in streams south of the area (Palazón et al. 2002) and captures in the Kadagua system (Zuberogoitia et al. 2005). Small distributional changes observed in previous works are more likely to be due to different sampling efforts than to a changing distribution pattern with continuous colonisation and extinctions in some areas.

American mink

Data of American mink in Biscay indicate a slow settlement of populations followed by a fast expansion first along the occupied catchments and afterwards to adjacent ones. Currently only the western area on the region seems to be free of American mink. Both previous data and data from the most recent survey indicate that American mink has settled in three of the main catchments in the area: Butroe, Lea and Artibai. In addition, there seems to be high pressure from dispersive individuals or already settled small populations in adjacent catchments (Asua, Bakio, Oka, Ibaizabal).

The main conclusion that can be drawn from the data is the need of a reliable and common (for all the regions) methodology to detect European and American mink, and its standard periodical application. Indeed, using different methods results in incomparable results and useless efforts. In our opinion, an in depth study is needed in order to develop a standardised technique, which should fulfil some basic requirements. An easy, cheep and, most important, harmless and reliable technique is needed.

LITERATURE

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Feral American mink populations sttled in the area as a consequence of scapes from furm farms.

CHAPTER 3‡

Resting site use and selection of European mink (*Mustela lutreola*).

ABSTRACT

Habitat change is one of the main factors influencing the decline of the European mink western population. However, data on the habitat selection of European mink are scarce. We studied landscape features influencing the habitat and resting site selection of riparian male European mink through radio-tracking. None of the habitat descriptors accounted for the habitat use of European mink during their activity periods. On the other hand, resting site selection was correlated to the presence of bramble patches. Intensive use of bramble patches is explained as a consequence of the mink' need of protection against predators. Moreover, high availability of bramble patches provides mink with profitable resting sites. Therefore, extensive bramble cover may help an efficient use of the home range. European mink conservation policies should pay more attention to conservation and restoration of riverbank features.

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‡ Originally published as: Zabala, J. Zuberogoitia, I. Garin, I. and Aihartza, J. R. 2003. Landscape features in the habitat selection of European mink (*Mustela lutreola*) in South-western Europe. J. Zool., Lond. **260**: 415-421.

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 (Youngman 1982). One nucleus in Eastern Europe, where several sub-populations have been documented, most of which experience 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 North part of its previous range (Youngman 1982, Maran and Henttonen 1995, Romanowsky 1990, Palazón and Rúiz-Olmo 1992, Tumanov 1992, Maizeret et al. 1998, Maran et al. 1998a, 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 and Henttonen 1995, Sidorovich et al. 1995, Tumanov 1996, Maran et al. 1998b, Lodé et al. 2001). Moreover, colonisation by the American mink has been suggested to be the reason for the disappearance of the native mink in the eastern area, mainly as a result of aggressive physical interactions between species (Maran et al. 1998b, Sidorovich et al. 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). On the other hand, studies on the potential hybridisation with polecat (Davison et al. 1999, Davison et al. 2000) and the effects of isolation on genetic variability of populations (Lodé 1999) tried to clarify the reasons underlying the regression of the species.

To our knowledge, no in-depth study has been conducted into the habitat selection of the European mink in spite of the fact that habitat change alone may have an important bearing explaining the current distribution and the decline of the species. Hitherto, only Lodé et al. (2001) 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 in North-western France (Lodé et al. 2001, Lodé 2002).

Knowledge of the habitat use of a species is paramount for its conservation, especially of resting sites. Indeed, it has been suggested that availability of suitable resting places may be a crucial factor in determining distribution and abundance of semi-aquatic mammals (Gerell 1970, Birks and Linn 1982, Weber 1989, Dunstone 1993, Halliwell and Macdonald 1996, Stevens et al. 1997). However, available data on habitat use and resting sites of European mink are, in most cases, descriptive and vague.

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

STUDY AREA

The study was conducted at the Urdaibai Biosphere Reserve, Basque Country (SW Europe). 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°C and 18°C respectively. Winters are mild and there is not effective snow cover.

The landscape is hilly and rugged. The 61% of the land is forested, mainly *Pinus radiata* and *Eucalyptus globulus* plantations. Native holm oak (*Quercus ilex*) forests are also common in rocky outcrops. Meadows and estuarine habitat occupy a 34% of the area; the remaining 5% is urban area with near 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 (Departamento de Ordenación del Territorio y Medio Ambiente del Gobierno Vasco 2001). Upper parts of the streams are the least modified of all, and they usually have alder (*Alnus glutinosa*) and willow (*Salix atrocinerea*) gallery forests. Medium 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 absent (Navarro 1980).

MATERIALS AND METHODS

Animals were live-trapped in single entry cage traps (25 x 25 x 45 cm). Trapping sessions were carried out in streams from February 1999 to January 2000. After immobilisation with 0.8 mg of Zooletil (Virbac. Carros, France) per 100 g of animal weight, animals were collared with radiotransmitters (Biotrack. Dorset, UK). Used radio-collars weighted c. 13 g (i.e. less that the two % of the animal weight in any case), had an expected medium life of six-seven months and their emission range was between 150-151 MHz. After radio-collaring, mink were set free 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 were caught. No other stream-dwelling mustelid but European mink was caught (Zabala et al. 2001). M4 died after capture and therefore, was nor considered for analysis (Zabala et al. 2001, Garin et al. 2002a). A hand-held 3-element Yagi antenna and TRX-1000S receiver (Wildlife Materials Inc. Carbondale, USA) were deployed usually on foot. Fixes were achieved by homing-in (White and Garrot 1990) and located in a map to the nearest 100 m, so as to minimise 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 three months, M5 and M6 for six months, and M3 for seven consecutive months, tracking periods and home range size are detailed elsewhere (Garin et al. 2002a). M1 included marshes within its home range and was discarded because of the different landscape features defining its range. In order to avoid bias due to data correlation, only one fix during the daytime rest and one at night, when mink become active were considered for analysis (Aebischer et al. 1993). The daytime location was taken between two hours after down and two hours before dusk, whilst the night location was taken at least one hour after the start of the activity period. Linear home ranges were calculated as meters of waterway used by mink with the 95% of the locations (White and Garrot 1990, Palazón and Rúiz-Olmo 1993, Garin et al. 2002a).

Table 1. Variables describing European mink habitat. Bramble cover stands for the degree of bramble cover in the riverbank. Riparian forest stands for the degree of forest cover in the riverbank. Forest cover stands for the degree of forest cover in the polygon. Forest cover stands for the forested area inside the polygon, and Cover of main species stands for the degree of diversity in the polygon. River represents the characteristics of the stretch in the polygon. Main use indicates the use given to the land inside the polygon. Meadows includes grasslands as well as small crop cultures. Road and Path show the metres of paved roads and forest paths included in the polygon respectively. Finally, Buildings indicates the number of buildings that fall totally or for the most part inside the polygon.

VARIABLE	CATEGORY	VARIABLE	CATEGORY
BRAMBLE COVER		MAIN USE	
	0-25%		Urban
	26-50%		Meadows
	51-75%		Forest Cultures
	76-100%		Autochthonous Forests
RIPARIAN FOREST			Others
	0-25%	ROAD	
	26-50%		0
	51-75%		1-150
	76-100%		>150
FOREST COVER		PATH	
	0-33%		0
	3·4-66%		1-50
	67-100%		>50
COVER OF MAIN		BUILDINGS	
SPECIES			0
	0-40%		1
	41-100%		2
RIVER			3 or more
	Streams		
	Main river		

We selected a set of nine variables describing habitat features and humanisation 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 and Boitani 1997, Zalewski 1997a, b). It has been stated that European mink prefers well-preserved streams with a high degree of forest cover (Youngman 1982, Palazón 1998, Sidorovich and Macdonald 2001). Therefore, we also considered variables describing the forest cover and species diversity of the river shore. Finally, since anthropic pressures are considered the main factor for European mink decline in neighbouring French study areas (Lodé et al. 2001), we included variables describing the degree of human disturbation.

On the other hand, taking into account the riparian behaviour of mink and that 100 per cent of their dens occur within 25 m of the stream (Youngman 1982, Dunstone 1993, Stevens et al. 1997, Palazón 1998, Garin et al. 2002a), 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 rest of variables were obtained with the aid of a GIS.

Firstly, we performed a Principal Components Analysis (PCA) as an exploratory tool in order to reject covariables (Kelt et al. 1994, Morrison et al. 1998). The PCA identified variables that helped distinguish the plots (Morrison et al. 1998). Components of the PCA with eigenvalues bigger than 1.0 were retained for ecological evaluation (Kelt et al. 1994, Morrison et al. 1998) Afterwards, we tested components with eigenvalues greater than 1.0 against presence of mink using the Spearman's correlation (Morrison et al. 1998, Zar 1999). Finally, in order to determine which variables ruled the resting site selection of the studied mink, we performed a Logistic Regression Analysis (LRA) with the components that were correlated with mink presence after running Spearman's correlations (Morrison et al. 1998). The LRA is a type of multivariate analysis that allows the inclusion of categorical variables (Ferrán 1996). For the LRA, we randomly selected 20 polygons plus eight more for each variable in the analysis, following the recommendations of Morrison et al. (1998). In total, we used 75 polygons 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 were mink was never detected. Note that every polygon, 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 one to identify 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 some requirements. The selection of variables ends when no further increase on the accuracy of the model can be achieved.

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

RESULTS

We characterised a total of 407 polygons within mink home ranges, and we recorded inactive mink 141 times in 83 of them. Resting sites were used two times (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 anecdotally. We recorded active mink 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 9 components. The two first components' eigenvalue was bigger than 1.0 and explained 35% and 14% of the variation respectively. We performed the Spearman Correlation with these two components (table 2) and activity and inactivity data. The first component was 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: $r_s=-0.055$, $p<0.266$).

Table 2: Composition of components of the PCA with eigenvalues bigger than 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 3: results of the LRA and predictive value of the models.

SELECTED VARIABLE		Wald	Degrees of Freedom	p	r	Predicts		
						Presence	Absence	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			

Therefore, we performed the Logistic Regression Analysis (Forward, Wald statistic) with the variables of the first component. For this purpose, we randomly selected a total of 75 polygons, 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 very 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).

Table 4. Resting site selection of male European mink assessed through the Jacobs' index. Values that reached statistical significance trough Bonferroni's inequality are marked with *.

VARIABLE	CLASS	JACOBS
BRAMBLE COVER		
	0-25%	*-0.6620
	26-50%	*-0.3988
	51-75%	0.1741
	76-100%	*0.5423
MAIN USE		
	Urban	0.0911
	Meadows	*0.1874
	Forest Cultures	*-0.4614
	Autochthonous Forests	-0.0904
	Others	*-0.6107

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, Lindstrom et al. 1995, Maran et al. 1998b, Palomares and Caro 1999, Sidorovich et al. 1999, Sidorovich et al. 2000), and especially by humans and their pets (Arambarri et al. 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 animals reported above are capable of digging their way 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, bearing in mind that European mink flee when harassed by the American mink (Sidorovich et al. 1999), it would be easier to run away from a bramble patch than from an underground burrow when caught by surprise. On the other hand, digging is an energetically demanding activity that is not likely to be carried out in all types of substrates (Neal and Cheeseman 1996). Therefore, burrowing would not allow mink to use many resting sites and could constraint the size of home ranges (Garin et al. 2002a).

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 thickets' use are far from the exclusivity shown at the Urdaibai Biosphere Reserve (table 5). The high number of resting sites used by mink and the low degree of fidelity showed to those 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 more than 50 % of the shore covered by bramble). This would also explain 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 often without sustaining severe energy cost. Furthermore, the European mink is known to show active bouts during diurnal resting periods (Palazón 1998, Garin et al. 2002b), 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 not-mutually exclusive factors: protection against predators, thermal insulation and proximity to preferred feeding areas (Weber 1989, Dunstone 1993, Brainerd et al. 1995, Lindstrom et al. 1995, Halliwell and Macdonald 1996, Genovesi and Boitani 1997, Zalewski 1997a, 1997b, Larivière and Messier 1998). The importance of protection against predators is stressed by our results, whilst the influence of the other two is difficult to determine. Thermal regulation plays an important role in resting place selection of small carnivores (Weber 1989, Lindstrom et al. 1995, Zalewski 1997a). This is hold true especially for semi-aquatic species, which tend to loss more heat due to the enhanced conductivity of water (Channin 1993, Kruuk 1995). Bramble patches on the ground provide poorer thermal insulation than burrows or other structures (Weber 1989, Brainerd et al. 1995, Zalewski 1997a, 1997b). On the other hand, 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 1997a, 1997b). The mild winters and warm temperatures year round at the Udaibai Biosphere Reserve (minimum absolute value during the study period was –8.0ºC, and coldest temperatures averaged 2.4ºC) probably allow mink to use bramble patches without severe energy cost.

Table 5: burrows of mink after several studies. Figures expressed in percentages with the exception of Gerell (1970) who does not provide with numeric values. Sidorovich and 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 and 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 and Jedrzejewska 1992

Although there is 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 et al. 1998a). One of the main habitat requirements of those small mammals is the availability of dense vegetation patches such as bramble patches (Castién and 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 and Mendiola 1989, Garde and Escala 2000), we can assume 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 at meadows might be explained on the grounds of their proximity to preferred feeding areas, such as has been shown for other species such as the 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 with prey availability and to change seasonally in relation with prey activity (Lodé 1994, 1995, 2000, Bonesi et al. 2000). Nevertheless, precise data on mink diet as well as on food supply is lacking at the study area, and thus, we cannot assess the importance of those factors.

Resting site availability is of big importance for the ecology and distribution of semi-aquatic carnivores (Gerell 1970, Birks and Linn 1982, Weber 1989, Dunstone 1993, Halliwell and 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 and 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 and 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 ranges, 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 riparian European mink may be affected by the depletion of the vegetation cover used for resting, even though quality of water is improved. Therefore, efforts made in order to improve water quality could achieve limited success as conservation measure unless efforts are made to preserve and restore riverbanks. Riverbank management experiments and policies are need in order to understand the importance of cover availability for European mink and to guarantee its conservation.

Dense and rank riverbank. vegetation provide mink with safe and abundant resting sites.

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Canalisation and eradication of riverbank vegetation mya have deleterious effects on Euroepan mink populations (see chapter 5).

CHAPTER 4§

Habitat use of male European mink (*Mustela lutreola*) during activity.

ABSTRACT

Data on the habitat use of European mink (*Mustela lutreola*) are scarce. We studied the habitat use of four male European mink from riparian habitats of south-western Europe during the activity period. For this purpose, we considered several habitat characteristics dealing with biologic features, humanisation level and land use. Mink used areas with a certain degree of bramble or shrub cover at the riverbank, and low degrees of forestall cover. On the other hand, avoided areas with dense forestall cover, whist other categories were used as available, including modified areas and areas with a medium-high degree of human activities. Dense bramble cover provides mink with safety to move hunt and handle prey, whilst dense forestall cover prevents development of undergrowth.

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§ Originally published as: Zabala, J, and Zuberogoitia, I. 2003. Habitat use of male European mink (*Mustela lutreola*) during the activity period in Soutwestern Europe. Z. Jagdwiss. **49**: 77-81.

INTRODUCTION

Precise knowledge of habitat requirements is of paramount importance for species conservation. No single factor could be identified as responsible for the decline (Maran and Henttonen 1995). In the eastern range aggressive physical interactions with the American mink have been suggested to be the reason for the disappearance of the native mink from some areas (Maran et al. 1998, Sidorovich et al. 1999, Macdonald et al. 2002). However, this seems not to be valid in western area where the regression seems to be result of anthropic pressures, more precisely, to the conjunction of intensive trapping, alteration of water quality and habitat modification (Lodé et al. 2001).

Habitat degradation is suggested in most papers as one of the possible causes for the rarefaction of the species (Maran and Henttonen 1995, Tumanov 1996, Maizeret et al. 1998, Maran et al. 1998), especially in the western population (Lodé et al. 2001). However, data are needed on the habitat use of European mink (Macdonald et al. 2002) as most studies on the subject are based on trapping data and are merely descriptive. Surprisingly, scarce radiotracking studies have been conducted so far on the habitat of the European mink. Previously, we analysed the landscape features ruling the resting site selection of the European mink (Zabala et al. 2003, Chapter 3), but paid little attention to the activity period since there was no clear selection of variables. The aim of this paper is to describe the habitat used by the European mink during activity based radiotracking data.

STUDY AREA

The study was conducted at the Urdaibai Biosphere Reserve (UBR), Basque Country (SW Europe) (Fig. 1). The UBR spreads over a whole basin with an area of 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°C and 18°C respectively. Winters are mild and there is not effective snow cover.

The landscape is hilly and rugged. The 61% of the land is forested, mainly *Pinus radiata* and *Eucalyptus globulus* plantations. Native holm oak (*Quercus ilex*) forests are also common in rocky outcrops. Meadows and estuarine habitat occupy a 34% of the area; the remaining 5% is urban area with near 45,000 inhabitants. The Oka, the main river, and tributaries show low pollution levels, except near the main towns, where levels of nutrients and heavy metals are high (Departamento de Ordenación del Territorio y Medio Ambiente del Gobierno Vasco 2001). Upper parts of the streams are least modified of all, and usually have gallery forests of alders (*Alnus glutinosa*) and willows (*Salix atrocinerea*). Medium parts of rivers are most diverse, including well-preserved stretches, stretches forested 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 absent (Navarro 1980). A sane population of European mink is known to inhabit the UBR (Zabala et al. 2001), and also few individuals of the American species have been found in the basin (Zuberogoitia et al. 2001).

MATERIALS AND METHODS

Animals were live-trapped in single entry cage traps (25 x 25 x 45 cm). Trapping sessions were carried out in streams from February 1999 to January 2000. After immobilisation with Zooletil (Virbac. Carros, France), animals were collared with radiotransmitters (Biotrack. Dorset, UK). In total six adult males were caught. No other stream-dwelling mustelid but European mink was caught (Trapping data are summarised in Zabala et al. 2001). A hand-held 3-element Yagi antenna and TRX-1000S receiver (Wildlife Materials Inc. Carbondale, USA) were used, usually on foot. Fixes were achieved by homing-in (White and Garrot 1990) and located in a map to the nearest 100 m, so as to minimise 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). The animals were tracked throughout a year period, from February 1999 to February 2000, in this paper we considered four male European mink inhabiting riparian habitats, males inhabiting marshes were excluded for the analysis as landscape features differ from those of rivers (individual tracking periods and home range size are detailed elsewhere (Garin et al. 2002). In order to avoid biases due to data correlation, only an active location per day was considered for analysis (Aebischer et al. 1993). Active locations were taken during the night activity period at least one hour after the start of the activity period. Linear home ranges were calculated, with 95% of the locations, as meters of waterway used by mink (White and Garrot 1990, Palazón and Rúiz-Olmo 1993).

Habitat was characterised after 9 variables dealing with biologic features and humanisation level, several classes were considered in each category (table 1). For this porpoise, with the aid of the GIS, a buffer area of 25 m was set at each side of river stretches included in home range of mink. Then, home ranges of mink were subdivided into several polygons of 100 m long each. Values for the variables Bramble cover and Riparian forest were estimated in the field for each polygon. Values for the rest of variables were obtained through the GIS. We only considered for analysis the home ranges of stream dwelling mink (n=4).

For each variable we tested independence between availability and use of categories using the X^2 analysis (Zar 1999), and we applied Bonferroni's inequality to test statistical significance of selection in each category (Manly et al. 1993). The aim of this paper is to describe the habitat used by the European mink at the study area, not to determine the variables ruling its habitat selection. Therefore, each variable with statistical significance after Bonferroni's inequality was considered as descriptive of the habitat used by the European mink, without testing independence between variables. The degree of electivity for each class within the variables was assessed through the Jacobs' index (Krebs 1989). The statistical significance limit was set at 0.05.

RESULTS

Table 1. Variables studied for habitat use. Bramble cover stands for the degree of bramble cover in the river bank. Riparian forest stands for the degree of forest cover in the river bank. Forestall cover stands for the degree of forest cover in the polygon. Forest cover stands for the forested area inside the polygon, and Cover of main species for the degree of diversity in the polygon. River represents the characteristics of the stretch in the polygon. Main use indicates the use given to the land inside the polygon, Meadows included grasslands as well as small crop cultures. Road and Path show, respectively, the metres of paved roads and forestall paths included in the polygon. Finally, Buildings indicates the number of buildings that fall totally or considerably inside the polygon. Values quoted in use stand for the Jacobs' index value for each class while statistical significance after Bonferroni's inequality is quoted with an asterisk (*)

Variable	Class	Use	Variable	Class	Use
Bramble cover			Degree of forestall cover		
	0-25%	-0.0629*		0-40%	0.0969*
	26-50%	0.1394		41-100%	-0.2132*
	51-75%	0.1709	River		
	76-100%	0.2262		Streams	-0.0560
Riparian forest				Steam river	0.0432
	0-25%	0.3233	Main use		
	26-50%	0.2559		Urban	0.2211
	51-75%	-0.0545		Meadows	0.1029
	76-100%	0.0216		Forestall cultures	-0.2353
Forest cover				Autochthonous forests	-0.0343
	0-33%	0.1447		Others	-1
	34-66%	-0.0588	Road		
	67-100%	-0.1909		0	-0.0314
Buildings				1-150	0.0014
	0	-0.0627		>150	0.2320
	1	0.0764	Path		
	2	0.2606		0	0.0009
	3 or more	0.1738		1-50	0.0637
				>50	-0.1099

During the activity period, male European mink used most habitat categories in an opportunistic way (Table 1). The only exceptions were areas with a high degree of forestall cover and areas with almost no bramble patches, which were rejected, and areas with low forestall cover, which were selected.

DISCUSSION

Instead of best conserved areas, mink used areas devoted to human uses like areas of scarce forestall cover and some degree of bramble cover by the river side. Non forested areas allow the development of heliophytic vegetation like brambles and grasslands. Dense bramble provides mink with shelter (Garin et al. 2002, Zabala et al. 2003) not only as resting site but probably also to hide, hunt and handle prey (Dunstone 1993, Zabala et al. 2003). On the other hand, grasslands with shrub patches enhance rodent availability (Castién and Mendiola 1985, Garde and Escala 2000), which are one of the main food items of European mink in the Iberian Peninsula (Palazón 1998). Indeed, selective use of the home range after availability of food is well documented in similar species (Weber 1989, Dunstone 1993, Lodé 1993, 2000, Brainerd et al. 1995). However, as precise data on mink diet and food availability in different habitats is lacking for the study area is difficult to assess their importance on the habitat use.

However, the most important result is the non selective use of most categories, which indicates tolerance, and in some cases preference, for modified and humanised habitats, which contradicts classical European mink habitat use data. In this way, studies carried out so far described the habitat of European mink as "small woodland streams" (Youngman 1982), "fast flowing small rivers or small brooks with high, steep and wooded bankside" (Sidorovich and Macdonald 2001) and "natural or naturalised riverbanks with dense vegetation" (Palazón 1998). However, these data are partially or totally based on distribution, trapping and historic data, and can be misleading. Our results suggest that European mink do not need pristine habitats, but habitats with some features like bramble patches or other. Tolerance to humanisation gives a glimpse of hope to the species as conservation seems possible also in populated areas. However, further research is needed in order to determine which habitat characteristics are favourable for the European mink and which are detrimental for the species, and make an effort for its conservation managing landscape and habitat features to favour its presence.

Both mink species move at ease beneath dense bramble patches.

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CHAPTER 5**

Factors affecting river-stretch occupancy by the European mink (*Mustela lutreola*) in Biscay.

ABSTRACT

In this chapter we have developed a model for mink distribution in Biscay in order to catalogue variables influencing its presence / absence. Sites were described with vegetation parameters, water quality, riverbank alteration, human-made structures and American mink presence. Then we performed a Logistic Regression Analysis that helped identifying ruling variables as well as 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 through a depression in prey availability. In the case of water pollution bioaccumulation is considered to possibly have a deleterious effect on the species' presence, whilst in the case of canalisations 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. From the rest of variables only these describing European mink's within-home range habitat use seemed to have a little influence on the presence of the species. Presence of the American mink was a bad predictor of the absence of its European counterpart. Based on the results, we suggest that improved riverbank management policies are needed in order to ensure the future of the European mink in the area. European mink introduction and reintroduction programs should consider our habitat model when seeking for suitable areas for the species. Besides

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** Originally Published as: Zabala, J., Zuberogoitia, I. and Martinez-Climent, J. A. *In Rev*. Factors affecting occupancy by the European mink in South Western Europe.

further research is needed on the effect of diverse types of water pollution on the European mink.

European mink is absent from canalised and very pollutes streams, regardless of presence of the invasive American mink. How the fragmentation of linear structures may affect the species remains unknown.

INTRODUCTION

The European mink *Mustela lutreola* Linnaeus is a riparian mustelid native to the continent. It has been present across most of Europe; from the Pechora River basin in the East to the Iberian Peninsula, and from the tundra near Arcanghel to the Caucasus (Youngman 1982). However, during the second half of the 20th century, it has experienced a severe regression resulting in two major population nuclei: one in the East, with mink divided in several populations and still declining, and another one in the West, which seems to be expanding Southwards while disappearing from the North (Youngman 1982, Maran and Henttonen 1995, Maran et al. 1998a, Sidorovich 2000a, Macdonald et al. 2002, Maizeret et al. 2002). Although no single factor has been identified as responsible for the decline in the whole area, habitat loss and degradation, interspecific relationships with the American mink *Mustela vison* Schreber and the Polecat *Mustela putorius* Linnaeus are usually pointed out as possible causes (Maran and Henttonen 1995, Sidorovich et al. 1995, Tumanov 1996, Maran et al. 1998a, Macdonald et al. 2002). The potential hybridisation with polecats (Davison et al. 1999, Davison et al. 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 as a consequence of this drastic regression, including captive breeding programs and reintroduction trials to islands (Maran 1996, Macdonald et al. 2002).

Although habitat loss and degradation are considered as two of the main causes of decline in most works, its effect has been poorly studied (Tumanov 1996, Maran and Henttonen 1995, Maizeret et al. 1998, Maran et al. 1998a, 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 of the European mink has been mainly studied in the Easter area, where the American mink has been suggested to be the reason for the disappearance of the native mink from some areas, an hypothesis emerging from aggressive physical interactions observed in captivity-held experiments (Maran et al. 1998a, Sidorovich et al. 1999, Sidorovich 2000a, Schröpfer et al. 2001, Macdonald et al. 2002). Interestingly, the only work conducted in the western area reviewed the decline of the species North-Western France in the last decades of the XXth century and concluded that the conjunction of intensive trapping, alteration of 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 due to the current protection status of European mink.

Knowledge of habitat requirements of a species is of paramount importance for its conservation. This is especially true for European mink and it is vital that conservation action be based on realistic understanding of the causes of population decline (Woodroffe 2001). For example, no amount of captive breeding can bring about the recovery of wild populations if they have declined as a result of habitat destruction (Woodroffe 2001). Thus, overlooking key variables can lead to inadequate definitions of the problems, inadequate solutions, and continued losses (Clark et al. 2001). Habitat use and selection is 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, Martínez et al. 2003, Weir and Harestad 2003). Johnson's second order of habitat selection (selection of the home range site on the available area) provides a good insight on the factors ruling the presence/absence of a species, and, indeed, has been used to describe medium scale distribution patterns of carnivores and other species (FitzGibbon 1993, Rodriguez and Andrén 1999, Carroll et al. 1999, Gates and Donald 2000, Suarez et al. 2000, Madsen and Prang 2001, Manel et al. 2001, Schadt et al. 2002). Besides, using adequate statistical techniques may help understand regression causes with the stress on 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 in order to develop a predictive model that helps to enlighten the factors responsible for the presence / absence of the species and therefore of its current regression, including possible synergies. The results should be a basic tool for forthcoming introductions and reintroductions of the species and stream management and improvement.

STUDY AREA

The study was conducted in Biscay, Basque Country (SW Europe) (Fig. 1). Biscay is 2236 km² and its population about 1.2 million inhabitants. Landscape is hilly and rugged, and altitudes range from 0 to 1475m a. s. l. (Gorbea Peak) Climate is oceanic, with annual rainfall ranging between 1200 and 2200 mm, and annual average temperatures varying from 13.8ºC to 12ºC. Winters are mild and there is not summer drought. There are several short, small and fast flowing catchments running into the Bay of Biscay. Streams show different degree of pollution ranging from heavily polluted to clean waters. Major infrastructures such as roads and villages run along valleys and some riverbanks haven been altered and partially canalised. The upper parts of the streams are the least modified of all, and usually there are gallery forests of alders *Alnus glutinosa* and willows *Salix sp.* in the banks. The medium 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, river bank vegetation is mainly composed of brambles (*Rubus sp.*) or it is absent (Navarro 1980). Several low parts are canalised. Out of the urban areas, land is mostly devoted to forest cultures, mainly exotic *Pinus radiata* and *Eucalyptus globulus*, which occupy more than half the surface of Biscay (Departamento de Ordenación del Territorio y Medio Ambiente del Gobierno Vasco 2001).

The European mink is known to inhabit Biscay since 1960, occupying most of the area with only small gaps in its distribution (Rodriguez 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, the oldest datum of a feral American mink dating back to 1993 (Zuberogoitia and Zabala 2003a).

MATERIALS & METHODS

European mink distribution and sample units:

In order to set the distribution of European mink we conducted an extensive live-trapping survey on the whole area. We also gathered all records of European mink available for the last three years, chiefly from other extensive distribution studies, local studies, radio tracking data and road kills, which were used to check and complete the distribution pattern.

Since riparian mink activities are closely related to streams (Youngman 1982, Dunstone 1993, Garin et al. 2002a) a buffer area of 25 m was set at each side of river stretches and, subsequently, river stretches were subdivided into polygons of 100 m long each to create homogeneous sample units (Zabala et al. 2003). To ensure that areas characterised as positive from single data were included in actual European mink home ranges (i. e. to avoid biases due to possible gaps in distribution areas), we created a confidence range based in the knowledge of the ecology of the species from one of the considered catchments (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 (*see* Zabala and Zuberogoitia 2003c). Then, we randomly selected a set of points within known home ranges (*see* Garin et al. 2002a, Zabala et al. 2003), and we compared a set of distances (100m, 200m, 300m, 400m, 500m, and so on) measured upstream and downstream from the randomly selected points with the distances actually included in the home range. Thus we set the confidence interval of distance that can be considered as included in the home range of an animal measured upstream and downstream from a random location. We randomly selected points in catchments where European mink are absent and also characterised the same number of polygons upstream and downstream. The comparison based on known home ranges of distances measured upstream and downstream from a randomly selected point within mink home range showed that distances of 500 metres at both sides could be considered as included in the home range, as there were no statistical differences among them (Table 1). Therefore, we characterised 500 metres upstream and downstream of the 36 considered points, for a total of 360 polygons (i. e. 36 kilometres of streams), of which 130 were within mink home ranges and other 230 were in areas with no evidences of the presence of European mink.

These polygons were equally distributed across the whole area in main rivers and big 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)

Table 1. Comparison with Wilcoxon's text and Student's t 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	500	1000	1500	2000	2500
Willcoxon's z	-1.6	-2.37	-2.8085	-3.1	-3.412
Sig.	0.11	0.02	0.005	0.001	0.001
Student's t	-1.7	-2.8	-3.8	-4.6	-6.1
Sig.	0.1	0.01	0.001	0.001	0.001

The comparison between used against available areas provides a much better approach than the comparison of used vs. unused (Jones 2001), since the unused areas must be suitable but unused because the species has not or can not reach in (Begon et al. 2006). So, in order to ensure the availability of the negative points we ensured that considered points were available to European mink by modelling their dispersion area. It is known that dispersal distance of mammals is best predicted by home range size, and that the relationship between maximum dispersal distance is isometric to the linear dimension of home range multiplied by a constant that ranges from 7 to 40 (Bowman et al. 2002). Therefore, we set a search radius of 13 kilometres as a basis, based in the home range sizes of male European mink in a catchment of the study area (Garin et al. 2002a, Lodé 2002). We only considered negative polygons into these dispersion areas measured from presence data. Dispersal distances of the European mink calculated as 7 times the linear magnitude of the home range (Bowman et al. 2002) covered the whole study area. The most conservative buffers of a radius of 13 km (more or less the linear dimension of mink home ranges) performed around European mink presence data included almost the whole region, and for this study we only considered polygons included in this area in order to assess the maximum availability.

Variable selection:

To characterise polygons, we selected a set of eight variables describing vegetation, impact of human activities and other factors that have been suggested as possible causes for the decline of the European mink (table 2). From a set that can potentially influence the habitat selection of small carnivores (Weber 1989, Brainerd et al. 1995, Genovesi and Boitani 1997, Zalewski 1997a, b, Sidorovich and Macdonald 2001) we considered those that in a previous work were retained for analysis after running exploratory analyses at other habitat use order *sensu* Johnson (1980) (*see* Zabala et al. 2003, Chapter 3). 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 (Maran et al. 1998a, 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 defined in five categories. The first two are representative of well preserved streams; the category Altered included rivers that had been intervened to a certain degree but the natural substratum has not been changed and vegetation is still present. Streams that had been canalised building an artificial bed of rocks which allows certain degree of vegetation growth where classified as Canalised, as well as rivers that where secluded in concrete walls but including some metres of natural shore. Finally streams running along concrete canals were classified as Aggressively Canalised. American mink presence was defined after 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 has been detected. American mink were considered rare in catchments where there are sporadic data on the species, probably dispersive individuals, and American mink was recorded as absent in catchments where there were no captures and there are no data on the species for the last five consecutive years. Data on water pollution were provided by the Department of Land Ordination and Environment of the Basque Government. Due to the characteristics of streams data from a single punctual sampling should not be considered as representative of the year-round conditions (Elosegi et al. 2002). Thus we used BMWP' (Biological Monitoring Working Party adapted for Spain) scores that represent not the status of the river during the sampling period but the overall status of the watercourse. BMWP scores were summarised into six categories. Values for the rest of the variables were obtained with the aid of a GIS.

Table 2. Variables describing stretches. Bramble cover stretches stands for the degree of bramble cover in the riverbank. Riparian forest stands for the degree of forest cover in the riverbank. Forest cover stands for the forested area inside the polygon. Riverbank alteration the degree of human intervention on the riverbank in the polygon. Presence of American mink was treated as "present" when stable populations are known in the area, "rare" when there have been individuals sporadically detected in the area, and "absent" when no American mink has been detected in the area in the last five years. Pollution stands for the quality of water after BMWP categories, with BMWP scores defining them in brackets. 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 fall totally or for the most part inside the polygon.

VARIABLE	CATEGORY	VARIABLE	CATEGORY
BRAMBLE COVER		RIPARIAN FOREST	
	0-25%		0-25%
	26-50%		26-50%
	51-75%		51-75%
	76-100%		76-100%
FOREST COVER		RIVERBANK ALTERATION	
	0-25%		NATURAL
	26-50%		SLIGHTLY ALTERED
	51-75%		ALTERED
	76-100%		CANALISED
POLLUTION			AGGRESSIVELY CANALISED
	CLEAN WATERS (>120)	AMERICAN MINK	
	UNPOLLUTED WATERS (101-120)		ABSENT
	CRITIC QUALITY (Signs of Pollution) (61-100)		RARE
	POLLUTED WATERS (36-60)		PRESENT
	VERY POLLUTED WATERS (15-35)		
	EXTREMELY POLLUTED WATERS (<15)		

Statistical analyses:

In order to determine which variables explained the presence of the European mink we performed a Logistic Regression (LR) with all the variables using the forward Wald Stepwise method (Morrison et al.1998). The LR is a type of multivariate analysis that allows the inclusion of both, categorical and parametrical variables (Ferrán 1996). For the LR, we randomly selected 20 polygons plus 8-10 more for each variable in the analysis following the recommendations of Morrison et al. (1998) and Vaughan and Ormerod (2003). In total, we used 108 polygons for the 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 polygons and 52 absence polygons). Polygons where randomly selected, extracting one from each catchemnt at a time to keep problems of spatial pseudo-replication at a minimum. The Stepwise method is an exploratory tool that allows one to identify the best predictors from the 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 on 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 prediction success understood as performance of the model, the Area Under Curves (AUC) of Relative Operating Characeristic (ROC) has been proposed as an alternative approach to measure discrimination capacity (Pearce and Ferrier, 2000, Manel et al. 2001). AUCs measured from ROCs are independent of prevalence and highly significantly correlated with the easily computed Cohen's kappa (Manel et al. 2001), therefore, we calculated Cohen's kappa to evaluate the models.

The selection of categories within the variables produced by the LR was tested using the X^2 test corrected with Bonferroni´s inequality (Manly et al. 1993). Electivity was assessed trough Jacobs' index (Krebs 1989). 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. In this way, and in order to assess the relative importance of the different hypotheses for the regression of the autochthonous species at the study area, we built a table assessing the explanatory value of variables considered individually. We first performed a LR with no variables and based in a constant that predicts that every datum will have a negative value (i. e. absence of mink) to assess the explanatory value of a model without variables or constant based model (CBM). Afterwards we modified the requirements of the LR in order to include variables in the model regardless of their statistical significance and performed a LR for variables that have been proposed as important for the presence-absence of the species (Maran and Henttonen 1995, Sidorovich et al. 1995, Tumanov 1996, Maran et al. 1998a, Lodé et al. 2001, Lodé 2002, Macdonald et al. 2002, Zabala et al. 2003). Of each LR we considered the explanatory value of the target variable and we calculated the increment of the explanatory value relative to the CBM as well as Cohen's kappa 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 value of the CBM from that of the variable-based model and multiplying the output by two. We assumed that the variable classifies correctly positive and negative data but only the change in positive data is noticeable due to the characteristics of the CBM. Finally we also considered the statistical significance of the variable, and Cohen's kappa of the model. When there was not a statistically significant relationship between the considered variable and the presence-absence of the European mink, Cohen's kappa's values were not considered. Note that independently of the model for the study area considering every variable, the purpose of this last analysis is twofold: first, it is intended as a tool suggesting management practices, and secondly as a way to assess the importance of different variables in the decline of the species.

RESULTS

We conducted over 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 mink road kills, 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 European mink were determined through radio tracking in three of the catchments, whilst in other three were obtained following the procedure described in methods. Presence of European mink in catchments where no radio-tracking was conducted had been reported also in previous studies (Palazón et al. 2002), so individuals were assumed to be residents.

The LR created a two-steps model (Table 3). Water pollution was included in the first, and Riverbank Alteration in the second. Both steps reached the statistical significance for Cohen's kappa, which had increasing values at each step (Table 3).

Table 3: results of the LR and predictive value of the model at each step.

STEP	INCLUDED VARIABLES	Wald	D.F.	p	Correctly predicts			Cohen's Kappa	Kappa's approx 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 Alt.	11.213	4	0.024					

We analysed the influence of these two variables using the X^2 test corrected with Bonferroni´s inequality and trough Jacobs' index. European mink dwelt in clean water streams, being absent from the polluted ones (Table 4). No polygon with extremely polluted waters was found within home ranges of European mink, and in consequence it could not be testes after Bonferroni's inequality but it doubtless has biological significance. On the other hand, mink also avoided canalised streams preferring natural or slightly altered waters (Table 4). Intermediate values of both categories where used as available.

Table 4. Variables influencing the presence of European mink assessed through the Jacobs' index. Values that reached statistical significance after using Bonferroni's inequality are marked with * (note that -1 Jacobs' values can not be tested with Bonferroni's inequality).

VARIABLE	CATEGORY	JACOBS
WATER POLLUTION		
	CLEAN WATERS	0.49*
	UNPOLLUTED WATERS	0.25
	CRITIC QUALITY (Sings 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*

Finally, among the series of LR performed with single variables (Table 5) only the variables Pollution, Riverbank Alteration, Bramble Cover and Riparian Forest were statistically 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. Besides, the model's performance tested with Cohen's kappa was statistically significant in several cases but no for Forest cover, Buildings, Roads and American mink (Table 5), suggesting that they are of scarce importance explaining the presence of European mink at the study scale.

Table 5. Performance of several variables after running a single variable LR. Values are approximate. SIG states for the level of statistical significance of the relation between the considered variable and presence-absence of European mink. Cohen's kappa measures the probability of the model being consequence of chance, in variables not related with the European mink presence, see text for further details.

VARIABLE	CORRECTLY PREDICTS	APPROXIMATE INCREMENT OF THE EXPLANATORY VALUE	SIG.	Cohen's Kappa	Kappa's approx significance
CONSTANT (Model without variables)	50.9%	0.00%	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

DISCUSSION

Our model explained the absence of European mink from catchments mainly through water pollution and the degree of canalisation. The model did not consider Bramble Cover that was among variables selected at a lower order of selection (Zabala et al. 2003).

At our study area, European mink were absent from every polluted water course, whilst they seem to actively select clean waters. Reasonable doubt persists as to the later being an artefact due to the lack of independence of habitat use data. The avoidance of polluted waters pushes locations expected there to other categories (Jones 2001). In some cases, European mink dwelt in stretches of polluted or even very polluted waters, but such areas were always close to the river's mouth and, thus, they are marginally represented in home ranges. A similar pattern was found by Lodé (2002) in France, where mink avoided poor quality watercourses. Lodé (2002) suggests that bioaccumulation and prey loss may explain that distribution pattern. Indeed, the high trophic level of carnivores makes them susceptible to the bioaccumulation of toxicants (Funk et al. 2001), and this factor has been singled out as one of the possible causes for 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 and they are little sensitive to seasonal effects, as opposed to other indexes, but also depict the effect of diverse types of pollution (Zamora-Muñoz et al. 1994, Zamora-Muñoz and Alba-Tercedor 1996, Ruse 1996, 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. Data on heavy metals, PCBs and other toxicants are scarcely available for our study area and not systematically collected. Interestingly, there are however small-scale studies that show above lethal tolerance levels of Cu, Cr, Cd, Pn, Ni and Mn and concentrations over the lowest effect level of naphthalene and other PAHs, Lindane and PCBs for four of the considered catchments were the European mink is absent (Martínez-Madrid et al. 1999a, Martínez-Madrid et al. 1999b). Moreover, heavy metals are known to accumulate in prey species such as the crayfish in direct relation with their availability in the medium (Anton et al. 2000). López-Martín et al.(1994) found important quantities of PCB-s in European mink tissues. Although bioaccumulation of toxicants is also a major reason for the decline of other semi-aquatic mustelids such as the otter (Chanin 1993, Yamaguchi et al. 2003), a minority of other mustelid populations may thrive in areas with levels of heavy metals that surpass the bioaccumulation of theoretically lethal doses (Kruuk 1995). Therefore, tough we can not be conclusive about the deleterious effects of pollution and which factors might be influencing the absence of European mink, we suggest that bioaccumulation might play an important roll, 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) point out that fishes contribute by 30% and amphibians by 1.5%. Interestingly, amphibians are the main prey item of the European mink in Belarus, with an important presence of fish and crayfish (Sidorovich 2000b). These prey species might be absent from areas with the worst BMPW values, as well as from areas with low BMWP scores. Lodé (2002) found that, in France, the European mink occupied watercourses showing the better fishing quality either in salmonid or cyprinid water courses. However, relationships between low BMPW scores and fish availability are difficult to assess. We propose the effect of water pollution as an important research issue for forthcoming studies on European mink conservation.

The second variable highlighted by the model was the degree of canalisation of the watercourse. Again there was a clear rejection of altered watercourses whilst less managed ones were used according to availability. Canalisation affects negatively European mink in a variety of ways. Prey availability, and denning and resting sites accessibility 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 can not burrow, nor use roots or dense riverbank bramble patches as denning or resting sites. Moreover, a high availability of such structures has been related to within-home range habitat use of the European mink, and to a safe and efficient exploitation of resources (Zabala et al. 2003, Zabala and Zuberogoitia 2003b). Canalisation also implies a severe alteration of the riparian mosaic. Through the change of 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). 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 amphibians availability by the river side (Escala et al. 1997, Marnell 1998, SEO/Birdlife 1999, Ouin et al. 2000, Zuberogoitia and Torres 2002, Carter and Bright 2003). Moreover, influx of leafs and wood into the streams is prevented, which in some cases is the main source of accumulation of organic matter and habitat diversity in watercourses, specially in heterotrophic upper reaches (Díez et al. 2000, Larrañaga et al. 2003). Thus food and habitat availability for aquatic organisms becomes reduced. Although mink diet is variable, probably the species can not thrive in areas with no aquatic food at all. Lodé (2002) suggested that since mink are not exclusive fish predators, availability of fish in watercourses may be expected to have a low impact on European mink presence. However, fish and aquatic food account for an important part of the diet in every study area (Maran et al. 1998b, Palazón 1998, Sidorovich 2000b, Macdonald et al. 2002) and although they may switch to other food sources, the complete absence of aquatic food (amphibians included) may bring about a severe degradation on habitat suitability for the species. Moreover, if canalisation is combined with polluted watercourses mink probably deal with both lack of food and the adverse effects of bioaccumulation of toxicants, which may eventually drive the species out. Loss of prey species may have other effects less direct and difficult to measure, such as the combination of reduced fecundity, reduced neonatal survival and reduced adult survival (Ginsberg 2001, Fuller and Sievert 2001).

Although there were several polygons including canalisations or altered riverbanks within European mink home ranges (*see* 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 are absent are long stretches of as much as 5-6 kilometres. From a species point of view, landscape is typically made of suitable habitat patches interspersed in a matrix of hostile areas precluding use or dispersal (Macdonald and Rushton 2003). Lodé (2002) considered that polluted watercourses may act as barriers for mink dispersal, and concluded that the European mink population from France suffers of severe fragmentation that may be reaching a critical threshold. However, provided that riverbank vegetation is preserved, polluted streams could act as valid corridors for long dispersal 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 no suitable for European mink, but probably also act a barriers for dispersion and create gaps on the distribution of the species. Although Sunquist and Sunquist (2001) suggested that the use of island biogeography theory for the prediction of the effects of habitat fragmentation may perform poorly under the assumption that animals can not travel through hostile habitat. The European mink population in South Western Europe is known to be a metapopulation fragmented into several subpopulations (Lodé 2002, Maizeret et al. 2002, Palazón et al. 2002) and canalised streams may interrupt the spatial structure of the metapopulation imperilling its viability. Finally, canalisations related to roadways crossings and similar structures within European mink home ranges probably have also a deleterious effect through enhancing probabilities 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 dispersal of medium-sized carnivores (Ferreras 2001) it is reasonable to conclude that canalisation of the rivers is a major threat for the persistence of the European mink. Despite the potential effect in the long run of inbreeding, heterozygote deficiency and genetic isolation (Lodé 1999, 2002, Saveljev and Skumatov 2001, Lodé et al. 2003, Michaux et al. 2004), in the short term, difficulties to breed, demographic stochasticity and other hazards for small and fragmented populations seem of mayor concern (Darwen and Green 1996, Rushton et al. 2000). Especially in areas like Biscay in which any barrier might create several very small isolated micropopulations due to the small size of the catchments. Finally, as can be drawn from the data exposed in Table 5, in areas where water pollution is low, riverbank alteration could be the main factor influencing European mink presence.

Lodé et al. (2001) estimated the importance of several factors on the regression of the European mink through the analysis of historical data, and their findings suggest that the conjunction of intensive trapping, alteration of water quality and habitat alteration are the critical factors explaining the decline in north-western France. Interestingly, the last two factors are the main explanatory causes for the absence of European mink in catchments in Biscay nowadays, what might support our model. Therefore, regardless of their possible role as causes of the historic regression, they seem to be main factors causing the current regression in European mink populations in densely populated areas of Western Europe. On the other hand, the referred authors, as well as some others (Tumanov 1992), state that competition with American mink can not be invoked as the main cause for the decline in France, disagreeing with the results from most works conducted in Eastern Europe (Maran et al. 1998a, Sidorovich et al. 1999, Sidorovich 2000a, Schröpfer et al. 2001, Macdonald et al. 2002). Interestingly, our model did not consider the presence of the American mink as a predictor for the absence of its European counterpart (Table 3). Furthermore, American mink presence was among the variables with the lowest performance in our series of exploratory LRs (Table 5), it was not related with the presence-absence of the European mink, and the model based on it did not reach statistical significance. This agrees with Lodé et al. (2001), who reported that American mink remained absent or rare in 62.4% of the area from which the European mink had disappeared. Therefore, the American mink should not be considered as the only mayor concern in the area. Moreover, behind 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. But this possibility still requires further analysis, and studies in areas less modified than Biscay and at fine-grained scale, studying the effect of American mink over the European one where they coexist on the same catchment, where it could be its major threat. Notwithstanding, there is the possibility 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 generalistic regarding habitat and diet (Niemimaa 1995, Palazón 1998, Ferreras and Macdonald 1999, Sidorovich 2000b, Jędrzejewska et al. 2001, Sidorovich and Macdonald 2001, Sidorovich et al. 2001, Zabala et al. 2003) may take advantage of the narrower habitat requirements of the former to take over. A note of caution is needed here though since the consequences of the settling of the American mink may have not yet run their full course (Macdonald and Thom 2001).

Table 5 shows that of those not included in the model, Bramble Cover and Riparian Forest are the variables best predicting European mink presence. Interestingly, these are among the variables ruling 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 determinant for a given habitat selection order also influence the habitat selection of related orders, although only in a second level of importance.

Rivers and river-systems are ecosystems of paramount importance for humankind. In our study area, like in all Western Europe, they are used for water, energy, food, transportation and also provide with fertile soils, whilst they represent potential hazards like floods (Elosegi et al. 2002). Therefore, they are intensely managed ecosystems supporting increasing pressure. In these areas, and bearing in mind that much of the between-species variation in extinction risk can be accounted for by external anthropogenic factors (Purvis et al. 2000), the future of the endangered European mink in the area is linked to a proper management of the streams in which it dwells. This involves especially water quality improvement and riverbank sensitive management and improvement, as opposed to traditional conservation policies carried out so far. Introductions of the species to new areas had been tried paying especial attention to American mink presence-absence (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 if they consider empirical evidence discussed in this paper, as well as in Zabala et al. (2003), because carnivore populations can be disproportionately hard to re-establish by means of reintroduction than other mammals, and the final success of reintroduction projects depends mainly on the habitat quality of the release area (Breitenmoser et al. 2001).

More research is needed in order to validate and improve our model in other areas of Western Europe as well as in European mink populations from Eastern Europe, and to gain more insight into the effect of water quality alteration on the species.

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CHAPTER 6††

Winter habitat preferences of feral American mink (*Mustela vison*) in Biscay.

ABSTRACT

We studied correlates of habitat use of riparian feral American mink during winter. During resting periods both sexes selected areas with dense scrub and near to deep waters. Both sexes used underground dens as well as resting sites located above the ground, but during cold days females rested in human buildings much more often than males. While in activity females used areas of dense scrub and males large scrub patches. The results are interpreted in the light of mink's hunting techniques and perceived predation risk. The strong preference for banks vegetated with dense scrub provides with opportunities for management options for the control of the species.

†† Originally published as: Zabala, J. Zuberogoitia, I. and Martinez-Climent, J. A. *In Rev*. Winter habitat preferences of feral American mink (*Mustela vison*).

INTRODUCTION

The American mink is a carnivore mustelid whose original range spreads over part of North America. However, introductions for fur purposes and escapes from fur farms have lead to the establishment of feral populations in many areas (Macdonald and Harrington 2003). These feral populations are claimed to be causing some trouble in many areas (Ferreras and Macdonald 1999, Previtali et al. 1998, Macdonald et al. 2002) and eradication and management schedules have been developed. Eradication is usually carried out by live-trapping to avoid killing non-target species, and from late summer to early spring so as to not interact with breeding of other riparian species such as the highly endangered European mink and because trapping success is usually higher during winter (Zabala et al. 2001). Management programs greatly benefit from knowledge and understanding of the target species, for it provides better tools and chances for success.

Research on the habitat requirement of listed species is a main concern for ecologists. However the term habitat has been widely used in a non unified way with very different meanings (Garshelis 2000). In this work we refer to habitat as the collection of resources and conditions that an animal needs to occupy an area (Garshelis 2000). Therefore, it is considered a species-specific term. Preferences are considered as the intense use of some areas, characteristics and/or structures with regard to their availability to the animal. Indeed, animals do not use their home ranges in an homogeneous way; rather they use some areas intensively while some others are seldom visited (Powell 2000, Yamaguchi et al. 2003), reflecting patterns of habitat preferences. Knowledge of these patterns helps making decisions about where to trap and how to manage the environment to favor or difficult the persistence of the species. Animals have different requirements at different ages or status (Palomares et al. 2000), and the same animal may use different resources according to its activity patterns (e.g., resting vs. activity). Activity is mainly devoted to food gathering, and hence habitat use during the activity period of small carnivores is mainly related to food availability (Lodé 1994, Yamaguchi et al. 2003). During rest, habitat use of small carnivores is usually correlated with safe and sheltered places (Zalewski 1997a, Zabala et al. 2003).

However, little is known on the habitat use by the American mink in many areas where it has been introduced, and most works conducted on riparian mink hitherto are old (Gerell

1970, Birks and Linn 1982) or have been carried out using medium-large spatial scales for the analysis (Yamaguchi et al. 2003). Johnson (1980) presented habitat selection as a complex process taking place at different scales, from landscape dynamics to the selection of within home-range areas at smallest scales. In this work we aimed to gain insight into habitat use and preferences at high-resolution spatial scales of American mink during winter, accounting for differences between sexes and patterns of activity.

MATERIALS & METHODS

Study area

The study was conducted in the Butron river system, Biscay, Northern Spain. This is a small catchment 40 km long along its main axis occupying an area of 174 km^2. Climate is oceanic, with annual rainfall around 1200 mm. Winters are mild, without summer drought; January and July average temperatures are 6°C and 18°C respectively. The study was conducted from November 2004 to March 2005, during the coldest winter in 20 years, and focused in 20 km of the medium part of the river system and its tributaries, where the biggest stretch of the main river is 10 m wide and 1.5 m deep under normal weather conditions, although most stretches are between three and six m wide and between 30 and 50 cm deep. Riverbank vegetation is composed by alder trees (*Alnus glutinosa*), willows (*Salix alba*) and heliophytic vegetation forming dense undergrowth especially where trees are absent. Locally riverbank vegetation has been completely extirpated for grazing. Main land uses are forest cultures in upper and step areas and grasslands and cattle rearing in the middle flatter ones. The medium and lower parts of the study area where mainly composed by rich lowland areas of water meadows, where cattle rearing has created kilometres of ditches for drainage. The oldest datum of feral American mink in the area goes back to 1993, but the population is suspected to have originated from a local fur farm closed more than 20 years ago. (Zuberogoitia and Zabala 2003).

Table 1. American mink tracking periods. The number of independent locations is shown. Mink that were not included in the analyses because of scarce data are marked with an asterisk.

Individual	Tracking period	Number of locations	Active	Inactive
MMV1*	16/11/04-13/12/04	5	2	3
MMV2	16/11/04-23/02/05	31	11	19
MMV3*	23/11/04-01/12/04	3	0	2
MMV4	26/11/04-24/01/05	18	4	14
MMV5	13/01/05-07/04/05	25	14	11
FMV1	18/11/04-28/02/05	27	6	21
FMV2*	24/11/04-07/12/04	1	0	1
FMV3	13/01/05-07/04/05	29	14	15
FMV4	14/01/05-07/04/05	25	14	11
FMV5	15/01/05-07/04/05	26	13	13

Trapping and radio-tracking

Animals were live-trapped in single entry cage traps (25 x 25 x 45 cm). Trapping was carried out in streams from November 2004 to January 2005. After immobilisation with 0.8 mg of Zooletil (Virbac. Carros, France) per 100 g of animal weight, animals were fitted with radiotransmitters (Biotrack. Dorset, UK). Radio-collars weighted c. 15 g, i.e. less than 3% of the animal weight in all cases. After radio-collaring, mink were closed again in the trap and set in concealed areas (bramble patches), where they were under observation until they completely came round and then released. During the handling, mink were kept warm using rags to prevent hypothermia. Five adult males and six adult females were caught, and ten of them (the five males and five females) were fitted with radiocollars. A hand-held 3-element Yagi antenna, and TRX-1000S (Wildlife Materials Inc. Carbondale, USA), Sika Model (Biotrack, Dorset, UK) and RX8910 (televilt International AB) receivers were deployed on foot. Fixes were achieved by homing-in (White and Garrot 1990) or triangulation at close distances with an accuracy of 1-2 m^2. Variables describing an area of 25 m^2 around locations were measured in the field. Afterwards fixes were located in high resolution aerial photographs (0.5m pixel) implemented in a Geographic Information System (GIS) with an accuracy of 3 m^2. Animals were classified as either active or inactive according to the level of variations in radio signal strength (Kenward 2001). Tracking periods are detailed in table 1. Mink were radiotracked twice a week. At the beginning we took two fixes per day at different times, but locations tended to be the same or very close, so, in order to avoid bias due to data pseudo-correlation, only one fix per day was considered for analysis (Aebischer et al. 1993). Linear home ranges were calculated as meters of waterway used by mink with the 100% of the locations (White and Garrot 1990, Dunstone 1993, Yamaguchi et al. 2003). With the aid of the GIS we produced a set of regularly distributed point in unused areas within home ranges, and we characterised them as positive locations in order to compare used against available sites. We considered locations and available sites from males separately from those of females.

Variable selection

We selected a set of 11 variables describing habitat features (table 2). Mink habitat use is known to be correlated with the vegetation present along the edge of water, mainly trees and scrub (Gerell 1970, Dunstone 1993, Yamaguchi et al. 2003, Zabala et al. 2003). Therefore we considered two vegetation variables describing the degree of tree and scrub cover, which was estimated in a categorical scale from 0 to 5 regardless of the species. Tall rank grass was recorded as scrub. We also measured the size of scrub patches (length x width x height) or estimated them when measuring was not possible. In addition we measured the width of the stream at the location point and estimated the mean depth. Finally, we included the land use on the immediate area, the distance from the location to the water and the slope of the bank, although these last two variables were only considered in the case of resting animals (Table 2). Regarding resting sites we also took in consideration if the resting site was or not underground (the latter being called dens), and the substratum of the area.

Table 2. Variables considered during rest and/or activity and main analysis in which they were included.

Variable	Activity	Resting	Analysis
Scrub Cover	Yes	Yes	LRA
Tree Cover	Yes	Yes	LRA
Scrub Patch Size	Yes	Yes	LRA
Land Use	Yes	Yes	χ^2
River Width	Yes	Yes	LRA
River Depth	Yes	Yes	LRA
Above ground / den	No	Yes	χ^2
Substratum	No	Yes	χ^2
Distance to water	No	Yes	U test
Bank Slope	No	Yes	LRA
Scrub species	Yes	Yes	χ^2

Statistical analyses

To seek for key variables of habitat preferences we performed a Logistic Regression Analysis (LRA), using the stepwise method and the Wald statistic (Morrison et al. 1998). The LRA is a type of multivariate analysis that allows the inclusion of categorical variables (Ferrán 1996). The Stepwise method is an exploratory tool that allows one to identify 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 some requirements. The selection of variables ends when no further increase on the accuracy of the model can be achieved. For the LRA analyses, we randomly selected 20 polygons plus eight more for each variable in the analysis, following the recommendations of Morrison et al. (1998). We performed separate LRAs for males and females as well as for resting and activity locations. In the LRAs we included all numeric and categorical variables fulfilling the requirements. For each activity period LRA we used between 76 and 90 observations, for which the representation of positives and negatives was balanced.

Afterwards, selection of classes within determinant categorical variables after the LRA was tested using the χ^2 test corrected with Bonferroni´s inequality (Manly et al. 1993). Electivity was assessed trough Jacobs' index (Krebs 1989). For the comparison of distance data sets we used the Mann-Whitney U test, and in the case of categorical variables the χ^2 test, with the Yates correction in the case of dichotomy tables (Zar 1999). α value was set at 0.05 in all cases.

RESULTS

Trapping and Monitoring

We captured and fitted with radio collars 10 individuals, and we successfully radio-tracked 8 of them. We gathered 267 locations, out of which 201 independent locations met criteria for their use in the analysis. Their distribution was 113 female locations (61 resting; 53 active), and 86 male locations (53 resting; 34 active). In addition we characterised following the procedure described in methods 72 non-use points within female home ranges and 73 more within male home ranges.

Resting sites

Resting sites and dens were located at 8 (SD=15) meters from the water, being the mean distance for females being 7 (SD=15) and 9 (SD=15) for males, and the difference statistically significant (Mann-Whitney U test, z=-2.434, p=0.015). The overall use of underground dens was low (30% of the locations, including dens inside barns and other buildings), and was related to rocky substrates ($X^2 11=44.5$, $p<0.001$). Females rested in dens in 36% of the occasions while males did it in 21%, but this difference did not reach statistical significance ($X^2 11=2.341$, $p=0.126$). Females were found resting inside human buildings (barns, henhouses, farms, cottages and similar) in 24.6% of the cases, while males only rested inside buildings in 1.9% of the cases ($X^2$11=10.075, p=0.002). There was a correlation between the use of buildings by females and spells of cold weather ($X^2$1= 17.63; < 0.001). Females reutilized resting sites 1.6 times (SD=0.9, range 1-4) and males 1.9 times (SD=1.5, range 1-7). The difference between sexes was not significant (Mann-Whitney U test, z=-0.484, p=0.628).

Table 3. Results of the LRA for resting sites of females.

Step	Included variables	Beta	Wald	d.f.	p	r	Correctly classifies
1	Tree Cover		28.8	5	0.001	0.360	74.0%
2	Tree Cover		24.4	5	0.001	0.416	73.3%
	River Width	-0.223	6.93	1	0.001		
3	Tree Cover		21.3	5	0.001	0.531	78.6%
	River Width	-0.709	16.8	1	0.001		
	River Depth	0.039	10.7	1	0.001		
4	Scrub Cover		4.6	5	0.033	0.560	83.2%
	Tree Cover		20.9	5	0.001		
	River Width	-0.723	15.6	1	0.001		
	River Depth	0.041	10.51	1	0.002		

The LRA for female resting sites produced a four-step model, extracting the variables Tree Cover, River Width, River Depth and Scrub Cover (Table 3). The LRA for males produced another four-step model with the variables Scrub Cover, Scrub size, Tree Cover and River Depth, differences between available and used sites being statistically significant for every variable but for River Depth (Table 4). The selection of categories within categorical variables for males and females is shown in Table 5. Both sexes selected areas with dense scrub and rejected areas with low scrub cover. Main scrubs used by mink in our study area where dense bramble *(Rubus sp.)* thickets. However, mink also used patches of rank grass, dense shrub underground of hazels (*Corylus avellana*) or reeds (*Arundo donax*), and other species that form dense vegetation structures at the ground level (*Rosa sp.*, *Smilax aspera*, *Lonicera sp.*). The use of areas with no scrub by females (Table 5) is a consequence of their use of human buildings. Both sexes selected positively areas of low tree cover while rejecting areas of high tree cover.

Table 4. Results of the LRA for resting sites of males.

Step	Included variables	Beta	Wald	d.f.	p	r	Correctly classifies
1	Scrub Cover		24.9	5	0.001	0.332	70.7%
2	Scrub Cover		11.1	5	0.001	0.402	72.4%
	Scrub Patch Size	0.001	3.8	1	0.051		
3	Scrub Cover		7.6	5	0.006	0.466	75.6%
	Tree Cover	-0.485	7.3	1	0.007		
	Scrub Patch Size	0.000	5.7	1	0.017		
4	Scrub Cover		6.7	5	0.010	0.494	76.4%
	Tree Cover		7.6	5	0.006		
	Scrub Patch Size	0.001	5.4	1	0.020		
	River Depth	0.014	3.7	1	0.056		

Activity Locations

The LRA for female mink produced a two-step model with the variables Scrub Cover and Tree Cover (Table 6). Females used preferentially areas of dense scrub and scarce tree cover, avoiding areas with scarce scrub and/or high density of trees (Table 5). Males, in turn, selected biggest scrub patches, as deduced by the single-step model produced by the LRA that highlighted Scrub Patch Size as the only important variable (Table 6).

Table 5. Assessment of selection over different categories and correlations between mink locations and land uses in the area. Numerical values indicate the Jacobs' index of electivity, values that reached statistical significance trough Bonferroni's inequality are quoted *.

Variable	Category	Females Resting sites	Females activity	Males Resting sites	Males Activity
Scrub Cover					
	5	0.46*	0.81*	0.70*	Not selected
	4	-0.27	0.00	-0.04	Not selected
	3	-0.04	0.22	0.25	Not selected
	2	0.63	0.00	-0.69*	Not selected
	1	-0.88*	-0.53*	-0.60*	Not selected
	0	-0.19	-0.82*	-0.85*	Not selected
Tree Cover					
	5	-0.83*	-0.68*	0.36	Not selected
	4	-0.91*	-0.88	-0.45	Not selected
	3	-0.34	-0.08	-0.89*	Not selected
	2	-0.28	0.49	-0.16	Not selected
	1	0.26	-0.07	0.38	Not selected
	0	0.74*	0.64*	0.38*	Not selected
Land Use					
	Scrub/Abandoned	0.64*	0.71*	0.88*	0.83*
	Meadow/Orchards	0.05	0.08	-0.78*	-0.64*
	Forest	-0.77*	-0.69*	-0.21	-0.36

Table 6. Results of the LRA for activity locations of females and males.

Step	Included variables	Beta	Wald	d.f.	p	r	Correctly classifies
			FEMALES				
1	Scrub Cover		25.36	5	0.001	0.400	76.3%
2	Scrub Cover		20.6	5	0.001	0.456	81.4%
	Tree Cover		9.5	5	0.002		
			MALES				
1	Scrub Patch Size	0.001	6.40	1	0.011	0.279	75.4%

Habitat use and land uses

Mink locations were unevenly distributed with regard to land uses in the area (Table 5). Selection of land uses was the same during activity and inactivity for each sex but differed between sexes. Both sexes used areas situated in big scrub patches, normally in where agriculture has recently been abandoned, running along step areas, or where riverbank management policies protecting a 5.5 m wide band along the shores have been implemented. Females avoided forested areas while used open areas according to their availability. Males avoided open areas but used forested areas according to their availability.

DISCUSSION

Resting sites were restricted to the immediate surroundings of the river. Although mink occasionally rested at distances of 100 m afar from the water, locations beyond 40 m only accounted for 2% of the total and 90% of locations were restricted to a strip of 10 m from the water level, normally in upper part of the river bank or close to it. Our results are similar to these reported in other works (Dunstone 1993, Yamaguchi et al. 2003). The fact that males rested a little more far away from the water than females is probably a consequence of males using larger streams (vid Table 3) and keeping bigger distances away from the water level due to bigger banks and higher risk of floods because of the torrential hydrology of the study area.

Resting sites were mainly located on the surface and the use of dens seemed to be opportunistic, mink using artificial holes mostly in manmade structures. Both sexes had similar preferences for resting site use. Both avoided resting in open areas, and selected spots with dense scrub cover and deeper water than available. Resting site use of small carnivores has been explained through the influence of three habitat features: shelter against predators, thermal insulation and proximity to preferred feeding patches (Weber 1989, Dunstone 1993, Brainerd et al. 1995, Lindstrom et al. 1995, Genovesi and Boitani 1997, Zalewski 1997a, 1997b, Zabala et al. 2003). Although thermal insulation is not likely to play an important role throughout the year due to the mild temperatures of the study area, it determined the use of human buildings by females. The high surface to volume ratio in mustelids is associated to high energetic costs of thermoregulation (Harlow 1994), and this is even more true for smaller females. Although female mink can probably cope with cold temperatures using underground burrows, they opportunistically used artificial warm structures where they also fed. Manmade structures probably are a potential hazard for mink rather than a valuable resource, for poaching of problematic individuals is common.

Shelter against predators seems to be the driving force for resting sites use. Dense scrub is a barrier to larger predators, and mink move easily beneath it. Mink observed during tracking sheltering in scrub seemed calm despite proximity of dogs or humans. Moreover, mink were rarely observed outside scrub and then only in quiet areas and moving fast. Other studies on habitat use by the American and European mink have also reported strong correlations with scrub (Yamaguchi et al. 2003, Zabala et al. 2003, Zabala and Zuberogoitia 2003). Therefore, the intense use of bramble reflects its huge availability rather than selection over certain vegetative species, because other thickets were scarce and their prevalence was not reflected in the points used to measure availability within home ranges. Studies of habitat use assume that the variables included in analyses are correlated or surrogates to variables or clues that animals use in their decision-making process (Battin 2004). Our results, together with others, suggest that the key for American mink resting site selection might be the preference for three-dimensionally complex structures near the ground that provide narrow passages as well as overhead cover keeping mink out of sight. In areas where little scrub is available, mink may use reed beds, tree roots or other sheltered areas (Gerell 1970, Dunstone 1993, Stevens et al. 1997). In addition, scrub may also offer a slight thermal insulation.

Both sexes also preferred areas with deep waters, although this was secondary to scrub cover. Mink use water as a means for running away by diving when attacked by predators (Dunstone 1993). Resting near deep water suggests that mink use areas with several escape ways in case they are detected. The fact that mink reused indistinctly some underground dens and resting sites in the surface and that they were not used continually, but mink in some cases returned to resting sites after periods longer than a month, suggesting that they use some resting sites in an opportunistic way while others are well known and regularly used. The later could be a consequence of the proximity to preferred feeding areas (Dunstone 1993). Two neighbouring males used the same resting site beneath a huge bramble patch, although they were never found together. In addition, when one of the males was poached, the other overtook most of its territory and used the same areas and some of the preferred resting sites of the former territory owner. This suggests that mink do conduct thorough selection of resting sites and habitat use. Interestingly, overlapping individuals of different sex did not use the same resting sites.

The different use of forested and open areas by males and females is difficult to explain. In any case mink were almost always in dense scrub patches, but females rarely used patches in forested areas whilst males did not use those in open areas. Possible explanations are different prey or microhabitat preferences, and the differential presence of possible predators. Female mink are much smaller than male and they are probably more vulnerable to some predators than males.

Both sexes had similar preferences during the activity and inactivity periods. Again the key variable was scrub, dense patches being preferred by females and large ones for males. In addition females used scrubs more often than available in open areas and less in forested areas (Tables 5, 6). If we assume that activity is mainly devoted to food finding and catching, the habitat preferences during activity are concordant with resting site preferences, bearing out the statement that resting sites are located near preferred food patches (Weber 1989, Dunstone 1993, Yamaguchi et al. 2003). Indeed, a male who remained for several consecutive locations in the same resting site was found to be intensively feeding in a nearby henhouse (100 m) where it killed more than 20 hens before being poached. Studies on habitat use by mink, and small mammals in general, have focused on food availability as estimated by prey abundance (Gerell 1970, Dunstone 1993, Bonesi et al. 2000, Yamaguchi et al. 2003). However, fish move along the rivers thus making their availability variable; small mammals might be abundant in both dense scrub areas as well as open ones (Escala et al. 1997); the presence of crayfish and amphibian is independent of scrub (Marnell 1998, Garcia-Arberas and Rallo 2000, Rallo et al. 2001) and hens, probably the most energetically rewarding prey at the study area, are kept in henhouses or free ranging in fields adjacent to farms, together with some domestic rabbits and other poultry. Therefore, we can hardly suggest that the main force driving habitat use in our study area is food abundance. In the same way, Gerell (1970) also noted that mink used densely vegetated riverbanks, and not adjoining fields despite the high availability of potential prey.

We suggest two not mutually exclusive explanations for the observed preferences in the study area. Firstly, mink do not hunt chasing prey but stalking and/or entering burrows (Dunstone 1993). Mink move easily beneath scrub thickets where they probably find prey and hunt more efficiently. In this way, the use of areas with dense vegetation cover at the ground level will be related to prey availability, but not necessarily to prey abundance. On the other hand, carnivores are subject to interspecific predation by larger carnivores, and intraguild predation can account for more than half the casualties (Palomares and Caro 1999). Otters, foxes, dogs, humans and probably cats and large raptors and owls kill mink (Zuberogoitia et al. 2001, Bonesi and Macdonald 2004). The importance of behavioral decisions made tacking into account predation risk has been widely studied in small mammals, birds and other prey groups (Lima and Dill 1990). Perceived predation risk may affect many, if not all, aspects of animal ecology, and it certainly influences time budgets, patch selection and food selection (Lima and Dill 1990, Buskirk and Powell 1994, Barreto and Macdonald 1999). Moreover, the response of prey to clues of predation risk is, is some cases, innate (Barreto and Macdonald 1999), and in the case of mink fearful response to humans, novel situations and foods is hereditary (Malmkvist and Hansen 2002), suggesting an evolutionary adaptation to avoid predation. In addition to hereditary traits, there is growing evidence that animals are able to assess and behaviorally influence the probability of being preyed upon (Lima and Dill 1990). Most works on habitat use and preferences of mink have pointed out the utilization of areas with vegetal cover and strong avoidance of open areas (Gerell 1970, Dunstone 1993, Stevens et al. 1997, Previtali et al. 1998, Bravo and Bueno 1999, Yamaguchi et al. 2003). In some cases, dense shrub entanglements or bramble thickets can prevent access to mink by other predators, while other structures such as reeds or rank grass can be entered by dogs, foxes and similar predators. They keep mink concealed and allow them to sneak out if harassed. In addition, all the vegetation covers reported in literature provide overhead story to mink, keeping them out of sight from avian predators.

The dependence of American mink to dense bank vegetation provides opportunities to habitat management in eradication and control programs. Scrub control in riverbank would lessen habitat suitability for the American mink and enhance its vulnerability, while small-medium patches at regular intervals would fit the requirements of other species such as the bank vole (Macdonald and Rushton 2003). However, such management decisions must be cautiously considered because they could interfere also with other riverbank species with similar requirements such as the endangered European mink (Zabala et al. 2003, Zabala and Zuberogoita 2003).

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Mink rest preferinatly close to deep waters and may dive to run away from predators.

CHAPTER 7‡‡

Sexual dimorphism, niche segregation and intersexual competition in American mink

ABSTRACT

Many animals, especially mustelids, show a spacing pattern known as intrasexual territoriality in which territorial animals defend areas against individuals of the same sex whilst there is extensive overlap between sexes. It has been argued that this overlap leads to share food resources between territorial individuals of different sexes having a net cost for territorial individuals. Several mechanisms have been proposed to reduce competition between sexes, many of them derived from sexual dimorphism, which is closely related to intrasexual territoriality. Among suggested mechanism is spatial segregation between animals with overlapping areas, although it remains largely untested. We hypothesized that sexual spatial segregation in mustelids could be a consequence of a niche partition in habitat between sexes due to different optimums. We conducted a fine-grained radio tracking survey of feral American mink, and we compared home ranges, relative spatial positions and radio-locations' characteristics of different sexes. We also considered relative distances between simultaneous locations of overlapping individuals to test for dynamic territorial interactions. There were differences in the home range composition of males and females, and in their relative spatial location, proving spatial segregation between sexes. The comparison of locations showed that females preferred smaller streams as opposed to males that preferred large streams. In addition relative spatial position of female locations

‡‡ Originally Published as: Zabala, J., Zuberogoitia, I. and Martinez-Climent, J. A. *In Rev*. Sexual dimorphism, niche segregation and intersexual competition.

was independent of location of males in overlapping pairs, suggesting niche segregation caused by different sexual habitat preferences. Sexual habitat segregation is discussed as a powerful means of avoiding intersexual competition in species exhibiting intrasexual territoriality as spacing pattern.

Female American mink used preferentially small brooks and tributary streams.

INTRODUCTION

Most animals develop their activities of food gathering, mating and caring for young into more or less confined areas called home ranges (Powell 2000). When individuals use their home range exclusively or preferentially defending it against other conspecifics we speak of territoriality (Begon et al. 2006). However territorial behaviour only takes place under certain conditions, and under different environmental conditions a species may show different spacing patterns ranging from group living territories to nomadism (Macdonald 1983, Kruuk 1989, Powell 1994). Traditionally invoked benefits to individuals defending territories are access to mates and exclusive or preferential use of food or other resources, whilst among disadvantages there are the net costs of defending a territory (energetics, risk of injuries etc.) and others (Powell 1994). Anyhow, in order that territoriality takes place, its benefits to individuals must outweigh its costs (Davies 1978, Madconald 1983, Begon et al. 2006, Powell 2000). Intrasexual territoriality is a spacing patter exhibited by many species and typical of mustelids and other small carnivores (Powell 1979, Macdonald 1992, Palomares and Delibes 1994). In such a spacing pattern males defend territories against males and females defend territories against females, whilst there is extensive overlap between sexes. It has been argued that this overlap leads to share food resources between territorial individuals of different sexes overlapping areas, intrasexual territoriality having a net cost for territorial individuals (Powell 1994, Yamaguchi and Macdonald. 2003). This cost might be more acute in the case of carnivores, for the behaviour of some prey species changes after a predator enters a patch, lowering their vulnerability, and thus their availability, and remains altered for as long as a day or more causing resource depression (Jedrzejewski and Jedrzejewska 1990). Several adaptations have been invoked to overcome this handicap. Thus, sexual dimorphism, closely related to species with intrasexual territories (Powell 1979), has been proposed as a mechanism for niche separation and resource partitioning between sexes (Birks and Dunstone 1985, Thom et al. 2004). Different sexes consuming different prey reduces the incidence of home range overlap on competition for resources (Thom et al. 2004). In the same way, sexual segregation in the activity patterns has also been proposed as a means of reducing competition between overlapping individuals of different sexes (Zalewski 2001, Marcelli et al. 2003). A third possibility has been proposed, that males and females rarely use the same suitable patches of overlapping areas, existing an spatial segregation between sexes (Gerell 1970, Erlinge 1977, Lodé 1996). However, little attention has been paid to this last hypothesis that remains largely untested.

The habitat concept might be misleading, for different people have used it with different meanings (Hall et al. 1997, Garshelis 2000). Based on Hutchinson's concept for niche, defined as a hypervolume of n dimensions with a dimension for each environmental condition and resource required for the species (Begon et al. 2006), here we consider habitat as the ranges of a set of physical variables within the niche's hypervolume. Therefore, in this paper habitat is considered a species specific characteristic, as a more or less differentiated part of the ecological niche. Research on trophic apparatus has shown that there is interspecific and intraespecific (intersexual) character displacement, which is thought to be related to niche partitioning as a consequence of competition (Dayan et al. 1989, Dayan and Simberloff 1994). In the same way, interspecific or intrasexual competition could provoke niche partition in other facets such as habitat, although little attention has been paid to this.

The American mink is a mustelid native to North America that has been introduced in many areas where it now is widely distributed (Macdonald and Harrington 2003). It is sexually dimorphic and exhibits intrasexual territoriality (Dunstone 1993, Yamaguchi and Macdonald 2003). Its population being structured along water courses, it is liable to more intraspecific competition pressure for having linear home ranges. Animals can respond to changes in quality of the home range (for instance to resource depletion or depression caused by conspecifics) by expanding it. However, this expansion would be more costly in mink due to the linear shape of their home ranges. We hypothesized that if carnivores with intrasexual territories show spatial segregation and/or habitat segregation as a means of avoiding intersexual competition it would be clear in mink. Moreover, we hypothesized that sexual spatial segregation in mustelids is a consequence of a niche partition in habitat between sexes. Therefore, we conducted a spatially explicit study of habitat use of American mink at very fine-grained scale during winter, the resource shortage season with more intraspecific pressure, to see if (1) sexes show spatial segregation and (2) there is a niche partition in habitat between sexes.

MATERIALS & METHODS

Study area

The study was conducted in the Butron river system, Biscay, Northern Spain. This is a small catchment 40 km long along its main axis and an area of 174 km². Climate is oceanic, with annual rainfall around 1200 mm. Winters are mild and there is not summer drought. The study was focused in 20 km of the medium part of the river system and its tributaries, where the biggest stretch of the main river is 10 m wide and 1.5 m deep under normal weather conditions, although most stretches are between three and six m wide and between 30 and 50 cm deep. Riverbank vegetation is composed of alder trees (*Alnus glutinosa*) and willows (*Salix alba*), and heliophytic vegetation forming dense undergrowth especially where tree species are absent. Locally riverbank vegetation has been completely extirpated for grazing. Main land uses are forest cultures in upper and step areas and grasslands and cattle rearing in the middle flatter ones. The medium and lower parts of the study area where mainly composed of rich lowland area of water meadows, where cattle rearing has created kilometres of ditches for drainage. The oldest datum of feral American mink in the area goes back to 1993, but the population is suspected to have originated from a local fur farm closed more than 20 years ago. (Zuberogoitia and Zabala 2003). Rabbits and other big rodents are absent from the study area and although the diet of mink in the study area is unknown scats collected during the study contained crayfish, fish, small mammals, poultry and berries (*own unpublished data*).

Trapping and radio-tracking

Animals were live-trapped in single entry cage traps (25 x 25 x 45 cm). Trapping sessions were carried out in streams from November 2004 to January 2005. After immobilisation with 0.8 mg of Zooletil (Virbac. Carros, France) per 100 g of animal weight, individuals were fitted with radiotransmitters (Biotrack. Dorset, UK). Radio-collars weighted c. 15 g, i.e. less that the 3% of the animal weight in any case. After radio-collaring, mink were closed again in the trap and set in concealed areas (bramble patches), where we observed them until they completely woke up and then let them free. During all the handling, mink were kept warm using rags to prevent hypothermia. Five adult males and six adult females were caught, and ten of them (five males and five females) were fitted with radiocollars. A hand-held 3-element Yagi antenna, and TRX-1000S (Wildlife Materials Inc. Carbondale, USA) and Sika (Biotrack. Dorset, U.K.) receivers were deployed on foot. In addition, a RX8910 receiver (Televilt International AB, Sweden) with an H shaped antenna was used at close distances. Fixes were achieved by homing-in (White and Garrot 1990) or triangulation at close distances with an accuracy of 1-2 m² and variables describing an area of 25 m² around the point were measured in the field. Then fixes were located in high resolution aerial photographs (0.5m pixel) implemented in a Geographic Information System (GIS) with an accuracy of 3 m². Animals were classified as either active or inactive according to the level of variations in radio signal strength (Kenward, 2001). Mink were radio tracked twice a week starting the next day after capture until early April. Tracking periods are detailed in Table 1. At the beginning we took two fixes per day at different times, but locations tended to be the same or very close, so, in order to avoid bias due to data pseudo-correlation, only one fix per day was considered for analysis (Aebischer et al. 1993). Linear home ranges were calculated as meters of waterway used by mink with the 100% of the locations (White and Garrot, 1990, Dunstone 1993, Yamaguchi et al. 2003). Birks and Linn (1982) reported that mink tracked twice a day revealed their entire home range in 10 days; therefore, conservatively, for home range-related calculations we only considered data from mink radio-tracked more than 20 times. To locate areas of intense use by individuals we built fixed kernel estimators with 95% of the locations and an *ad hoc* cell size of 25 metres (Powell 2000, Kenward 2001). For setting the window size we performed the Least Square Cross Validation (LSCV) (Powell 2000, Kenward 2001), but it did not consider streams as paths and yielded different window sizes for different individuals depending on the scattering of their locations, so we used and *ad hoc* window size of 150 metres, an approximation to the mean LSCV of all individuals. Using digital cartography overlaid to aerial photographs we defined two type of streams based on cartographic generalization (Corsi et al. 2000): main streams were those represented at 1:50000 scales, and tributary or secondary ones these represented only at larger scales (1:25000; 1:5000) but no at 1:50000. To gain insight into the spatial arrangement of the population, using the GIS we measured the position of locations with regard to main axis (i.e. main river). To find out if there was dynamic territoriality, i.e. preferential use by one animal of the shared patches, we measured the distance between simultaneous locations of overlapping individuals of different sex and compared it to one set of potential distances between obtained locations, following Kenward's (2001) procedure.

Table 1. Detailed tracking periods, MMV stands for male American mink and HMV for female American mink. Locations shows the number of independent locations used to build home ranges (capture point included), and active and inactive the number of independent locations obtained to each individual during activity and resting period, respectively. Home range indicates length of the home range expressed in metres. Tributaries shows the portion of the home range composed by tributaries (in metres), and % tributaries the proportion of the home range composed by tributaries.

Individual	Tracking period	Number of locations	Active	Inactive	Home range	Tributaries	% Tributaries
MMV1*	16/11/04-13/12/04	6	2	3	2237	0	0%
MMV2	16/11/04-23/02/05	32	11	19	4085	391	9.3%
MMV3*	23/11/04-01/12/04	4	0	2	1017	36	3.5%
MMV4	26/11/04-24/01/05	19	4	14	1193	123	9.6%
MMV5	13/01/05-07/04/05	26	14	11	15874	10167	64.1%
FMV1	18/11/04-28/02/05	28	6	21	10486	5161	49.2%
FMV2*	24/11/04-07/12/04	3	1	1	332	55	83.4%
FMV3	13/01/05-07/04/05	30	14	15	2099	1539	73.3%
FMV4	14/01/05-07/04/05	26	14	11	4063	2300	56.6%
FMV5	15/01/05-07/04/05	27	13	13	3051	1111	36.4%

Variable selection

We selected a set of 7 variables describing habitat features (table 2). Mink habitat use is known to be correlated with the vegetation present along the edge of water, mainly trees and scrub, with some differences in preferences between sexes (Yamaguchi et al. 2003, Zabala et al. 2003). Therefore we considered two vegetation variables describing the degree of forest cover and scrub cover. In both cases estimations were made in a categorical scale from 0 to 5 regardless of the vegetative species; tall rank grass was included in scrub. We also measured the size of scrub patches (length x width x height) or estimated it when measuring was nor possible. In addition we measured the width of the stream at each location and estimated its mean depth. Finally, we included the distance form the location point to the water and the slope of the bank, although these last two variables only were considered in the case of resting animals.

Table 2. Variables describing locations as measured *in situ*. "Activity" or "rest" show wheter they were considered to characterise each period.

Variable	Description	Activity	Rest
Shrub cover	Density of shrubs within 5 m from each location	Yes	Yes
Tree cover	Density of trees within 5 m from each location	Yes	Yes
Shrub size	Size of the shrubs concealing mink.	Yes	Yes
River width	Width of the water stretch in the river's adjacent point to each mink location.	Yes	Yes
Depth	Depth of the water stretch in the river's adjacent point to each mink location.	Yes	Yes
Distance to bank	Distance from each location to the adjacent water.	No	Yes
Bank	Angle of the bank closest to each location.	No	Yes

Statistical analyses

To seek for differences in niche between sexes we plotted separately active and inactive of males against these of females and compared them using a Logistic Regression Analysis

(LRA), using the stepwise method and the Wald statistic (Morrison et al. 1998). The LRA is a type of multivariate analysis that allows the inclusion of categorical variables (Ferrán, 1996). The Stepwise method is an exploratory tool allowing to identify 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 some requirements. The selection of variables ends when no further increase on the accuracy of the model can be achieved. For the LRA analyses, we randomly selected 20 polygons plus eight more for each variable in the analysis, following the recommendations of Morrison et al. (1998). In total, we used 60 locations for the activity LRA and other 80 for the inactivity locations LRA. The dependent variable was in both cases the sex of mink (male against female), and the independent variables were those in table 2. The number of locations of male mink was similar to those of female in both analyses.

Subsequently, selection of classes within determinant categorical variables after the LRA was tested using the X^2 test corrected with Bonferroni´s inequality (Manly et al. 1993), and electivity was assessed trough Jacobs' index (Krebs 1989). For the comparison of distances' data sets we used the Mann-Whitney U test and Wilcoxon's paired test (Zar 1999). α value was 0.05 in all cases.

RESULTS

MMV3 and FMV2 took off the collar few days after tagging. MMV1 disappeared shortly after radio-tagging and was not found despite a big searching effort along the whole catchment and adjacent ones, radio-tag failure and poaching were suspected (Table 2). Indeed, poaching was confirmed in the case of MMV2, FMV1 and other three untagged animals during the study period.

The mean size of male home ranges, considering only those tracked sufficiently, was 7092 (S.D. 6763) metres, while females' was 4825 (S.D. 3793). Composition of the home range was different between sexes, with males encompassing mainly main river stretches and females a bigger proportion of tributaries (table 2). This tendency is clearer if we pay attention to the location of kernel centres inside animals' home ranges (table 3), with males having most of their intense use areas on main streams and females preferentially in tributaries. Spatial position of the radio-locations was different, males tended to be closer to the main stream than females (Mann-Whitney U=1865.0, p<0.001, n=163). This pattern held in both activity (Mann-Whitney U=265.0, p<0.006, n=60) and resting locations (Mann-Whitney U=548.5, p<0.001, n=99), and also held when locations on main streams (with a 0 value) were not considered for analysis (Mann-Whitney U=437.0, p<0.001, n=98).

Table 3. Composition of the kernel activity centres. Main stream and Tributary indicate length of main streams and tributaries included in kernels. % Tributary shows the percentage of tributaries in the composition of kernel areas. % Home range indicates the percentage of the home range included in kernel centres.

Individual	Main stream	Tributary	% Tributary	% Home range
MMV2	1878	159	7.8	46
MMV4	607	0	0	50
MMV5	3011	1295	30.1	17
HMV1	250	1489	86.6	32
HMV3	0	1390	100	34
HMV4	531	1177	68.9	27
HMV5	500	789	61.2	81

In addition, there were no differences between the distances between simultaneous locations and the set of possible distances among randomly selected locations of overlapping individuals Wilcoxon paired test Z=-0.175, p=0.861, n=432).

The LRA with resting locations produced a two step model, which extracted the variables River Width and Scrub Cover, both reaching statistical significance (table 4). The LRA with activity locations produced a single step model that extracted the variable River Width, reaching statistical significance (table 4).

Differences in niche composition in Scrub Cover were due to females usin areas with lower cover, mainly dens in buildings (Table 5).

Table 4. Results of the Logistic Regression Analyses comparing male and female locations.

Step	Included variables	Beta	Wald	Degrees of freedom	p	r	Correctly classifies
				R E S T I N G			
1	River Width	0.266	11.59	1	0.001	0.215	75.3%
2	Scrub cover		11.50	5	0.042		
	River Width	0.334	6.64	1	0.010	0.369	79.4%
				A C T I V I T Y			
1	River Width	0.180	4.167	1	0.041	0.081	56.7%

Table 5. Differences in niche composition between categories of shrub cover. Ivlev's index show positive values when a category is more used by males. Statistical significance of the differences in use after the X^2 test corrected with Bonferroni´s inequality is expressed with an asterisk

Cover degree	Ivlev's index
5	0.24
4	0.32
3	0.47
2	-0.75*
1	0.32
0	-0.84*

DISCUSSION

American mink in the study area showed spatial segregation in the location and use of their home ranges. Males mainly included in their home ranges stretches of main rivers while females included large stretches of tributaries and little proportion of their home range was composed by main streams, usually at the tributary's junction. Besides, as can be drawn from the location of the kernel activity centres (Table 3), when including considerable distance of main streams, females used them as corridors between tributaries. In addition, contrary to males, females ventured up far inside tributaries and smaller streams, and tended to stay far from the main rivers for most of the time while males tended to remain at them. The fact that males did travel less than females into tributaries suggests that they used them only marginally and mainly near the junction with the main streams. The only exception to this pattern is MMV5 that included 10 km of tributaries within its home range, and used them more often than other males, but still less than females.

On the other hand, the comparison of male locations against female locations yielded river width as a key variable for niche segregation. It is widely assumed that animals use environmental clues to use and select their habitat (Battin 2004). Therefore, the observed segregation could be due to different sexes using slightly different environmental clues or to females being pushed by larger males to lower quality areas. The fact that there were no differences between the distances between simultaneous locations and the set of possible distances among randomly selected locations of overlapping individuals suggests that there are no dynamic interactions between individual of different sexes (Kenward 2001). Therefore, our data does not bear out the hypothesis of males driving out females to suboptimal habitats. In addition, if this were true, we could expect females to enter the main streams when males are absent, but we did not find such tendency. Notwithstanding, male's scats and other marks could inform females and keep them out, but the fact that females did cross large sections of main streams when moving from one tributary to other, and also used dens and resting sites in them does not support this hypothesis. On the other hand, the observed segregation could arise from different sexes having different habitat preferences and different optimum habitats, and in consequence using different clues for making decisions on where to settle and which areas to use. Interspecific competition is supposed to lead to compression from fundamental niche to realized niche, thus allowing species with moderate niche overlap to coexist by segregating the niche (Begon et al. 2006). Intraspecific competition can also drive sexual dimorphism as a result of different selective pressures acting over sexes and lead to niche partition (Dayan and Simberloff 1994, Bolnick and Doebeli 2003). Dimorphic sexes must therefore match different challenges and mustelid females being smaller have different energetic requirements and different thermal tolerance (Peters 1983, Zalewski 2001) and probably different predators. This would explain the second variable extracted by the LRA for resting sites. Females used significantly more areas with low scrub cover as resting sites, but all of them were dens inside buildings. Their use seems associated with snow or cold days and possibly reflects different thermoregulation capability.

Although niche and habitat are commonly treated as species' specific, they actually are characteristics of individuals and much of their variation is due to individual specialization (Bolnick et al. 2003). We suggest that in dimorphic mustelids individuals of the same sex will have more similar niche breath than individuals of different sexes, due to similar sizes and same selective pressures acting over individuals of the same sex. In addition, this would not only be valid for time budgets or trophic niche (Sidorovich et al. 2001, Thom et al. 2004) but also for habitat issues as suggested by our results. Different habitat preferences, or different clues for assessing habitat quality, lead to spatial segregation according to the distribution of preferred patches, and to reduced intersexual competition. Indeed, some studies have reported spatial segregation between overlapping couples in mustelids (Gerell 1970, Erlinge 1977, Lodé 1993, Yamaguchi *et al* 2003) although they did not test for habitat segregation between sexes. Furthermore, Yamaguchi et al. (2003) found that the presence of individuals of one sex within 200-m long river sections was not influenced by the presence of individuals of the opposite sex. They also found some differences in the preferences of two sexes and that presence of females with kits was positively related to the presence of other water sources (i. e. tributaries) (Yamaguchi et al. 2003). However the 200-m long sections they used may have marked segregation patterns that more fine-grained analysis could reveal. In our study area reasonable doubt persist whether River Width is the clue used by mink or it is a surrogate of other structural variables.

The spacing pattern derived from habitat segregation is concordant with that proposed for intrasexual territoriality (Powell 1979, 1994). It has been suggested that the presence of females might be a clue of habitat quality for males of polygamous species, and that dominant males settle their territory and defend areas with females to monopolise reproduction (Powell 1994). The reproductive tactics of the American mink are not very well understood. Recent research has shown that males rarely shire the litters of adjacent females, and that if they do it is only partially (Yamaguchi et al. 2004). During the matting season the spatial structure of the population collapses and males roam seeking for receptive females (Yamaguchi et al. 2004). It is not known what benefit they may obtain bay sharing their areas with females rearing non related cubs. However, knowledge of females' distribution previous to roaming might provide a benefit ensuring the first copula with females and small probabilities to shire some cubs plus these shired after roaming. In addition, costs of sharing territory would be reduced to a minimum through niche segregation. Anyway, breakdown of population structure was not observed in our study area and this phenomenon could be not so widely extended as thought.

Home range of male mink spread mainly over main stream stretches. Although home ranges of males also emcompassed stretches of main stream they seldom used them, and seemed to act as corridors between tributaries.

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CHAPTER 8§§

Environmental correlates of American mink distribution in biscay and relationships with the European mink: physical aggressive displacement, human facilitation, or both?

ABSTRACT

Home range site placing of the American mink in Biscay was studied. American mink home ranges were preferably polluted stretches in areas with historical presence of fur farms, avoiding very polluted and unpolluted stretches. The lack of prevalence of habitat features describing home range site suggests a very adaptative ecology, whilst the linkage to catchments with presence of fur-farms suggest a slow colonization by the American mink in the study area. The linkage with polluted waters and slow displacement of European mink from clean waters suggest that the expansion of the species could have been greatly favoured by human activities. This pattern also explains the regression and expansion experienced respectively by the European and American mink in the last years in southwester Europe and posses out management options for the invasive species in European mink areas.

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§§ Originally published as: Zabala, J. Zuberogoitia, I. and Martinez-Climent, J. A. *In Rev*. Home range site of American mink in Biscay and relationships with the European mink: physical aggressive displacement, human facilitation, or both?

INTRODUCTION

The American mink (*Mustela vison* Schreber) is a widespread introduced carnivore (Dunstone 1993) which may cause severe impacts on the native fauna (Maran et al. 1998a, 1998b, Sidorovich et al. 1999, Macdonald et al. 2002, Yamaguchi et al. 2003). The range of species upon which negative effects have been reported includes not only waterfowl or riverbank rodents (Ferreras and Macdonald 1999, Rushton et al. 2000), but also native species of its guild, such as the huillin or southern river otter (*Lutra provocax*) (Previtali et al. 1998) and especially the European mink (*Mustela lutreola* L.) (Maran et al. 1998b, Sidorovich *et al.* 1999, Sidorovich 2000, Macdonald et al. 2002, Macdonald and Thom 2001). Nonetheless, the American mink does not seem to act always as a pest, in some cases adapting to its new environment without severe repercussions on the native fauna (Gerell 1985, Bartoszewicz and Zalewski 2003, Boitani 2001).

The European mink has experienced a severe, still ongoing regression in the last centuries leading to extirpation from most countries of its previous range. As a consequence, the European mink range is divided in two major populations thousands of kilometres afar from each other, being thus considered one of the most endangered carnivores in Europe (Youngman 1982, Maran and Henttonen 1995, Maran et al. 1998a, Macdonald et al. 2002). One of those populations is subdivided into several scattered subpopulations throughout Eastern Europe (Youngman 1982). Most of these subpopulations are still in regression, most probably due to aggressive interactions with the American mink (Maran et al. 1998b, Sidorovich et al. 1999, Sidorovich 2000, Sidorovich et al. 2000, Schröpfer et al. 2001, Macdonald et al. 2002). The American mink has been shown to display aggressive behaviour towards its European counterpart in captivity-held experiments (Sidorovich et al. 1999, Macdonald et al. 2002, Schröpfer et al. 2001). There is also radio-tacking evidence for such interactions in the wild, with male and female American mink getting out of their way to harass European mink (Macdonald et al. 2002). Accordingly, it has been proposed that American mink populations established in main rivers divide European mink populations into non-viable small subunits along small forest streams (Saveljev and Skumatov 2001).

The other European mink population ranges across south-western France and the north of the Iberian Peninsula (Youngman 1982). This population is disappearing from the north whilst its situation in the south is unclear (Lodé et al. 2001, Maizeret et al. 2002, Zabala and Zuberogoitia 2003a). Interestingly, Lodé et al. (2001) studied the regression of the European mink in France, where it has disappeared from half of its previous range in the last 20 years, and found that the American mink was absent or was rare in 62.4% of the area where the European mink had disappeared from. Thus they concluded that anthropic pressure through the conjunction of intensive trapping, alteration of water quality and habitat modification was the critical factor for the decline in the area (Lodé et al. 2001). Interestingly enough, the presence of American mink in the area had a very poor performance as explaining variable (Lodé et al. 2001, Lodé 2002). In this paper we study the site occupancy of the American mink at the home range location level (approximately equivalent to Johnson's (1980) second order habitat selection) in an area where habitat requirements of the European mink are known (Zabala and Zuberogoitia 2003b, Zabala et al. 2003) in order to get further insight into the relationships between the two species.

STUDY AREA

The study was conducted in Biscay, Basque Country (SW Europe). Biscay, has an area of 2236 km² and a population about 1 200 000 inhabitants. Landscape is hilly and rugged, and altitudes range from 0 to 1475m a. s. l. (Gorbea Peak) Climate is oceanic, with annual rainfall ranging between 1200 and 2200 mm, and annual average temperatures varying from 13.8ºC to 12ºC. Winters are mild and there is not summer drought. There are several catchments whose streams are short, small and fast flowing, running into the Bay of Biscay (Table 1). Streams show different degree of pollution ranging from heavily polluted to clean waters. Besides, main infrastructures such as roads and villages run along valleys and some riverbanks haven been altered and partially canalised. In a typical catchment upper parts of the streams are the least modified of all and usually there are gallery forests of alders *Alnus glutinosa* and willows *Salix sp.* Medium parts of rivers are the most diverse, including well-preserved stretches, stretches forested with exotic plantations, disturbed areas with heliophytic formations and canalised stretches. Finally, lower parts are the most modified if they are not canalised or without vegetation, forested areas are rare and, with the exception of some scarce well-preserved stretches, river bank vegetation is mainly composed of brambles (*Rubus sp.*) (Navarro 1980). Outside of urban areas, land is mainly devoted to forest cultures, mainly exotic *Pinus radiata* and *Eucalyptus globulus*, which occupy more than half the surface of Biscay (Department of Environment and Land Ordination 2001). American mink are known to be present in the area, mostly escapes from fur farms, the oldest datum of feral American mink dating back to 1993 (Zuberogoitia and Zabala 2003).

MATERIALS & METHODS

Distribution and sample units:

We conducted an extensive live-trapping study over the study area in order to check the distribution of the species in Biscay. In total we conducted 1259 traps-night equally distributed over the study area, plus some 500 more conducted in intensive studies on areas where presence of mink species was known or suspected In addition we considered previous data from local trapping studies and from a review on the American mink distribution in the area (Zabala et al. 2001,. Zuberogoitia and Zabala 2003). We assumed that areas 300 metres upstream and downstream from where an American mink capture had occurred could be included in their home ranges. Then, with the aid of a GIS we measured 300 metres upstream and downstream of every American mink considered datum, divided it into 100-metres long segments and performed a buffer of 25 metres at each side of the stream segment (Zabala et al. 2003 Zabala et al. 2004). This length of 25 metres at each side was selected because mink activities are linked to water bodies and their dens are closely related to them (Youngman 1982, Dunstone 1993, Stevens et al. 1997, Palazón 1998, Garin et al. 2002a, Zabala and Zuberogoitia 2003b, Zabala *et al.* 2003). The 100 metres long distance was set as a means to reduce environmental heterogeneity into more or less homogeneous units and to enhance comparability with studies conducted in the area on European mink ecology. The 100 x 50-metres wide polygons created were characterised with several variables and used as sample units.

To assess site availability, we considered a median dispersal distance of seven times the lineal dimension of the home range (Bowman et al. 2002). Home ranges of American mink described in literature tend to be lineal (i.e., strongly bound to rivers), and the reported lengths range from about 1 km to 7.519 km (Gerell 1970, Niemimaa 1995, Stevens et al. 1997, Yamaguchi and Macdonald 2003). Therefore, we considered a conservative home range distance of 3 km and dispersal distances of 21 km (see also Macdonald and Rushton 2003). Then we created buffers of 21 km around each American mink location and considered the area included in them as available for the species. We considered catchments without records of American mink presence included in the available area and randomly selected points, approximately one point for each 10 kilometres of main stream length. We also considered 300 metres upstream and downstream of every such datum and created polygons through the GIS following the above described procedure.

Variable selection:

For polygons characterisation, we selected a set of nine variables describing habitat features, humanisation level and other factors that can potentially influence the ecology of the species (table 1). We chose variables from a set that can potentially influence the presence and habitat use and selection of small carnivores (Weber 1989, Brainerd et al. 1995, Genovesi and Boitani 1997, Zalewski 1997a, b) and more specifically mink (Dunstone 1993, Sidorovich and Macdonald 2001, Yamaguchi et al. 2003, Zabala et al. 2003). Moreover, we also included as a variable the historical presence of American mink farms in the catchment, based on governmental records, and the presence of European mink in the area, in order to detect possible interactions between species. The variables Bramble cover, Riparian forest and Riverbank alteration were estimated in the field for each polygon. Riverbank alteration was represented by five categories, the first two are representative of well preserved streams, the category "Altered" included rivers that had been intervened to a certain degree but where the natural substratum had not been changed and vegetation grows up to date. Streams that had been canalised building an artificial bed

Table 1. Variables describing stretches. Bramble cover stands for the degree of bramble cover in the riverbank. Riparian forest stands for the degree of forest cover in the riverbank. Forest cover stands for the forested area inside the polygon. Riverbank alteration the degree of human intervention on the riverbank in the polygon. Presence of European mink was treated as "present" when stable populations are known in the area, "rare" when there have been individuals sporadically detected in the area, and "absent" when no European mink has been detected in the area in the last five years. Pollution stands for the quality of water after BMWP categories, with BMWP scores defining them in brackets. Road and Buildings and Farms variables were not categorical, but considered as the total length of paved roads inside the polygon in metres, the number of buildings that fall totally or for the most part inside the polygon, and the number of fur farms known to have been active in the catchement.

VARIABLE	CATEGORY	VARIABLE	CATEGORY
Bramble cover		**Riverbank alteration**	
	0-25%		Natural
	26-50%		Slightly altered
	51-75%		Altered
	76-100%		Canalised
Riparian forest			Aggressively canalised
	0-25%	**European mink**	
	26-50%		Absent
	51-75%		Rare
	76-100%		Present
Forest cover		**Pollution**	
	0-25%		Clean waters (>120)
	26-50%		Unpolluted waters (101-120)
	51-75%		Critic quality (Sings of Pollution) (61-100)
	76-100%		Polluted waters (36-60)
			Very polluted waters (15-35)
			Extremely polluted waters (<15)

of rocks, which allow a certain degree of vegetation development where classified as Canalised, as well as rivers that where secluded in concrete walls but including small stretches of natural shores. Finally, streams running along concrete canals were classified as aggressively canalised. European mink presence was defined with the results of the live-trapping survey and considering also Zabala and Zuberogoitia (2003a). For each catchment, European mink was recorded as present where there are established populations and breeding has been recorded. European mink were considered rare in catchments where there are only sporadic records (probably dispersive individuals). They were regarded as absent in catchments where there were neither captures nor records for the last five years.

Data on water pollution were provided by the Department of Land Ordination and Environment of the Basque Government. Due to the characteristics of the streams, data from a single sampling should not be considered as representative of water quality (Elosegi et al. 2002). Thus we used BMWP (Biological Monitoring Working Party adapted for Spain) scores that represent not the status of the river during the sampling period but the overall status of the watercourse. BMWP scores were summarised into six categories. (Table 1). Values for the rest of the variables were obtained with the aid of a GIS.

Statistical analyses:

In order to determine which variables explained the presence of American mink, we performed a Logistic Regression (LR) using the forward Wald Stepwise method (Morrison et al. 1998). The LR is a type of multivariate analysis that allows the inclusion of both, categorical and parametrical variables. For the LR, we randomly selected 20 polygons plus 7-8 more for each variable in the analysis following the recommendations of Morrison et al. (1998) and Vaughan and Ormerod (2003). In total, we used 98 polygons for the LR, for which the dependent variable was the binary variable presence/absence of the American mink. The number of polygons with presence of mink in the 98-polygon sample used in the LR was similar to that of the polygons from areas were the American mink was never detected. The Stepwise method is an exploratory tool that allows one to identify the best predictors from the pool of potentially useful parameters. 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 on 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 prediction success understood as performance of the model, the Area Under Curves (AUC) of Relative Operating Characeristic (ROC) has been proposed as an alternative approach to measure discrimination capacity (Pearce and Ferrier 2000, Manel et al. 2001). AUCs measured from ROCs are independent of prevalence and highly significantly correlated with the easily computed Cohen's kappa (Manel et al. 2001), therefore, we calculated Cohen's kappa to evaluate the models, a simply derived statistic that measures the proportion of all possible cases that are predicted correctly by a model after accounting for chance.

The selection of categories of the variables produced by the LR was tested using the X^2 test corrected with Bonferroni´s inequality. Electivity was assessed through Jacobs' index (Krebs 1989). α value was 0.05 in all cases.

RESULTS

We captured 18 American mink, and other three were found road-killed, in four different catchments.

The LR created a two-step model (Table 2). "Fur farms" was included in the first step and "Water pollution" in the second. Each step had increasing predictive value, and better performance as shown by kappa values.

Table 2: Results of the logistic regression and predictive value of the model at each step.

STEP	VARIABLES	Wald	D. F.	p	Correctly predicts			Cohen's Kappa	Kappa's approx. significance
					Presence	Absence	Total		
1	Fur farms	27.86	1	0.001	84.0%	72.9%	79.2%	0.581	0.001
2	Fur farms	17.22	1	0.001	92.0%	95.7%	93.8%	0.875	0.001
	Pollution	22.68	5	0.001					

We assessed the influence of categories of "Fur Farms" and "Water pollution" using the X^2 test corrected with Bonferroni´s inequality and trough Jacobs' index (Table 3). The presence of American mink was related to the historic presence of fur farms in the catchment. Besides, American mink used waters of medium qualities whilst avoided extremely polluted as well as clean water streams/catchments.

Table 3. Variables influencing the presence of the American mink assessed through the Jacobs' index. Values that reached statistical significance after running a Bonferroni's inequality test are marked with * (note that -1 Jacobs' index values can not be tested after Bonferroni's inequality).

VARIABLE	CATEGORY	JACOBS
FUR FARMS		
	ABSENT	-0.57*
	PRESENT	0.57*
POLLUTION		
	CLEAN WATERS	-0.75*
	UNPOLLUTED WATERS	-0.44*
	CRITIC QUALITY (Sings of Pollution)	0.26
	POLLUTED WATERS	0.42
	VERY POLLUTED WATERS	0.17
	EXTREMELY POLLUTED WATERS	-0.82*

DISCUSSION

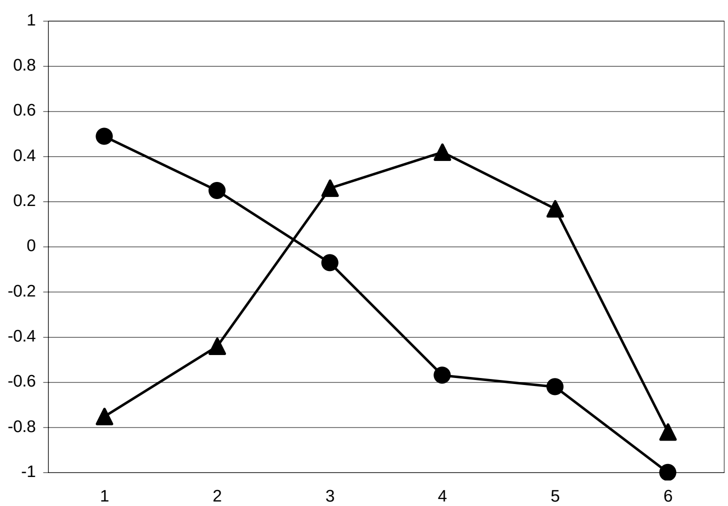
The models produced by the LR are based on two variables: "Fur farms" and "Water pollution". The best performance was obtained in the second step as can be drawn from Cohen's kappa's values. The historical presence of fur farms is understandably an important variable for populations dating back no more than twenty years (*vid.* Zuberogoitia and Zabala 2003). As in other countries, American mink escaped from farms and become feral (Dunstone 1993, Brzezinski and Marzec 2003). New populations increased in density and spread out to adjacent streams. Nonetheless, this is a coarse predictor since there is no information available on determinant factors such as the numbers of breeding females held in captivity, neither the actual number of escapes. The relationship, however, suggests a poor colonizing capacity of the species in the area. The American mink permanently inhabits two catchments in the area (one of them since the eighties) and several individuals have been occasionally detected in adjacent catchments, which suggests that they may be wandering individuals. Furthermore intensive trapping revealed the absence of American mink in one of them (Zabala et al. 2001, Zuberogoitia and Zabala 2003).

Water quality, expressed as BMWP' scores, also affected the distribution of the American mink in Biscay. Surprisingly, American mink avoided waters of the best quality. American mink locations were clustered around polluted areas, avoiding only extremely polluted stretches. The avoidance of extremely polluted waters is comprehensible by the deleterious effects of pollutants, although American mink have been reported to thrive in severely polluted waters despite of abnormalities caused by bioaccumulation (Sidorovich and Savcenko 1992). The avoidance of clean and unpolluted waters is more difficult to understand. This could be related to the use of these areas by the European mink (Figure 1), which in the study areas uses clean waters. The European mink is present in every catchment in which American mink occur in the study area. Catchements where dispersive American mink have been reported are occupied permanently only by European mink, as revealed by intensive live-trapping (Zabala et al. 2001). However, the American mink is common in main streams where once dwelt the European one and now the later is relegated to second order streams (Zuberogoitia and Zabala 2003). This result is clearly contrary to the results from other study areas, where the American mink drives out its European counterpart via aggressive interactions (Maran et al. 1998b, Sidorovich et al. 1999, Sidorovich 2000, Macdonald et al. 2002). On the other hand, other studies have concluded that the regression of the European mink is related to habitat modification and water quality degradation and not to the expansion of the American mink's range (Tumanov 1992, Lodé et al. 2001) which seems to be in agreement with our results. Besides, in areas where the American mink drove out or is still driving out the European mink, studies have shown that the American mink uses main and small rivers, relegating European mink to small streams and brooks (Sidorovich and Macdonald 2001, Saveljev and Skumatov 2001). In this context, the landscape of the study area, composed mainly by small streams flowing northwards to the Gulf of Biscay, may resemble watercourses described as small streams and brooks in other study areas and therefore, could be a poor quality habitat for the American mink, especially the least polluted small ones.

Several conclusions can be drawn from our data, on one hand, the observed pattern could be a consequence of the short time span so that the process of between-species exclusion described in Eastern Europe is not fully exposed here (Maran et al. 1998b, Sidorovich *et al.* 1999, Sidorovich 2000, Macdonald et al. 2002). If this were true, our results could represent the early stages of the invasion (Macdonald and Thom 2001). On the other hand, the regression of the European mink could be caused mainly by human activities or other unaccounted factors, American mink taking advantage of it to expand their range. Studies on the ecology of the American mink have shown its high adaptability to a wide range of environmental conditions (Macdonald and Harrington 2003). Moreover, the compared ecology of both species showed that the American is more generalist regarding both diet and habitat (Niemimaa 1995, Palazón 1998, Ferreras and Macdonald 1999, Sidorovich 2000b, Jędrzejewska et al. 2001, Sidorovich 1992, Sidorovich and Macdonald 2001, Sidorovich et al. 1998, 2001, Mech 2003, Yamaguchi et al. 2003a, Zabala et al. 2003, 2004). Besides, European mink have larger home range, which suggests a poorer exploitation of the environment and lesser population density (Garin et al. 2002a, b, Zabala et al. 2003, Zabala and Zuberogoitia 2003b, Lodé et al. 2003). However American mink not only have smaller home ranges but also a larger degree of overlap between and within sexes (Gerell 1970, Birks and Linn 1982, Dunstone 1993, Yamaguchi and Macdonald 2003, Yamaguchi et al. 2003b) In this sense, regardless of the possibility of American mink driving out European mink through aggressive physical interactions (Maran et al. 1998b, Sidorovich, et al. 1999, Sidorovich 2000, Macdonald et al. 2002), our result suggest that American mink take advantage of extirpated, weakened or disturbed European mink populations to widen their range. Lodé et al. (2001) studied the recent decline of the European mink in France and found that the American mink remained rare or absent in 62.4 % of the area from which the European mink had disappeared. Moreover, they concluded that the decline was mainly a result of intensive trapping, habitat modification and alteration of water quality. Taking into account the habitat preferences described in this study and in Lodé et al.

(2001), the absence of American mink from some areas reported by Lodé et al. (2001) could be the consequence of a process of severe habitat degradation that renders it useless even to American mink. Less degraded areas could support dispersive American mink, but no European mink. Indeed, habitat disturbance is known to be an important factor determining whether invading species take hold (Macdonald and Thom 2001), and there is empirical evidence of several invasive species thriving in perturbed habitats, whilst native species survive in preserved native habitat patches (Simberloff 1995, Macdonald and Thom 2001). Moreover, there is no clear-cut case of continental extinction of an indigenous species due to competence with an introduced species from a different continent (Macdonald and Thom 2001). Therefore, we suggest that, at least in Western Europe, much of the rapid substitution of the European mink by the American mink and the decline of the former has probably been favoured by human activities causing habitat modification and water quality alteration.

Figure 1. Ivlev's indexes of electivity of different levels of water pollution for the American mink (triangles) and the European mink (circles). Water pollution levels are classed as: 1- clean waters, 2- unpolluted waters, 3- critic quality, 4- polluted waters, 5- very polluted waters, 6- extremely polluted waters. Data for European mink presence were adapted from own unpublished data.



Interestingly, based on a theoretical model Ferdy and Molofsky (2002) suggested that a species experiencing the Allee effect can not establish itself in a patch already occupied by a competitor unless its density is over a critical value. Translated to metapopulations, migrants are unable to colonize patches, or catchments, where the competitor species is established, concluding that species could resist displacement if stronger competitors experience an Allee effect (Ferdy and Molofsky 2002). This is in agreement with the slow expansion of the American mink in the area. In Biscay, catchments adjacent to American mink territories are occupied by European mink, and although some American individuals have been detected into the later catchments, they did not settle, and European mink populations still thrive. Interestingly, European mink males live-trapped in areas adjoining to American mink populations averaged 950 gr (Zuberogoitia et al. 2001), a similar weight to that of mink from Belarus after the arrival of the American mink, which represents a possible response to selection for heavier individuals to face aggression from dispersive American mink (Sidorovich et al. 1999). However, our data suggest that the invasive species, although experiencing the Allee effect, might out-compete the resident species (i. e. European mink) if the later were below a critical density caused by human activities.

In conclusion, we suggest that management of European mink populations in Western Europe, especially reintroduction programs focused on eradicating the American mink, should consider that preservation or restoration of high-quality habitat for the native species must be the main goal. Where habitat is good enough for European mink, linear barriers or partial eradications of the American mink effective enough to create an Allee effect on the American species might prevent its expansion and the displacement of the endangered European mink, even if the complete eradication of the American mink is not achieved (Courchamp et al. 1999, Ferdy and Molofsky 2002). More fine-grained research is needed on the relationships between the two mink species, on the ways in which land management prevents or facilitates the expansion of the American mink, and on possible niche-compression or displacement caused to European mink by the American mink.

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CHAPTER 9

Modelling the incidence of fragmentation at different scales in the European mink (*Mustela lutreola*) population and the expansion of the American mink (*Mustela vison*) in Biscay.

ABSTRACT

Fragmentation of populations is a major threat to modern wildlife that may act at different scales. We used a GIS to create matrix based on landscape features relevant to European mink and modelled breeding and dispersion of mink across it. We also simulated expansion of American mink populations. Simulations suggested incidence of fragmentation at different scales due to habitat degradation and perturbation by the American mink. Intensification of urbanisation and river canalisation, and expansion of American mink populations are a threat to the persistence of European mink populations in eastern Biscay.

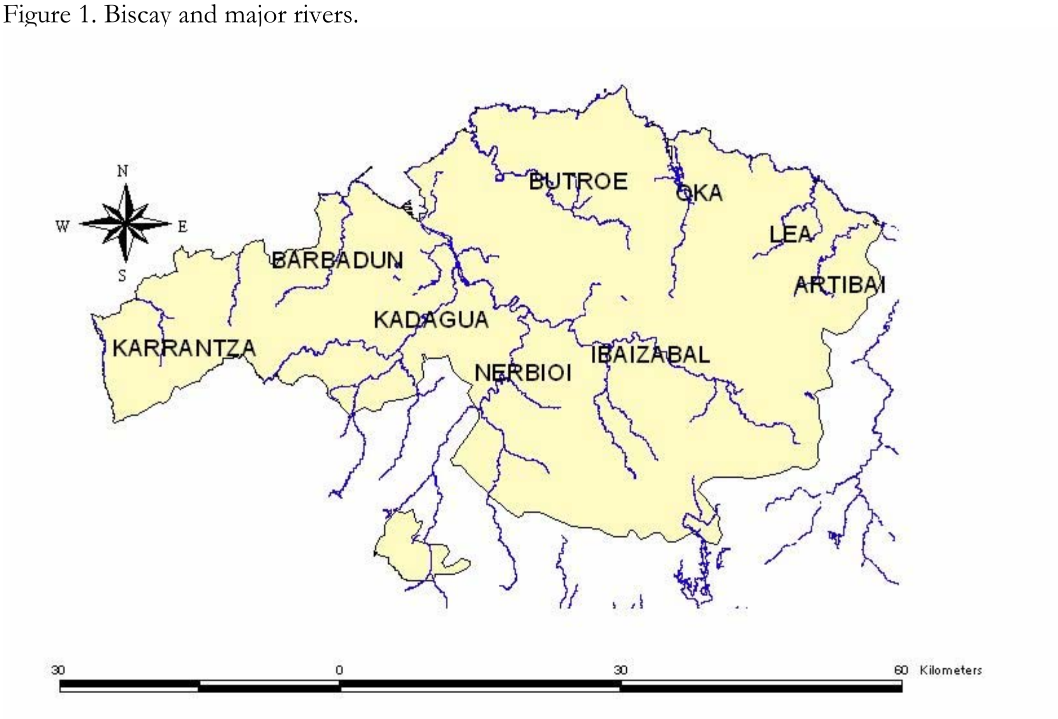
INTRODUCTION

The European mink is a semi-aquatic carnivore that has undergone a severe populational decline in the last century. As a result, there are two distribution nuclei at the two extremes of its previous range, which in turn are subdivided in more or less isolated sub-nuclei. These small subpopulations are more extinction-prone due to demographic stochasticity, breeding fail and other problems characteristic of small populations (Goodman 1987). Recently, Lodé (2002) studied the subdivision of European mink populations in France and suggested that they may be reaching a critical threshold for conservation. Fragmentation has not been considered as a threat to the species in the Western European area, and in the Iberian Peninsula the population has been assumed to be form a main unit along the axis of the Ebro River with some unconnected streams of the north of the Basque area (Palazon et al. 2002). Streams in the north of the Basque area are short and fast flowing, running into the Bay of Biscay, made up by small catchments separated by rough sloppy terrain (*see* Chapter 5). Therefore, the local landscape itself could be a functional barrier for the movements and dispersal of European mink and other river dwelling species' populations. Understanding of the structure of landscape and its effects on dispersion are needed to achieve conservation goals (Fahrig and Merriam 1994).

Geographically explicit models, those considering geographic data for calculations, have provided a good tool for wildlife and landscape management. In this paper we aimed to model European mink's movements and dispersal in a complex landscape matrix, as a tool that could help in detecting problematic areas for the species and main ways for communication among different subpopulations. In addition we used the same matrix to model expansion areas of American mink and to detect places where a high pressure over European mink populations is exerted.

Study area

Figure 1. Biscay and major rivers.



The model was created using Biscay (North Iberian Peninsula) as study area. Biscay has an area of 2236 km² and a population about 1 200 000 inhabitants. Landscape is hilly and rugged, and altitudes range from 0 to 1475m a. s. l. Climate is oceanic, with annual rainfall ranging between 1200 and 2200 mm, and annual average temperatures varying from 13.8ºC to 12ºC. In the region there are several catchments whose streams are short, small and fast flowing, running into the Bay of Biscay (Figure 1). Data of European and American mink distribution in Biscay were taken from the recent most survey conducted by Zuberogoitia et al. (2005). In addition, in order to detect possible breeding linkage through adjacent populations we included the nearest populations of European mink as reported by Palazón et al. (2002).

Fragmentation scales

The fragmentation of a population is a phenomenon that might act at multiple scales, from disturbed breeding systems due to small or temporal barriers to segregation of the original population into several subunits linked by short or large distance dispersals, or even into completely isolated subunits (Lord and Norton 1990). Therefore, in the case of the European mink, we performed different approaches at two different scales:

1. On the one hand, breeding ecology of European mink revealed polyginous subunits, with dominant male holding territories that encompass those of several females (Garin et al. 2002a). During the matting period males exhibit the highest degree of activity and movement as a way for both seeking for receptive females and female monopolization within their own territory (Lodé 2001, Garin et al. 2002b, Lodé et al. 2003). Besides, based on works on related species (Lodé 2001, Lodé et al. 2003), we assumed the existence of short breeding dispersal movements of territorial males, specially subdominants or poor quality territory holders, that may link otherwise unconnected breeding units (Lodé 2001). For the calculation of the distance at which breeding dispersal may act, we used home ranges of mink from the study area as standard breeding dispersion distances.
2. On the other hand, we considered the possibility of metapopulation linkage by short-medium distance dispersive individuals. Mink populations are assumed to be composed by territorial individuals and by floating ones without a territory. The latter may disperse colonising new areas and connecting otherwise isolated populations (Dunstone 1993).

In the case of the American mink we conducted a single simulation, modelling its expansion along the matrix from current currently occupied areas.

Building the matrix

To study the incidence of fragmentation on the population we used a Geographic Information System (GIS) to build a landscape matrix by digitalizing 2230 km of rivers and streams. We mapped rivers and streams with European mink presence, and after the results exposed in Chapter 4 we assumed aggressively canalized streams to have a negative effect on the dispersive behaviour, and mapped the long canalizations. Save from rivers, all structures were considered equal but highways, main roads, urban areas and American mink presence areas that were considered potentially dangerous areas, and cliffs and sheer rocky outcrops that where considered as barriers for dispersion (Sidorovich et al. 1999, Grogan et al. 2001, Macdonald et al. 2002, Rondinini and Doncaster 2002). We created 20 meter buffers along linear structures (rivers and roads) in order to keep their represented, and then converted the landscape matrix into a raster layer with 10 x 10 m cells covering the whole Biscay and adjacent areas. Then we reassigned different cost values for each cell depending on their structure (table 1). Cost values represent the distance that the animal must travel and the risk involved in travelling across the cell. For instance in a cell representing river the cost is 1, representing only the distance, but in a cell crossing a highway the cost is 6, representing the avoidance of such structures and the high chance of being killed in crossing them. Values are different in the two analyses we conducted, because dispersive animals need to cross just once while territorial animals need to cross and face the risk involved once and again.

The cost involved in crossing each type of cell ranged between 1 and 12 (*ad hoc* established limits) and was settled after the following criteria:

- Both mink species are river-dwelling so, displacements along streams had the lowest cost.
- American mink may interact aggressively with European mink driving it out of its way (Sidorovich et al. 1999, Macdonald et al. 2002). In consequence, we assumed a medium cost for a dispersive individual (probability of encountering and American mink and being attacked) and highest cost for a territory holder (sharing the same areas continuously supposes many encounters with the other species).
- Aggressive canalisation of streams posses a problem for both mink species because they must cross long areas without the protection of vegetal over story or underground dens. During a dispersive movement such areas need to be crossed once so we settled a medium-low cost, while for territory holders crossing these areas many times involves several risks so we assumed a maximum cost for these movements.

- The streams' crossing point under highways and roads are usually canalised or made with tubes, structures that may pull mink out of streams and move across the road instead of doing it along the canalised bank.
- Territorial mink rarely venture out of the riverbank. In addition, water, thickets and rank riverbank vegetation are the main refuges mink use. Therefore moving across land has been considered to have an accumulative cost.
- Land movements have been considered to have a higher cost if mink must move across roads, urban areas and similar structures.

Table 1. Value (cost of crossing) for European mink of each cell type in the landscape matrix for breeding and dispersion movements. For American mink River and River with European or American mink had the same value (1).

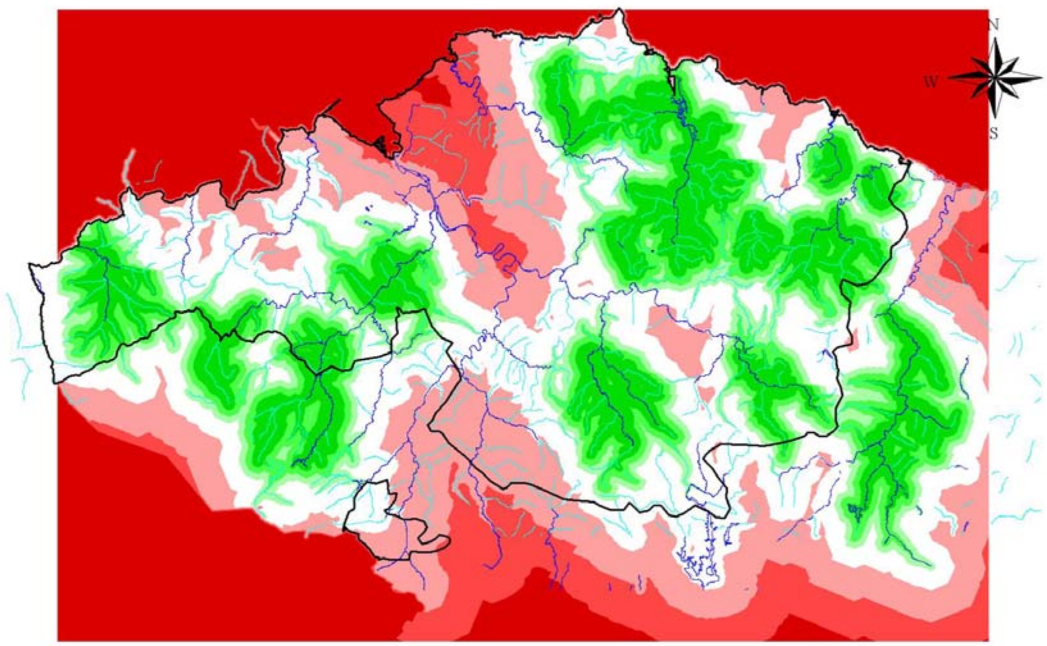
Cell type	Value (Cost)	
	Dispersion	Breeding
River	1	1
River with European mink	1	1
River with American mink	6	12
Canalised river	4	12
River under Highway/Major road	6	10
Canalised river under Highway/Major road	7	12
Land	5	8
Land in areas with European mink	4	8
Land in areas with American mink	6	9
Urban	10	12
Highways / Major roads	12	12
Cliffs, Sheer rocky outcrops	10	10

Over the resulting grid we mapped areas where European mink is present (from Zuberogoitia et al. 2005) and we calculated movement cost considering them as movement origin/destination. For the American mink simulation we mapped areas with presence of American mink populations (from Zuberogoitia et al. 2005) calculated the cost of advance considering them as sources.

RESULTS AND DISCUSSION

Breeding movements and breeding dispersal

Figure 2. Breeding units of European mink. Green areas are assumed to be connected in the model, with light green indicating areas connected by breeding dispersal. White represents areas unlikely to be visited by territorial breeders while red indicates major barriers.

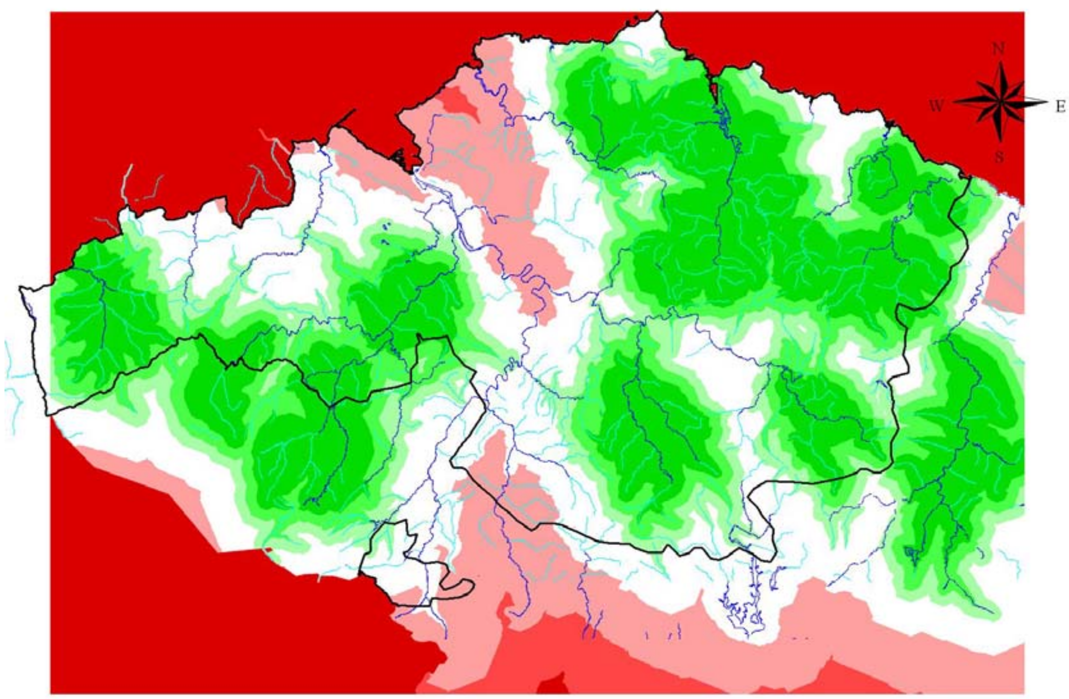


Results for the breeding simulation are shown in figure 2, where there are four problematic areas that cause fragmentation of the population into several units of different sizes. In addition many of the subunits are only marginally linked . One of the problematic areas is the Butroe catchment, that holds a dense American mink population. Another one is the Lea-Artibai area where both mink species are present, but European mink are relegated to small tributaries of the central upper parts of the catchments. A third one is composed of the central and lower Ibaizabal and Nerbioi catchments, in which American mink presence has been sporadically detected and European mink is absent from big areas. Besides those catchments support a high density of infrastructures along the main river axis and several canalised stretches. The fourth problematic area is the Barbadun catchment in the north part of western Biscay, there the lack of linkage is due to absence of European mink from the, apparently suitable, area.

Short-medium distance dispersal

Results of the short-medium distance dispersion simulation are shown in figure 2. In this case Biscay appears to harbour two main populations separated by the urban area of Bilbao, the Butroe catchment and the canalised and industrial area of the Nerbioi. The population in the west forms a continuum with an empty area in its north, in the Barbadun catchemnt.

Figure 3. Short medium dispersal linkage of European mink. Green indicates area easily reachable by dispersive mink. White represents areas that require medium distance dispersive movements while red ones are major barriers.

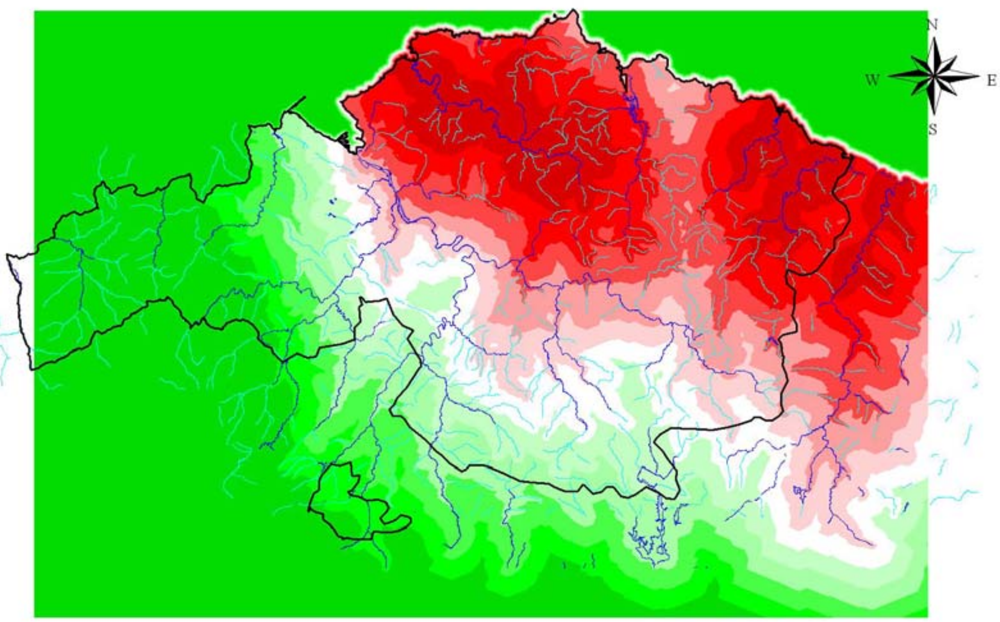


The east population seems well connected in the north but disruption caused by American mink presence in the medium-low parts of Lea and Artibai catchments is apparent. Southern areas of the east population, in turn, may be isolated among them and marginally linked to the northern one.

Expansion areas of American mink

The results of the model for American mink expansion areas are shown in figure 4. From it, it can be drawn that areas of American mink expansion encompass most of the European mink presence areas. The only European mink areas that for the moment seem to be safe from American mink expansion are the catchments in western Biscay.

Figure 4. Most probable expansion of American mink. In dark red areas already occupied, in lighter hues areas likely to be occupied in a short period of time, in white areas likely to be occupied in medium periods of time, and in green areas unlikely to be occupied by the moment.



Although geographically explicit models are fallible and heavily rely in values given to cells, they can be useful as indicators of most likely scenarios in the short run and as tools for finding management hot-spots. In our case the first two models show fragmentation in the population of Biscay at different levels, in every case due to two main factors: (1) large urban and their influence belt areas with canalised streams and degraded riverbanks and (2) growing American mink populations. In deed, coastal populations seem most vulnerable, currently their gene and individual flow with mainland populations relay on marginal populations form upper Ibaizabal and its tributaries. The quality, and not only the existence, of the dispersion routes is of great importance and affect the likelihood that animals use it and that they survive dispersion (Fahrig and Merriam 1994). Indeed, patches connected by dispersion routes of bad quality may act as sinks (Fahrig and Merriam 1994). In the Ibaizabal area, there are a highway, a mayor road, a railway and many urban areas between the coastal population and the small populations in the south. Besides, unoccupied rivers and streams along dispersion routes are of low quality for European mink (Chapter 4), and might also act as a sink by leading mink to establish in poor quality but unoccupied areas. In addition the area is highly menaced by the expansion of the American mink and further habitat degradation. Plans on canalising most of the main streams and lack of control policies on American mink could worsen the situation in the short run. Actually the best situation for European mink in Biscay seems to happen in the western catchments, where the urbanisation degree is lower and local populations are connected with those from Araba and Burgos, and free of American mink.

The future of the European mink is uncertain without habitat conservation and restoration policies, American mink eradication and monitoring of the recolonisation of European mink.

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CHAPTER 10***

Site and landscape features ruling the habitat use and occupancy of the polecat (*Mustela putorius*) in a low density area: a multiscale approach

ABSTRACT

We studied the habitat of the polecat at different scales in a low density area. For this purpose we gathered data on the presence of the species and characterised them by location, home range and landscape scales. Polecats selected areas of high diversity close to, but not in, streams whilst avoided intensively managed conifer plantations and dense urban areas. Variables determining the presence/absence of the species were found at home range scales, what implies that management and conservation practices for the species should be aimed mainly at this scale. Finally, our results agree with previously published works, what validates GIS based approaches as a tool for carnivore management in areas with scarce data or in cases of rare species.

*** Originally published as: Zabala, J. Zuberogoitia, I. and Martinez-Climent, J. A. 2005. Site and landscape features ruling the habitat use and occupancy of the polecat (*Mustela putorius*) in a low density area: a multiscale approach. Eur. J. Wildl. Res. **51**: 157-162.

INTRODUCTION

Polecat (*Mustela putorius*) is a widespread carnivore in Europe whose populational trends are poorly understood. Whilst their distribution area has expanded northwards, in some areas polecats have undergone a decline in the last decades (Blandford 1987, Brzezinski et al. 1992, Birks and Kitchener 1999). They use a great variety of vegetation types and structures and some studies have pointed out its preference for watercourses (Blandford 1987, Brzezinski et al. 1992, Jedrzejewski et al. 1993, Sidorovich et al. 1996). However, other studies showed selection for other vegetation formations such as prairies, forests or human settlements and nearby areas (Blandford 1987, Lodé 1993, Virgós 2003). But, with some exceptions (Lodé 1993, 1994, 1995), habitat requirements of the species are poorly known, especially in low density areas (Virgós 2003). Therefore, management guidelines for low density areas are usually extrapolated from high density areas or from similar species.

Habitat selection and use are the result of several processes that take place at different scales. Johnson (1980) defined four levels of habitat selection. But, for carnivores, some scales of habitat selection have been scarcely considered (Carroll et al. 1999, Gough and Rushton 2000, Schadt et al. 2002).

Cryptic, nocturnal and rare species usually require indirect approaches for studying their habitat requirements, especially when they occur at low densities. In such cases, indirect methods have been widely used (Gese 2001, Wilson and Delahay 2001, Virgós 2003). However, each technique deals with different methodological and logistic drawbacks, and in every case the rarity of the species could yield scarce data for analysis (Gese 2001, Kenward 2001).

In this work we merged data from different sources and modellized them to obtain an approximation of the habitat of the polecat at three different scales: use of features within the home range, location of home range with respect to surrounding area and use at the landscape level. Secondly, we developed a GIS with all the relevant habitat features for the species which occurs at very low densities in the area, and contrasted the results with published works on polecat's biology in order to assess the reliability of the proposed procedure. Thus we aim to provide a rational, efficient tool so as to develop more efficient monitoring plans in a changing landscape.

Study area

The study was conducted in Biscay, Basque Country (SW Europe). Biscay, is 2236 km² with a population about 1.2 million inhabitants. Landscape is hilly and rugged, and altitudes range from 0 to 1475m a. s. l. (Gorbea Peak) Climate is oceanic, with annual rainfall ranging between 1200 and 2200 mm, and annual average temperatures varying from 13.8ºC to 12ºC. Winters are mild and there is no summer drought. The region has several catchments whose streams are short, small and fast flowing, running into the Bay of Biscay. Main infrastructures such as roads and villages are located along valleys. In the mountains and valleys far from urban areas, land is mainly devoted to forest cultures, mainly exotic *Pinus radiata* and *Eucalyptus globulus* that occupy more than half the surface of Biscay (Departamento de Ordenación del Territorio y Medio Ambiente del Gobierno Vasco 2001).

Methods

Firstly we gathered all data available on polecats dating back up to eight years from wildlife keepers, scientists, naturalists and the regional wildlife rescue centre. We only considered reliable data such as trapping data (5 animals with a trapping effort over 6000 traps/night), road kills (7 animals) and torching and sightings (10 animals). In the latter cases, records were disregarded when carcasses were not available for identification or the sighting had not been reported by us. In total we gathered 22 records of polecat presence. Based on these records we built polygons representing polecat distribution in the study area. Besides, we set a buffer around the area to avoid the misrepresentation of presence areas of outlier data outside the polygon. For the buffer we used a distance of three kilometres, based on the linear dimension of the home range (Bowman et al. 2002) obtained from a radio tracked polecat in the study area. The size of this home range was similar to those previously reported in the literature (Brzezinski et al. 1992, Blanford 1987, Lodé 1996a).

The analysis was performed at three different scales: (1) use of features within home range, (2) home range site location and (3) the importance of landscape correlates with presence of polecats. Vegetation cover and distance calculations were made through a GIS using digital cartography at 1:5000 and 1:25000 scales, provided by the Department of Environment and Land Ordination of the Basque Government. To ensure the availability of sites from which polecats are absent, so as to provide a better approximation (Jones 2001), we modeled the polecat's dispersion area by setting buffers of six km around the built polecat distribution area and considered that surface as available for the species (Bowman et al. 2002), and created 31 random points in the area.

For the first analysis we created buffers with a radius of 10 metres around known polecat locations and considered the habitat composition in these areas using a 5 metres grid, and measured distances from them to the nearest river and to the nearest ecotone. We also generated 23 random points within the potential polecat distribution area and characterised them in the same way.

In the second analysis we made an approximation of the home range area location. To ensure representativeness of areas considered as home ranges we first calculated the area that can be considered as part of the home range with statistical significance. For doing so we considered a home range area of 2.5 km² based on own data from a radio-tagged polecat and data reported in literature (Brzezinski et al. 1992, Blanford 1987, Zuberogoitia et al. 2001). Taking into account the home range size of polecats, we created a circle with an area of 2.5 km² and, assuming a regular distribution of the locations within the home range, created 20 normal random points inside the circle. Then we calculated the distance from each point to the circle border, listed a series of distances and compared them to the actual distances included in home ranges. Wilcoxon's paired samples test (Zar 1999) were performed to find for which distance pairs there were no statistically significant differences between distances considered and those actually included in the home range. The maximum distance to consider was 100 metres (for 50 metres: Wilconxon's $z=-1.604$, $p<0.109$; 100 metres: $z=-1.826$, $p<0.068$; 150 metres: $z=-2.366$, $p<0.018$). Thus, we created circles with a 100 metres radius around polecat locations and considered the resulting circular areas as part of the home ranges of the animals.

Vegetation cover of positive and negative areas was described using a GIS to create a vegetation grid (5 m resolution). Besides, we also considered the number of polygons included in the area and the length of streams and ecotones inside the area (Table 1).

Table 1: Variables considered at each scale for habitat description. Radius states for the distance considered around the exact polecat location (in metres).

Variables considered for		Land Uses						River	Mosaicism
Analysis order	radius								
Selection within home range	10	Main land use in the area						Distance to nearest river	Distance to nearest ecotone
Home range site selection	100	Conifer Forests	Broad leaf forests	Meadows	Urban (Human Settlem.)	Bush Land	Others	Length of rivers included in the area	Polygon border length in the area
Landscape	2000	Conifer Forests	Broad leaf forests	Meadows	Urban (Cities)	Bush Land	Others	Length of rivers included in the area	Numbers of polygons in the area

Finally, for landscape analysis we considered, as a rule of thumb, a radius of 2 km, giving circular areas of 12.5 km². To avoid spatial biases and pseudo-replication only one point was considered in overlapping areas, and negative points with buffers considerably overlapping the distribution area were not considered. In consequence only 14 presence points and 19 absence points were used.

The data was analyzed using different statistical tests. In the first case we performed χ^2 analysis with Bonferroni's inequality (Manly et al. 1993, Morrison et al. 1998). In addition, electivity for the different habitat categories was assessed through Jacob's index (Krebs 1989). Differences in the distance to the nearest river and ecotone were tested with the Mann-Whitnes U test. Mann-Whitnes U tests were also performed at home range order and landscape use order (Table 1). Finally, in order to determine which variables ruled habitat use at the home range and landscape scales we performed a Logistic Regression (LR) with the variables using the forward Wald Stepwise method and the binary response variable presence/absence of polecat as dependent variable (Morrison et al. 1998).

Finally we performed a LR considering only the variables that reached statistical significance in previous tests at any of the three orders of habitat use considered; in order to determine which selection order ruled the overall habitat use of the polecat and was responsible for the presence/absence of the species in an integrated context.

RESULTS

Use of areas within the home range

Polecat locations showed statistically significant avoidance of pine forests, using all the other habitat categories according to their availability. However, there was a marked tendency of preference for human settlements, which reached statistical significance at the 92.5%-level. Besides, polecat locations were significantly nearer than randomly selected points to both, rivers and ecotones ($Z=-2.983$, $p=0.003$ and $Z=-2.387$, $p=0.017$ respectively).

Table 2. Results of the home range analysis (Mann-Whitney U test). Mean values express the proportion of home range occupied by each land use type. River stands for river length within the home range (in metres), and polygons for the amount of habitat polygons in the home range (numbers). Standard deviation is given in brackets.

Variable	Mean Value		U value	Z value	Signif. (2-tailed)
	Presence	Absence			
Conifer forests	17.4 (31.6)	23.7 (32.8)	293.0	-0.969	0.333
Broad leaf forests	22.2 (35.6)	11.7 (26.3)	309.0	-0.663	0.507
Meadows	25.1 (35.9)	25.8 (38.1)	300.5	-0.729	0.429
Urban	16.0 (25.7)	22.2 (37.4)	335.0	-0.128	0.898
Bush land	11.6 (20.8)	12.8 (24.2)	328.0	-0.289	0.773
Others	7.6 (13.4)	3.8 (13.0)	278.0	-1.604	0.109
River	180 (195)	46 (86)	180.5	-3.202	0.001
Ecotones	261 (182)	185 (146)	257.0	-1.523	0.128

Selection of home range location in comparison to surrounding habitat

Only differences in the length of the rivers included in the area reached statistical significance, with more rivers in the presence polygons (Table 2). The LR selected the same feature (Table 3).

Table 3: Results of the LR and predictive value of the model at different scales.

Scale	Variable	Wald	Degrees of Freedom	p	Correctly predicts		
					Presence	Absence	Total
Home range	River length in area	8.798	1	0.003	80.6%	59.1%	71.7%
Landscape	Urban area	4.581	1	0.032	73.7%	78.6%	75.8%
All orders	River length in 100 m. area	4.828	1	0.028	72.7%	68.2%	69.7%

Landscape use

Polecats selected landscapes significantly more diverse and with less presence of urban areas (Table 4). The LR for this order pointed out presence of urban areas as the variable ruling the habitat use (Table 3). Indeed, there was a statistically significant negative correlation between the proportion of urban habitat in the area and mosaicisim expressed as number of different habitat polygons (Pearson's correlation's coefficient, $r = -0.710$, $P < 0.001$, $n=33$).

Finally, the LR including variables significant at all the three orders highlighted the length of rivers included in the 100 metres radius as the most determinant of all for the presence of European polecats (table 3).

Table 4. Results of landscape selection analysis using Mann-Whitney U test. Data are given in proportion of polygon occupied by different structures, river in kilometres and polygon in numbers. Standard deviation is given in brackets.

Variable	Mean Value		U value	Z value	Signif. (2-tailed)
	Presence	Absence			
Conifer forests	34.32 (16.85)	24.96 (19.72)	94.0	-1.457	0.152
Broad leaf forests	20.60 (13.24)	14.28 (10.55)	94.0	-1.421	0.163
Meadows	26.20 (14.76)	26.71 (12.83)	125.0	-0.291	0.788
Urban	4.04 (7.49)	18.70 (20.04)	32.00	-3.679	0.000
Bush land	14.85 (11.90)	15.34 (20.04)	123.0	-0.364	0.733
Others	7.6 (13.3)	3.8 (13.0)	278.0	-1.604	0.109
River	7.23 (3.32)	9.09 (5.59)	113.0	-0.729	0.483
Polygons	250.91 (77.23)	189.79 (66.90)	73.5	-2.168	0.029

DISCUSSION

Habitat use of the polecat has been explained by seasonal variations in trophic resources, mainly small mammals and amphibians (Blandford 1987, Weber 1989, Brzezinski et al. 1992, Jedrzejewski et al. 1993, Lodé 1993, 1994, 1995, 1996b, 1997, De Marinis and Agnelli 1996, Sidorovich et al. 1996, Zuberogoitia et al. 2001, Baghli et al. 2002). Moreover, the polecat is known to intensively exploit areas where resources are locally abundant (Lodé 1994, 1995). Our results agree with this pattern of selection by polecats of a high degree of structural diversity near to streams and ecotones, where amphibians and small rodents are abundant (Escala et al. 1997, Marnell 1998, Houlahan and Findlay 2003). In Biscay, areas surrounding streams are typically most diverse and productive. Moreover, meadows and areas close to streams are usually damp as a consequence of the rainy climate and may function as amphibians spawning and gathering sites, while human rural settlements in such areas improve their productivity. Polecats avoided conifer forests, which apparently contradicts the results of some works that pointed out the use of forest by polecats (Lodé

1994, Weber 1989) and relationships between the presence of native pine forest in the landscape and polecats (Virgós 2003). However, in the study area pine forests are intensively managed timber monospecific plantations of poor floristic and faunal diversity. Moreover, intensive forest management has reduced amphibian diversity and abundance, whilst lack of floristic diversity affects rodents and other small mammals (Waldick et al. 1999, Zuberogoitia 2002, Holulahan and Findlay 2003, Chan-Mcleod 2003). Conifer forests are most commonly in abandoned rural areas, usually in the poorest agricultural lands and in steep lands.

The different use of human settlements (i. e., urban areas) emerging at different scales was very interesting. On the one hand, the observed tendency of the polecat towards urban areas might be the consequence of two factors: a bias towards humanised areas created by the nature of data (road kills, capture of problematic individuals damaging poultry), and the selection of small rural villages and human settlements often reported in literature (Blandford 1987, Weber 1989, Brzezinski et al. 1992). On the other hand, polecats were absent from highly urbanised areas at a landscape scale. Urban areas avoided by polecats were cities, industrial areas and big concentrations of country residential areas, as opposed to traditional farm exploitations found in the first level. Such areas create a great human pressure over wildlife and a simplification and fragmentation of the landscape, which is no longer devoted to agricultural production. Besides, polecats occupied patchy landscapes also at the landscape scale Two important factors may explain this result. Firstly by including diversity of habitats polecats would enhance food resources allowing them to cope with temporal scarcity or seasonal shifting on habitat-specifity of prey resources. Secondly, landscape and vegetation cover diversity may enhance connectivity in the landscape matrix.

It is remarkable, however, that in spite of the use for areas close to rivers only a single datum was located in riverbank. This can be explained by the rugged landscape of the area, with rural areas and productive lands clustered in the valley-bottoms. In the study area several frog and toad species cluster for reproduction on boggy meadows and forest bogs rather than in fast flowing and usually polluted streams (Bea 1989). Indeed, on several occasions we have found typical polecat feeding signs, common frog heads and skins, in forest bogs. The tagged polecat had an areal home range rather than a linear one, and never used streams (Zuberogoitia et al. 2001). This implies that although in experiments conducted in captivity polecats showed an aggressive behaviour towards European mink (Schröpfer et al. 2001) there seems to be a strong component of spatial segregation between species in the wild, thus reducing the likelihood of aggressive encounters (see Lodé 1993, Sidorovich et al. 1996, Sidorovich et al. 2000).

The LR model including features selected at any habitat use order singled out the length of rivers in the 100-m radius as the variable determinant for the presence of the polecat. Predators view and respond to habitat fragmentation and modification at different scales depending on their vagility, with less mobile or more stenophagous predators responding to habitat modification at smaller scales (Gehring and Swihart 2003). Polecats have a relatively small body size for carnivores and usually exhibit home ranges of around 1.5 km^2 (Blanford 1987, Weber 1989, Lodé et al. 2003, but see Brzezinski et al. 1992 for nomadic behaviour). Therefore, we could expect polecats to respond to landscape modifications and to have a low response threshold to fragmentation (i. e. responses at smaller scales) as shown by our results. This result has several conservation and management implications. For instance, it can be suggested that the survival of the species depends heavily on changes made at local scales rather than at wider geographical ranges. It can also be suggested that abandonment or modification of local traditional agricultural practices or the creation of barriers could eventually eradicate polecats. Moreover, if we consider that polecat populations are composed of scattered breeding units with intrasexually exclusive territories (Lodé 1996a, 2001, 2003, Lodé et al. 2003), modifications at local scales might isolate breeding units making populations more susceptible to local extinctions (the allee effect; Frank and Woodroffe 2001, Lodé et al. 2003).

Finally, regarding methodology, our multiscale approach is concordant with previous works in revealing the relative importance of different habitat features at biologically meaningful spatial scales (Martinez et al. 2003). The approach at different scales provides further insight in wildlife-landscape relationships and a best understanding of the way in which different order of habitat selection and use interact, thus becoming a powerful technique for management and conservation.

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CONCLUSIONS

1. Although it can not be definitively stated, every data indicates that the European mink is a new arrival to the Iberian fauna, and that its arrival in Biscay is consequence of a long shift in its distribution range, expanding westwards while disappearing from central Europe.

2. The most plausible hypothesis is that the European mink arrived in Biscay around 1960 and fast colonised east and central areas but apparently its expansion was stopped at the densely urban Nerbioi catchment, and only recently colonised the western catchments.

3. Several escapes and dispersion from neighbouring areas led to the settlement of feral American mink populations in Biscay. Currently the American mink occupies three catchments in the area and individuals have been found in other three catchments.

4. Resting sites and during activity habitat use of European mink are closely related to dense riverbank vegetation, especially bramble thickets; use of underground dens was very rare. This is understood as a need for protection against predators and humans and as an energetically cheap way of exploiting their home ranges. Prey abundance also seems to play a role in resting site selection of European mink, although paucity of diet data precludes assessing its importance.

5. The distribution of European mink in catchments of Biscay is related to water quality and riverbank management. Water pollution and canalisation have adverse effects on European mink. The presence of American mink in the catchment was in no case cause of European mink absence, although at finer-grained scales there are areas where dense American mink populations occur and the European mink is absent.

6. American mink resting site selection and habitat use are linked to scrub and resting sites also to deep water, which is explained by the protection and escape possibilities provided by these structures. Males and females used similar resting sites but females used human buildings significantly more often than males, probably as a consequence of different thermoregulation needs.

7. During winter-spring, the spacing pattern of the American mink in the study area consist on males occupying and using main river stretches while females settled preferentially on tributaries. Despite of large overlap between individuals of different sexes there was a spatial segregation in the areas of intense use. Differences in structure of used areas suggest sexual segregation in niche.

8. The American mink distribution in Biscay is linked to stretches of medium-low water quality and areas where, or adjacent to, there have been American mink fur farms.

9. In catchments where both mink species are present, European mink occupies areas with unpolluted waters whilst American mink occupies mainly polluted stretches, though not very polluted ones. This suggests that the

American mink may take advantage of areas already unfavourable to European mink to settle and afterwards expand to better preserved ones. Current riverbank management policies may be favouring the expansion of American mink.

10. The fact that within-home range habitat use of both mink species is related to the same structures may lessen chances for coexistence.

11. Habitat degradation and American mink expansion are causing fragmentation of the European mink population at different scales. Some subpopulations are threatened by further fragmentation due to habitat degradation and/or American mink expansion, and rely in others for individual and gene flow with populations from other regions. American mink expansion threatens some of the hitherto most important European mink populations in Biscay.

12. The polecat is rare in the area and linked to valley bottoms, meadows and rural settlements. It does not use linear areas along streams, reducing possibilities of competition or aggressive interaction with European mink.

13. European mink conservation in Biscay requires policies and programs for conservation and improvement of water quality and riverbank management, as well as American mink eradication programs. Programs focused only in American mink eradication as conservation policy for the European mink would fail in the medium-long term.

CONCLUSIONES

1. Aunque actualmente es imposible afirmarlo taxativamente, todo indica que el visón europeo es un elemento relativamente nuevo en la fauna ibérica, y su presencia en Bizkaia es consecuencia de cambios en su área de distribución que se ha ido ampliando hacia el oeste mientras se extinguía de las zonas centrales de Europa.

2. Lo más probable es que el visón europeo llegara a Bizkaia hacia 1960 extendiéndose rápidamente por la zona centro y este de la provincia pero deteniéndose en la altamente urbanizada e industrial cuenca del Nervión, y sólo en los últimos años ha colonizado las cuencas más occidentales.

3. Diversas fugas y/o sueltas de visón americano y la expansión desde núcleos de zonas adyacentes tuvieron como consecuencia el establecimiento de poblaciones de visón americano en Bizkaia, donde actualmente presenta poblaciones en tres cuencas y se han detectado individuos en otras tres.

4. El uso del hábitat y de encames por parte del visón europeo está relacionado con espesa vegetación de ribera, especialmente zarzales, siendo el uso de madrigueras subterráneas raro. Ello se entiende como consecuencia de una búsqueda de protección frente a depredadores y personas, a la par que una manera energéticamente eficiente de explotar el área de campeo. La abundancia de presas también parecer jugar un papel en la selección de zonas de descanso por parte del visón europeo, aunque la escasez de datos relativos a la dieta impide valorar su importancia.

5. Los factores determinantes de la presencia de visón europeo en las cuencas de Bizkaia son la calidad del agua y el estado de la orilla. La polución del agua y la canalización de los ríos tiene efectos perniciosos sobre le visón europeo. El visón americano no determinó en ningún caso la ausencia del visón europeo en ninguna de las cuencas en las que la especie halóctona se halla presente, aunque dentro de las cuencas se dan zonas donde existen altas densidades de visón americano y el visón europeo está ausente.

6. El uso de hábitat y encames por parte del visón americano se relaciona con zonas de maleza en la orilla del río, y, en el caso de los encames, próximas a aguas profundas. Ello se interpreta como una consecuencia de la protección y posibilidades de huida que esas estructuras permiten. Machos y hembras utilizan lugares similares, aunque las hembras utilizaron significativamente más a menudo construcciones humanas durante el reposo, probablemente como consecuencia de diferentes necesidades de termorregulación.

7. Durante invierno-primavera el patrón de ubicación espacial del visón Americano en el área de estudio consistió en machos ocupando y utilizando tramos de río principal mientras que las hembras ocuparon tributarios. A pesar de existir gran solapamiento de áreas de campeo entre individuos de diferente sexo, se encontró una segregación espacial en las áreas de uso intenso. Diferencias entre las zonas usadas por los distintos sexos sugieren una segregación de nicho entre los sexos.

8. La distribución del visón americano en Bizakia está relacionada con tramos con una calidad de agua media-baja, en áreas en las que han existido granjas en tiempo reciente, o adyacentes a las últimas.

9. En aquellos cauces en los que ambas especies de visón están presentes, el europeo ocupa zonas de aguas no contaminadas mientras que el americano ocupa principalmente tramos de calidad media-baja, pero no los muy contaminados. Ello sugiere que el visón americano podría establecerse primeramente en zonas desfavorables para el europeo, y después expandirse a los tramos mejor conservados. La gestión actual de orillas y zonas de ribera puede estar ayudando a la expansión del visón americano.

10. Ambas especies utilizan el mismo tipo de estructuras y vegetación dentro de sus área de campeo, lo que reduce las oportunidades de coexistencia.

11. Tanto la degradación del hábitat como la expansión de las poblaciones de visón americano están ocasionando la fragmentación de la población de visón europeo a distintas escalas. Algunas subpoblaciones de visón europeo pueden seguir subdividiéndose a consecuencia de una mayor degradación del hábitat y/o la predecible expansión de las poblaciones de visón americano. Además, dependen de otras subpoblaciones para el intercambio de genes e individuos con poblaciones de otras áreas. La expansión del visón americano amenaza las que hasta hace poco eran las principales poblaciones de visón europeo en Bizkaia.

12. El turón es una especie escasa en Bizkaia, y su presencia se relaciona con prados y zonas rurales en fondos de valle. No tiene áreas de campeo lineales a lo largo de los cursos de agua lo que minimiza las probabilidades de competencia y/o interacciones agresivas con el visón europeo.

13. La conservación del visón europeo en Bizkaia requiere de políticas y programas de conservación y mejora de la calidad del agua y gestión de las

orillas y riberas, así como de programas de erradicación de visón americano. Programas exclusivos de erradicación de visón americano podrían resultar un fracaso en la conservación del visón europeo en un periodo medio-largo de tiempo.

ACKNOWLEDGEMENTS

I wish to express my gratitude to Dr. Zuberogoitia and Dr. Saloña for the direction and supervision of this work.

I also wish to thank to Prof. T. Lodè, Prof. E. Virgòs, Dr. T. Maran and several anonymous referees for critical comments on one or some of the original mss of some of the chapters herein contained. I. Zuberogoitia and J.A. Martínez-Climent also checked and reviewed many or all of the original mss. And J. R. Aihartza and I. Garin made critical comments to chapter 3. J.A. Martínez-Climent checked and corrected the English of all the text, and E. Gonazalez, A. Albizua and G. MacDonald helped with the English in some parts, to all them my gratitude.

Chapter 3 is partially the result of a research project funded by the Research and Environment Departments of the Basque Government through the project PU-1998-8, and a scholarship granted to the author by of the Agriculture Department of the Basque Government. In the same way, chapters 5 to 9 are partially or totally based on the results of a research project Funded by the Servicio de Conservación y Espacios Naturales Protegidos, Departamento de Montes of the Biscayan Regional Council, and conducted at Icarus E. M. S. L. Regional Council of Biscay laso provided authorisation for animal handling and tagging. In the Same way I wish to thank the Junta de Castilla y León, Delgación Territorial de Soria, specially J. M. Meneses, and S. Hornilla from the Deparatamento de Medio Ambiente y Ordenación del Territorio of the Basque Government for their help and information, and to the Department of Environment and Land Ordination of the Basque Government for providing digital cartography. To all them my deepest gratitude.

I. Zuberogoitia, L. Astorkia, S. Larrañaga, S. Hidalgo, A. Iraeta, A. Azkona, J. Iturralde, F. Ruiz-Moneo, J.J Torres, J.R. Aihartza, I. Garin, S. Lekerika, A. Espartza, I. Gonzalo, L. Campos, I. Castillo, I Garmendia, A. Gomez-Gayubo, J. Lopez de Luzuriaga provided field assistance, and A. Secilla for helped with the maps. The Bizkaia Wildlife Recuperation Centre and regional wildlife keepers for providing information on trapped animals and road kills. To all them my deepest gratitude.