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

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Abstract

Fragmentation of populations is a major threat to modern wildlife that may act at different scales. We used a Geographic Information System to create a matrix based on landscape features relevant to European Mink *Mustela lutreola* and modelled breeding and dispersal of minks across it. We also simulated expansion of American Mink *M. vison* 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.

Keywords: canalisation, dispersal, interspecific interaction, riparian vegetation, roads, urbanisation

Resumen

La fragmentación de las poblaciones es un problema que se presenta a diferentes escalas y constituye una de las principales amenazas para la fauna silvestre en la actualidad. Por medio de un Sistema de Información Geográfica creamos una matriz basada en formaciones vegetales y artificiales de importancia para el visón europeo *Mustela lutreola* y simulamos los movimientos de reproducción y dispersión del visón europeo sobre ella. Del mismo modo, realizamos una simulación de la posible expansión de poblaciones de visón americano *Mustela vison* conocidas en la región. Los resultados de las simulaciones sugieren la existencia de fragmentación a diferentes escalas, como consecuencia de la degradación del hábitat y la presencia del visón americano. La intensa tendencia a la urbanización del territorio y a la canalización de ríos y arroyos, así como la expansión del visón americano suponen actualmente una seria amenaza para la supervivencia de las poblaciones de visón europeo del este de Vizcaya.

Introduction

The European Mink *Mustela lutreola* is a riparian mustelid native to the continent of Europe. Its distribution experienced a severe regression during the second half of the 20th century and the species disappeared from most countries (Youngman 1982, Maran & Henttonen 1995). As a result of this decline, nowadays there are two major population nuclei: one in the East (Tumanov 1992, Maran & Henttonen 1995), and the other in the West. The eastern population has disappeared from some countries in the last few decades, and it continues to decline in other areas as well (Maran & Henttonen 1995, Maran *et al*. 1998). The western population seems to be fragmented into subpopulations (Lodé 2002).

These small subpopulations are more extinction-prone due to demographic stochasticity, breeding failure 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 a threat to the species in the Western European area, and in the Iberian Peninsula the population has been assumed to form a main unit along the axis of the Ebro River with some unconnected streams of the north of the Basque area also holding European Mink (Palazon *et al*. 2002). Streams in the north of the Basque area are short and fast flowing, running into the Bay of Biscay, and drain only small catchments separated by rugged terrain. Therefore, the local landscape itself could be a functional barrier to the movement and dispersal of European Mink and other river dwelling species's populations. Understanding of the structure of landscape and its effects on animal dispersal are needed to achieve conservation goals (Fahrig & 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 modelled European Mink movements and dispersal in a complex landscape matrix, as a tool to help in detecting both the problematic areas for the species and the main ways for communication between different subpopulations. In addition, we used the same matrix to model expansion areas of American Mink and to detect places of likely high pressure from them for European Mink populations.

Methods

Study area

The model was created using Biscay (North Iberian Peninsula; c.o. 43ºN, 3ºW) as the study area. Biscay has an area of 2,236 km² and a human population of about 1,200,000. Landscape is hilly and rugged, and altitude ranges from 0 to 1,475 m a.s.l. Climate is oceanic, with annual rainfall ranging between 1,200 and 2,200 mm, and annual average temperatures varying from 13.8 ºC to 12 ºC (January is the coldest month with 6 ºC and July the warmest with 18 ºC.). In the region there are several catchments whose streams are short, small and fast flowing, running into the Bay of Biscay (Fig. 1). Data of European Mink and American Mink distribution in Biscay were taken from the recent survey of Zabala (2006). 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

Fragmentation of populations can act at multiple scales, from disturbed breeding systems due to small or temporal barriers, to seg-

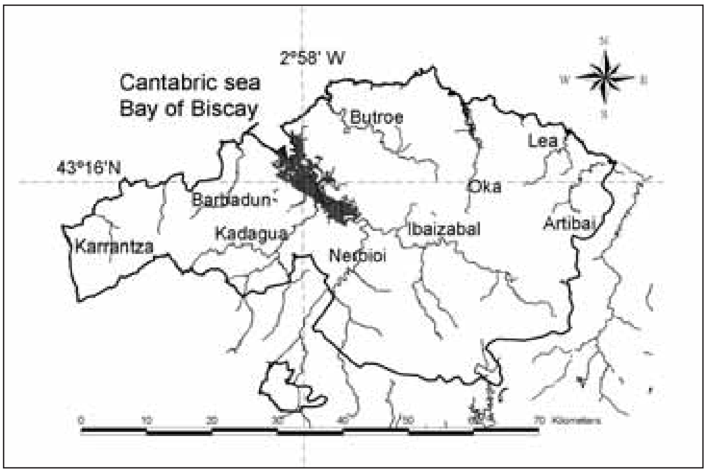

Fig. 1. Biscay and major rivers in the study area. Dark shading represents Bilbao city and major periurban area.

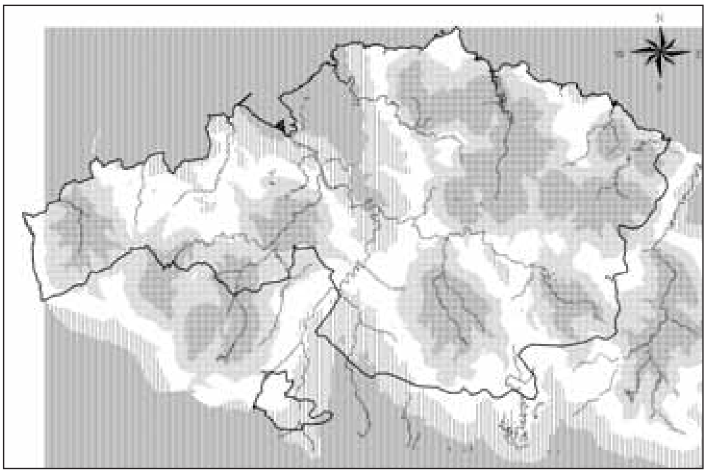

Fig. 2. Breeding units of European Mink. Spotted areas are supposed to be connected, after the Breeding dispersal model. Dense spotting indicates fully connected areas and lighter spotting indicates areas connected by breeding dispersal. White represents areas unlikely to be visited by territorial breeders while vertical-striped ones are major barriers, the darker striping indicating the most unlikely areas to be visited by breeders.

regation of the original population into several subunits linked by short or long distance dispersals, or even into completely isolated subunits (Lord & Norton 1990). Therefore, in the case of the European Mink, we performed different approaches at two different scales:

On the one hand, breeding ecology of European Mink revealed polygynous subunits, with dominant males holding territories that encompassed those of several females (Garin *et al*. 2002a). During the mating period, males exhibited the highest degree of activity and movement as a way for both seeking receptive females and then monopolising females within their territory (Lodé 2001, Garin *et al*. 2002b, Lodé *et al*. 2003). Besides, based on results from 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 European Mink from the study area as standard breeding dispersal distances (resident minks are known to stay within their home ranges during the rutting season).

On the other hand, we considered the possibility of metapopulation linkage by short–medium distance dispersive individuals. European Mink populations are assumed to be composed by territorial individuals and by floating ones without a territory (Zuberogoitia & Zabala 2003). 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 currently occupied areas.

Building the matrix

For studying the incidence of fragmentation on the population we used a Geographic Information System (GIS) to build a landscape matrix by digitising 2,230 km of rivers and streams. We mapped rivers and streams with European Mink presence, and after results of Zabala *et al*. (in press), who found that minks were absent from aggressively canalised streams, we assumed such streams to have a negative effect on the dispersal behaviour, and mapped the long canalisations. Out of rivers, all structures were considered equal. Highways, main roads, urban areas and areas with permanent American Mink presence were considered potentially dangerous areas, and cliffs and sheer rocky outcrops were considered as barriers for dispersal (Sidorovich *et al*. 1999, Grogan *et al*. 2001, Macdonald *et al*. 2002, Rondinini & Doncaster 2002). We created 20-metre buffers along linear structures (rivers and roads) in order to keep their representation, and then converted the landscape matrix into a raster layer with 10 × 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 dispersing animals need to cross just once while territorial animals need to cross, and face the risk involved, repeatedly.

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 dispersing individual (probability of encountering an 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 poses a problem for both mink species because they must cross long areas without protection of vegetal overstorey 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.
- Stream crossing points under highways and roads are usually canalised or made with pipes, structures that may dispel minks

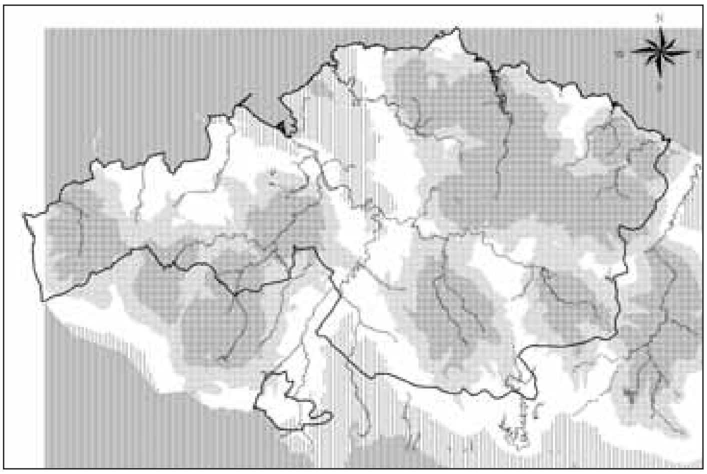

Fig. 3. Short–medium dispersal linkage of European Mink. Spotted areas are those easily reached by dispersing minks, with dense spotting indicating the most easily reachable areas and lighter spotting those less so. White represents areas that require medium distance dispersal movements, while vertical-striped ones are major barriers. Light striping indicates areas that only very far distance dispersing animals could reach, and dark striped areas are assumed to be unreachable by minks.

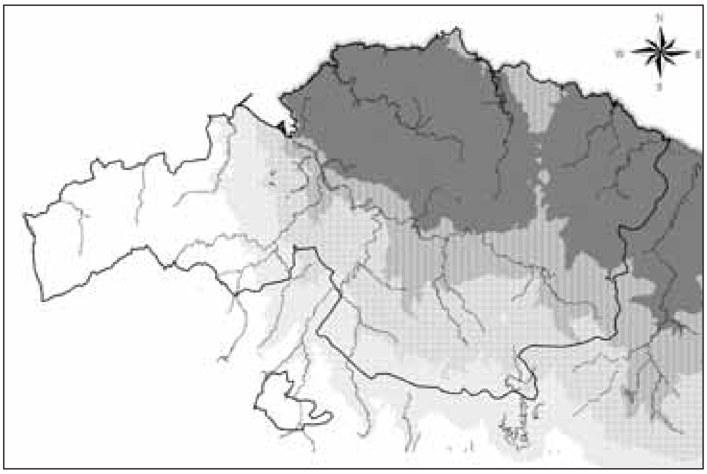

Fig. 4. Modelled expansion of American Mink. The darkest shading shows the areas already occupied. Progressively sparser spotting shows areas progressively less likely to be occupied in a short period of time while white areas are unlikely to be occupied in the short/mid term (more that 10 dispersive movements or generations).

out of streams and force them to move across the road instead of along the canalised bank.

- Territorial minks rarely venture out of the riverbank. In addition, water and thickets and rank riverbank vegetation are the main refuges minks use. Therefore moving across land has been considered to have an accumulative cost.
- Land movements have been considered to have a higher cost if minks must move across roads, urban areas and similar structures.

Over the resulting grid we mapped areas where European Mink is present (from Zabala 2006) and we calculated movement costs considering them as movement origin/destination. For the American Mink simulation, we mapped areas with presence of American Mink populations (from Zabala 2006) and calculated the cost of movements considering known American Mink populations as the origin of dispersing individuals.

Results and Discussion

Breeding movements and breeding dispersal

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 (Fig. 1) that holds a dense American Mink population. Another one is the Lea-Artibai area (Fig. 1) where both mink species are present, but European Mink is 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 (Fig. 1), in which American Mink presence has been sporadically detected and European Mink is absent from big areas. Moreover, those catchments have dense infrastructure along the main river axis and several canalised stretches. The

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

	Value (Cost)	
Cell type	**Dispersal**	**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
Land	5	8

fourth problematic area is the Barbadun catchment (Fig. 1) in the northern 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 for the short–medium distance dispersal simulation are shown in Figure 3. In this case, Biscay appears to harbour two main populations separated by 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 catchment.

The eastern 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 eastern population, in turn, may be fragmented internally, and only marginally linked to the northern area.

Expansion areas of American Mink

The results of the model for American Mink expansion areas are shown in Figure 4. American Mink expansion areas encompass most of the current European Mink presence areas. The only European Mink areas that in the short-term seem to be safe from American Mink expansion are the catchments from western Biscay.

Conclusions

Although geographically explicit models are fallible and heavily reliant on values given to cells, they can be useful as indicators of the most likely scenarios for the short term, and as tools for predicting management hot-spots. In our case, assuming the dispersal values are even broadly reflecting reality, the first two models show that fragmentation in the population of Biscay at different levels is in every case due to two main factors: (1) large urban and periurban areas with canalised streams and degraded riverbanks, and (2) growing American Mink populations. Coastal populations seem most vulnerable because they are in areas of highest American Mink densities and prone to American Mink colonisation (Fig. 4) and currently their gene and individual flow with mainland populations relies upon marginal populations in the upper Ibaizabal and its tributaries. The quality, not simply the existence, of the dispersal routes is of great importance and affects the likelihood that animals use them and that they survive dispersal (Fahrig & Merriam 1994). Indeed, patches connected by dispersal routes of bad quality may act as sinks (Fahrig & Merriam 1994). In the Ibaizabal area, there are a highway, a major road, a railway and many urban areas between the coastal population and the small populations in the south. Besides, unoccupied rivers and streams along dispersal routes are of low quality for European Mink (Zabala 2006, Zabala *et al*. in press) and might also act as a sink by leading minks to establish in poor quality but unoccupied areas. In addition, the area is highly menaced by American Mink expansion and further habitat degradation. Planned canalisation of most main streams and lack of control policies of American Mink are very likely to worsen the situation in the short run. In sum, this means that the best situation for European Mink in Biscay seems to be in the western catchments, where urbanisation is less extensive and local European Mink populations are connected with those from Araba and Burgos, and, at least for now, free of American Mink. The future of the European Mink is uncertain without both habitat conservation and restoration policies, and American Mink eradication.

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