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ORIGINAL PAPER

Space use and habitat preferences of the invasive American mink (*Mustela vison*) in a Mediterranean area

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Abstract Space use, intra-territorial habitat preferences, and factors affecting both were studied in an invading population of American mink, *Mustela vison*, in two rivers of a Mediterranean region of Spain. Average linear home range was 1.19±0.73 km (±SD) and core area was 0.21±0.08 km for resident males (n=10); while for females (n=5) they were 0.54±0.14 and 0.19±0.11 km, respectively. Overlapping between the home ranges of residents was low. In no case their core areas overlapped. Home ranges were small in comparison to other study areas and in general the resident minks were territorial. Linear home range length was related to individual weight and to the river. Weight had a positive effect indicating a potential body condition effect, while river may be showing a habitat quality effect. Habitat preferences were positively affected by the abundance of helophytic vegetation and negatively by the presence of human activity. Helophytic vegetation offers both food and refuges, while human activity may represent a potential danger. Percentage of captures was higher inside the core areas and was slightly influenced positively by abundance of helophytic vegetation. All this information should be considered when designing and implementing measures to control the expansion of American minks. We recommend keeping going with the trapping sessions but, given the results obtained, reducing the distance between traps down to 200 m to maximize capturability (i.e., about doubling the trapping effort), and, when available, placing them near helophytic vegetation. In the absence of helophytic vegetation, traps should be located near any kind of vegetation providing coverage for mink and far from human activity.

Keywords *Mustela vison* · Home range · Habitat selection · Control management · Spain

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Introduction

The American mink (*Mustela vison*) has become a serious conservation problem in Europe, Russia, and South America since its introduction for fur farming. The species has an impact on wildlife, game species, and livestock. It can reduce and locally exterminate potential prey such as watervoles *Arvicola terrestris* (Strachan and Jefferies 1993; Barreto et al. 1998; Macdonald and Strachan 1999) or birds (Nosdström and Korpimäki 2004; Craik 1999; Ferreras and Macdonald 1999). Moreover, it seems that it is outcompeting some of the remaining populations of European mink (Maran et al. 1998), one of the most endangered mammals in Europe (IUCN 2007). In Europe, some governments are currently developing control programs to eradicate the invading populations in order to protect the native prey and the European mink. Since 1999, Spain has a program founded by different regional governments, the central government, and the European Union to control the American mink and to protect the European mink (02MNAT/8604 European Life Program 2001–2005, Generalitat de Catalunya and MMA 2006). Currently, in Spain, several trapping campaigns have been made to control American mink populations placing. Traps were placed along reaches and located at a distance of 300–500 m from each other on both river banks and checked daily. To reduce its establishment and its spread, we need to improve the efficiency of trapping and hence it is important to know the patterns of space use and the habitat requirements affecting the establishment of this species.

The American mink is commonly associated with vegetated areas adjacent to water (Dunstone 1993) exploiting inland waterways and coastal habitats (Dunstone and Birks 1983). The American mink may establish in its natal territory or after natal dispersal. Once established, it holds the territory until death when the space becomes available for new individuals (Macdonald and Rushton 2003). Its linear home range is between 1 and 15.9 km of rivers' length (Birks 1986; Dunstone 1993; Yamaguchi and Macdonald 2003; Zabala et al. 2007a). Several factors can affect the patterns of space use of mustelids. For example, home range size can vary seasonally depending on the availability of resources (Erlinge and Sandell 1986; Robitaille and Raymond 1995). As what occurs with other small mustelid species (Sandell 1989), the mink shows intrasexual territoriality: with males having larger home ranges than females and with male territories encompassing those of females (Dunstone 1993). Moreover, the mink defends its own territory against individuals of the same sex during the non-breeding season (Gerell 1970; Birks 1981; Ireland 1988; Dunstone 1993).

The American mink may also need particular habitat features to establish its home range, survive, and breed. The space use is related to vegetation types and vegetation density, presence of water, pollution, and to the availability and distribution of food and dens (Gerell 1970; Erlinge 1972; Birks 1981; Birks and Linn 1982; Dunstone and Birks 1983; Clode and Macdonald 1995; Halliwell and Macdonald 1996; Loukmas 1998; Loukmas and Halbrook 2001; Yamaguchi et al. 2003).

In this paper, we describe the patterns of space use and intra-territorial habitat requirements of an invasive population established in a Mediterranean area. Studies of Mediterranean populations are scarce but important since mink behavior can differ from other areas due to differences in natural conditions and in the types and availability of habitat and food resources. We present data on home range and core area sizes and overlap and investigate the relationship between home ranges and core area size and sex, age, and weight. We also describe the relation between the number of radiolocations per river section and habitat variables.

Materials and methods

Study area

The study area was located in Catalonia, Spain (1°53′ N, 41°49′ E) along the rivers Llobregat (6 km) and its tributary Gavarresa (5 km). The average annual rainfall is 490 mm approximately, while the altitude ranges between 160 and 350 m. The riparian forest is mainly composed of giant reed (*Arundo donax*), common cattail (*Typha latifolia*), common reed (*Phragmites* spp.), rush (*Juncus* spp.), elmleaf blackberry (*Rubus ulmifolius*), white poplars (*Populus alba*), and willows (*Salix* spp.). As a Mediterranean area, summers are dry, while autumns are characterized by strong rainfalls with the subsequent flooding reducing vegetation coverage yearly.

The main competitors sharing the riparian habitat with *M. vison* are the river otter (*Lutra lutra*), the genet (*Genetta genetta*), and the stone marten (*Martes foina*; Ruiz-Olmo and Aguilar 2002). The main potential preys are several species of cyprinids (*Cyprinus carpio*, *Barbus* spp.), Salmonids (*Salmo trutta*), the American crayfish (*Procambarus clarkii*; Doadrio 2001), and rodents (*Mus musculus*, *Apodemus sylvaticus*, and *Arvicola sapidus*; Palomo and Gisbert 2002).

Mink trapping

One trapping session of 588 trap-nights was conducted annually in 2003, 2004, and 2005. The sessions were set each year between October and December at both rivers. Animals were live-trapped in single cage traps (15×15×60 cm) located on both riverbanks at a distance of 300–400 m and checked every day. After immobilization with 0.15 ml of ketamine (Imalgéne, Rhone Merieux, Lyon, France) and 0.03 ml of medetomidine (Domtor, Pfizer SA, Madrid, Spain), the captured animals were manipulated and classified as either a new capture or a recapture. Trapping was carried out during the post-breeding season when all animals were older than 5 months and there were no juvenile minks (<4 months old). Individuals were classified by sex and age (subadults 5–8 months old; or adults >8 months old) based on the combination of teeth condition and weight. Captured animals were individualized with a transponder (Trovan Ltd., Madrid, Spain). Once fully recovered all animals were released in the same area where they had been captured.

Radiotracking

Several captured animals were marked with waterproof radiotransmitters fitted with collar necks (frequency 150 and 151 MHz, Biotrack, Ltd., Wareham, Dorset, UK and Tinyloc Ltd., Mataró, Spain). Radiocollars weighed approximately 15 g, less than 3% of the lightest adult mink captured during the study (510 g). Signal was received using receiver model TR4 (Telonics Ltd., Mesa, AZ, USA) and multidirectional or bidirectional antennas. Radiolocations were recorded by homing to the animals (U.T.M. positions, using a Garmin GPS, Romsey, Hampshire, UK) without triangulation since mink movements follow the river course (Gerell 1970; Birks and Linn 1982; Ireland 1988; Bonesi 1996). Animals were radiotracked until transmitters stopped working, being the latest locations in early March. Mink were radiotracked each day and fixes were taken every hour if possible.

Radiotracking and capture data analysis

Birks and Linn (1982) reported that mink radiotracked at least twice a day revealed more than 80% of their total home range in <5 days and the entire home range in <10 days. Also Zabala et al. (2007b) conducted incremental analyses of American mink home ranges and found that some individuals may reveal as little as 30% of their home ranges after 15 radiotracking fixes taken in different days. Therefore, only individuals tracked for either ≥5 days or ≥15 fixes in different days were included. Only locations separated by at least 2 h were used to calculate home ranges. We consider this time enough to remove temporal correlation between consecutive locations because in our study area it takes about 2 h for a mink to cover its entire home range. Among successive inactive fixes (without displacement as feeding, hunting, or grooming), only one location was picked up for analysis. Resident and transient minks were distinguished based on their spacing patterns. Transients did not stay in any area for more than five consecutive days and moved. Home ranges (areas with the 99% of the fixes) and core areas (areas with the 50% of the fixes and therefore areas most used within the territory) were calculated as kernel home range using the extension Animal Movement SA v.2.04 beta from the program ArcView GIS 3.2 (Environmental Systems Research Institute, Inc., USA) and afterwards linear home range was calculated based on the linear distance of waterway included in the kernel. Areas used by the animals were calculated using an ad hoc cell size of 25 m and an ad hoc window size of 100 m. A generalized-linear-mixed model (GLMM; McCulloch and Searle 2001) was used to analyze the influence of factors on linear home range and on linear core area. Sex, weight, age, river, and the interaction of the number of tracking days with the number of radiolocations were set as possible fixed factors (independent variables) affecting the spacing pattern of resident minks. Home range size was set as dependent variable. Year and individual were set as random variables.

Overlapping between mink ranges was defined as length of river shared between two minks, calculated using ArcView GIS 3.2 (Environmental Systems Research Institute, Inc., USA), expressed as the percentage of the total home range shared per individual. The effect of the variables sex, age, and status on the percentage of overlapping was studied using a GLMM. Year and individual were set as random variables.

Percentages of captures inside the core areas, inside the rest of the home ranges, and outside the home ranges were calculated for captures of resident minks.

Habitat description

The most obvious habitat characteristics that can affect mink space use are rivers and associated vegetation types as the species does not tend to move far away from water courses (Dunstone 1993; Bonesi 1996). Rivers were divided in approximately 100-m-long sections and the following variables were measured in each section: river depth, river width, abundance of vegetation, and presence of human activity. River depth was taken in the mid of each 100 section; at each mid point, depth was measured in three points along the river width (50 cm of each shoreline and in the middle width). River width was also calculated in the mid point of 100 sections. Vegetation type was recorded along the shoreline and classified into four types: grass, helophytic vegetation (*Tarundo donax*, *Phragmites communis*, and *Juncus* spp.), shrub (*R. ulmifolius*, *Buxus sempervirens*, *Cornus sanguinea*, and *Sambucus nigra*) and trees (*P. alba*, *Salix* spp., and *Pinus pinea*). The abundance of each type was ranked according to its cover between 1 (0–25%), 2 (25–50%), 3 (50–75%), and 4 (coverage 75–100%). Presence of human activity was taken into account if it was on the shoreline (0–10 m) or in the riparian forest (minimum 10 m from water) and it was set as 0 (absence), 1 (agriculture activity), and 2 (industrial activity).

Habitat data analysis

Since vegetation types are correlated, we decided to select those that offer coverage for mink and then that are biologically more important: helophytic vegetation and shrub. River width and depths are also correlated variables, so they were joined in a new variable called river section (area of the polygon draw from river width and river depths). Habitat preferences of radiotracked minks were analyzed using the percentage of radiolocations per each 100-m river section. Percentage of radiolocations of each resident individual was calculated and then summed for each 100-m river section. Therefore, we had the percentage of total radiolocations in each river section. The influence of the habitat variables—helophytic vegetation and shrub, river section, and human activity (dependent variables)—was tested on the percentages of the total radiolocations using a GLMM. Habitat variables were set as fixed effects; year and individual were set as random effect.

Percentage of captures per each river section was also obtained and the influence of the habitat variables on the percentage tested using a GLMM. In this case, we removed human activity from the analysis because all traps were located close to agriculture fields then we would have only a rank. Habitat variables were also set as fixed effects; year and individual were set as random effects.

All statistical analyses were carried out using SAS statistical package version 9.1 (SAS Institute Inc., Cary, NC, USA) and SPSS version 12.0 (SPSS Inc., Chicago, IL, USA).

Results

Mink trapping

A total of 58 captures were obtained, in which 50 minks and eight recaptured minks were trapped: 26 in 2003, 16 in 2004, and 8 in 2005. Overall 35 minks were marked with transmitters, 18 of them provided enough information to study their home range (5 from 2003, 9 from 2004, and 4 from 2005; Table 1). The rest of them lost the collar (n=10) or were lost after being released due to collar failure before having enough radiolocations (n=7). Female F1 was the only mink trapped and marked two consecutive years (in the same trap). However, in the second year we could not obtain enough data. The other radiotracked minks were new individuals each year.

Resident minks were captured with higher frequency inside the core areas (66.67%) than inside the home ranges but outside the core areas (33.33%; χ^2=5.71, df=1, P< 0.025). There were no mink captured outside their home ranges.

Home range

All radiotracked animals stayed closer than 10 m to the nearest water source. The mean linear home range (±SD) size of adult resident males was 0.89±0.46 and 0.21±0.09 km of core area (n=7); mean home range of adult resident females was 0.61±0.14 and 0.21±0.14 km (n=3) of core area (Table 1, Fig. 1). Both resident males and females had between one and three core areas inside their home range (Fig. 1). The mean home range size of subadult resident males was 0.82± 0.17 and 0.20±0.04 km of core area (n=3); mean home range of subadult resident females was 0.43±0.01 and 0.14± 0.01 km of core area (n=2).

There was intrasexual and intersexual overlap between resident minks (Table 1, Fig. 1a,d, and g). However, there was no difference in overlap between sexes (F=0.35, df=1, P=0.56) and neither between ages (F=0.51, df=1, P= 0.48). The overlap was larger between the home range of the residents and those of transients than between residents (F=10.56, df=1, P=0.03; Table 1, Fig. 1c and f). Mink M12 was not included in the overlapping analysis because the individual was found dead before M13 and F5 were trapped, therefore overlapping may not have occurred between them. Nevertheless, core areas never overlapped (Fig. 1b,e, and h).

Factors affecting home range and core area size

We found that heavier minks showed a tendency to have larger home range sizes than lighter minks (F=8.44, df=1, P=0.017). Mean home range size for Llobregat was 0.83± 0.44 km (n=9), and for Gavarresa it was 0.65±0.16 km. Differences between home ranges located in each river were significant (F=5.94, df=1, P=0.02). Sex (F=0.42, df=1, P=0.53), age (F=2.07, df=1, P=0.18), and the factor interaction between tracking days and the number of radiolocations (F=0.12, df=1, P=0.73) were not significant for home range size. No factor was found significant in the case of the core area size analysis (F<8.44, P>0.17 in all cases).

Habitat preferences inside the home range

The GLMM analysis found that abundance of helophytic vegetation had a positive effect on the percentage of radiolocations per section (F=3.45, df=3, P=0.007), while the presence of human activity had a negative effect (F=3.18, df=2, P=0.047). Abundance of shrub (F=0.69, df=3, P=0.63) and river section (F=1.94, df=1, P=0.17) had no effect on the number of radiolocations per river section.

Core areas presented a mean rank of 4±1 (n=35) for abundance of helophytic vegetation and 3±1 (n=35) for abundance of shrub. Home ranges outside the core area presented a mean rank of 3.6±1 (n=50) for abundance of helophytic vegetation and 2.7±2 (n=50) for abundance of shrub.

Percentages of captures, of the total of 58 captures, for each rank of helophytic vegetation were: 20.68% (n=12) for rank 1; 17.24% (n=10) for rank 2; 29.31% (n=17) for rank 3; and 32.76% (n=19) for rank 4. In the case of shrub, results were as follows: 37.07% (n=21) for rank 1; 23.27% (n=14) for rank 3; and 39.65% (n=23) for rank 4. Sections

Table 1 Size of the home range, core areas, and home range overlap (%) of radiotracked individuals (2003, 2004, and 2005)

Individual	Age	Status	Home range (km)	Core area (km)	Home range overlap (%)	Tracking period	No. of tracked days	No. of locations
2003								
Male 1	SA	r	1.01	0.19	67 (F1) 58 (M3)	26/9–10/10	5	8
Male 2	A	r	1.01	0.19	–	24/9–4/12	33	66
Male 3	A	t	2.56	0.23	16 (M1) 14 (F1) 19 (M4)	2/10–16/11	13	34
Male 4	A	r	0.71	0.36	68 (M3)	13/11–29/12	22	34
Female 1	A	r	0.77	0.37	87 (M1) 46 (M3)	23/9–4/12	34	61
2004								
Male 5	A	r	0.44	0.13	–	19/10–2/11	11	15
Male 6	SA	t	2.61	0.31	14 (M7) 16 (M8) 16 (M9) 19 (M10) 5 (F3) 8 (M11)	2/12–15/2	31	99
Male 7	A	r	1.86	0.27	20 (M6) 33 (M11)	21/12–1/2	14	40
Male 8	SA	r	0.77	0.17	59 (M10) 53 (M6)	10/11–22/12	25	53
Male 9	A	r	0.71	0.15	57 (M6) 9 (M11)	10/11–3/12	15	28
Male 10	A	r	0.65	0.10	70 (M8) 75 (M6)	3/11–26/11	14	39
Male 11	A	t	1.60	0.11	39 (M7) 4 (M9) 12 (F2) 13 (M6)	14/12–19/1	23	48
Female 2	A	r	0.52	0.09	37 (M11)	19/10–9/12	34	83
Female 3	SA	r	0.44	0.14	27 (M6)	1/12–6/3	47	436
2005								
Male 12	SA	r	0.68	0.24	–	18/10–4/11	13	33
Male 13	A	r	0.87	0.29	47 (F5)	8/12–21/12	8	22
Female 4	A	r	0.53	0.19	–	31/10–25/11	19	32
Female 5	SA	r	0.42	0.15	100 (M13)	23/11–14/12	11	24

Individual in rows overlaps individual in brackets.
SA Subadult, *A* adult, *r* resident, *t* transient

with rank 2 did not have any capture. No factor (abundance of helophytic vegetation, abundance of shrub, and river section) was significant ($F<0.87$, $P>0.53$ in all cases).

Discussion

Home ranges and spacing pattern

The American mink inhabits long linear home ranges confined to a narrow ribbon of riparian habitat (Dunstone 1993; Bonesi 1996) and that can vary in size depending on its adaptations to different environments. Birks and Linn (1982) found a mean home range length of 4.5 km for males and 2.85 km for females in the UK; Gerell (1970) found 2.13 km for males and 1.85 km for females in Sweden; Palazón and Ruiz-Olmo (1995) observed a female home range size of 2.9 km in Spain; Zabala et al. (2007b) found a mean home range length of 7.1 km for males and 4.9 km for females also in Spain; Yamaguchi and Macdonald (2003) obtained a mean of 6.8 km for males and 2.7 km for females in the UK. Meanwhile, in its original environment of North America, results were higher showing a mean of 11.08 km for males and 5.63 km for

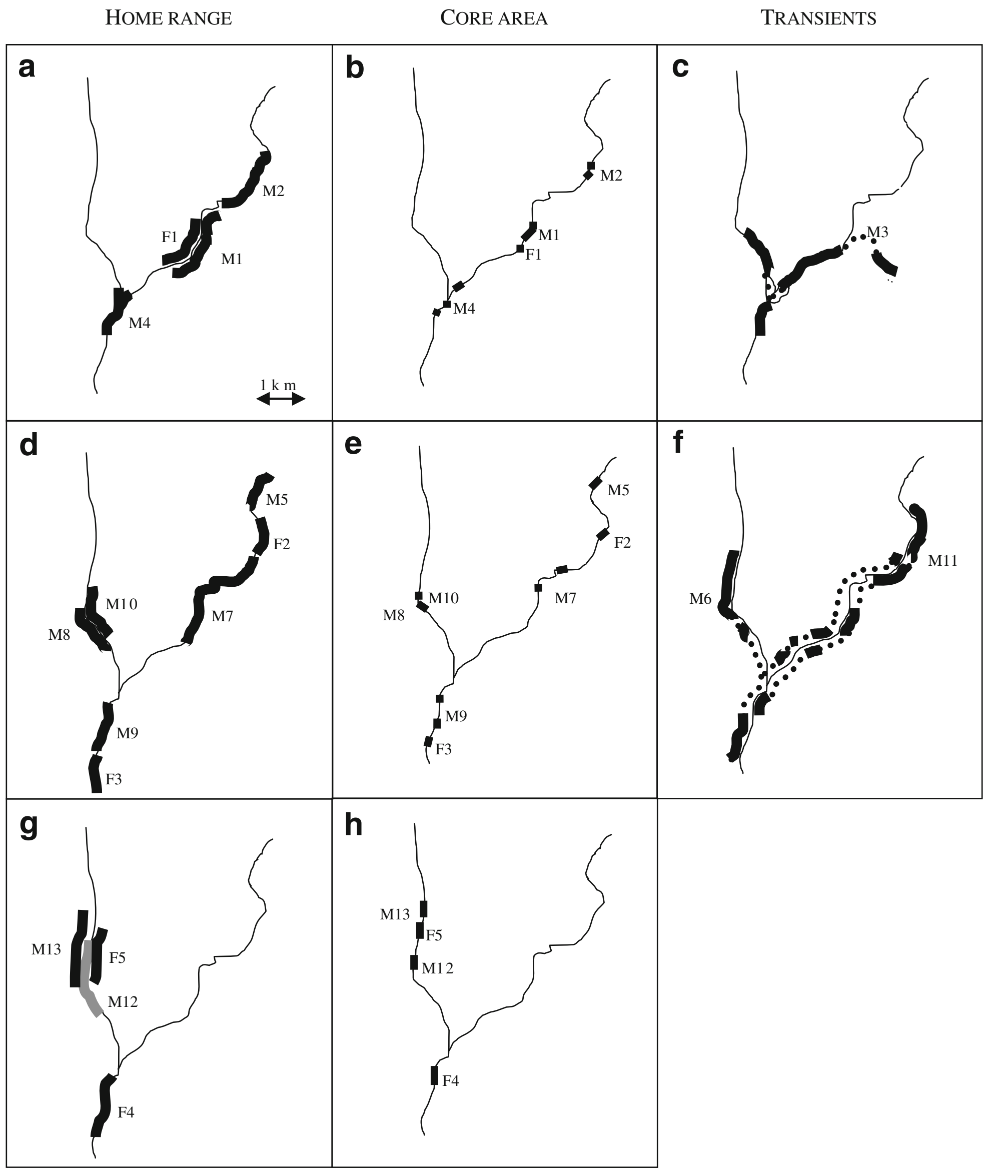

Fig. 1 Linear home ranges and core areas of animals captured in 2003 (**a**–**c**); 2004 (**d**–**f**); and 2005 (**g**, **h**). Home range of transients is shown in *continuous line* for areas where they were radiolocated, and *dichotomous line* for areas where they were not radiolocated but through they may pass in order to reach other areas

females (Stevens et al. 1997). Apart from Palazón and Ruiz-Olmo (1995), the studies were made all the year round so that comparisons with our results are difficult. However, Yamaguchi and Macdonald (2003) did not find seasonal differences for female's home ranges and males are supposed not to hold their territory during the breeding season (Dunstone 1993). Therefore, seasonal variations may not be the only reason for the differences between studies. Variation might be caused by differences in prey availability in each environment since animals are expected to utilize home ranges that are "minimum economically defensible" areas (Gill and Wolf 1975), but which are large enough to satisfy their metabolic needs over time (McNab 1963). In our study, the area holds a high population of the invasive American crayfish, *P. clarkii*, which is the main prey item in the American mink diet (Melero et al., accepted for publication). This prey in combination with small mammals, fishes, and birds provides high prey availability for minks in their small home ranges.

We found home ranges of few resident minks overlapping, and the length of overlap was small, thus, in general the studied minks showed a clear pattern of territoriality. In all cases, for this study, core areas were completely exclusive as the American mink spent most time there and other minks avoided their neighbors' core areas. However, 18 of the 35 captured minks were tracked. Therefore, some of the non-tracked minks can be overlapping their home ranges with the tracked minks. In conclusion, we cannot assure that minks showed a clear territoriality in the study area. The authors Sandell (1989) and Garin et al. (2002) found exclusivity of home ranges for the American and European mink, respectively. Territoriality, though, can be broken due to a dynamic behavior of the individuals trying to expand their territories. An example of this was the overlapping between the American minks of the same sex found by Yamaguchi and Macdonald (2003) in the UK. Overlapping between resident and transient was higher than between resident minks. However, it is not considered as a real overlap since transient minks do not stay long in another mink's territory that is already established. All transients in our research were dispersing subadults looking for a territory.

Habitat selection inside the home range

The American minks do not spend the same amount of time along their home range, being most of the time in areas richer in dens and prey inside the home range (Gerell 1970; Birks and Linn 1982; Dunstone 1993, Halliwell and Macdonald 1996). These areas are the core areas and their selection depends on the factors that make them the more suitable to forage and breed. Site selection by small carnivores is the effect on three factors: protection against predators, proximity to preferred feeding areas, and thermal isolation (Weber 1989; Dunstone 1993; Brainerd et al. 1995; Lindström et al. 1995; Halliwell and Macdonald 1996; Genovesi and Boitani 1997; Zalewski 1997a).

In our study area, the selection of core areas was dependent on helophytic vegetation and the lack of human activity. The presence of helophytic vegetation can be interpreted as offering both refuge and prey. This vegetation is abundant in the area and tends to expand widely along the shoreline, forming areas of difficult access for humans and large animals, thus providing protection to minks (Palazón 1998; Zabala et al. 2003). Vegetation structure changes throughout the year as a consequence of the autumn floodings and the fast recovery of the vegetation in spring. Our minks did not select complex structures as found in other studies (e.g., Zabala et al. 2007b) probably due to the easier access to helophytic vegetation. Furthermore, helophytic vegetation provides easier access to aquatic prey (mostly American crayfish). The importance of helophytic vegetation for thermal isolation should be restricted to winter (Zalewski 1997a, b), and even then, the mild winters of Mediterranean areas might allow the minks to use it at low energetic cost. The presence of human activity either agricultural or industrial had a negative effect on minks. Agriculture in the area is represented by small private vegetable gardens where owners usually had guard dogs, which can prey on minks. However, Zuberogoitia et al. (2006a) observed some interactions between mink and dogs. Interestingly, in their study, mink used areas where there were human activities. Moreover, minks, especially females, were usually found inside henhouses and barns where they preyed on poultry. Gerell (1970) also found mink near agricultural areas.

Management implications

The American mink in Catalonia represents a focus of population spread and a danger because of the considerable negative impacts that it can potentially have on native species through competition or predation (Palazón and Ruiz-Olmo 1997; Palomo and Gisbert 2002; Bonesi and Palazón 2007). First, this population can spread and enter in contact with small and isolated populations of native prey that are actually vulnerable or endangered, for example, the European crayfish, *Austropotamobius pallipes*, or the Iberian desman, *Galemys pyrenaicus* (Palazón and Ruiz-Olmo 1997; Palomo and Gisbert 2002). Secondly, this population can spread through the river Ebro and enter in contact with the west side of the European mink population living in northern Spain. The American mink population of Central Spain has already surrounded European mink populations in its northern, western, and southern part. Only the eastern side is so far free from the American mink pressure (Palazón and Ruiz-Olmo 1997; Bonesi and Palazón 2007). Therefore, if the American mink population of Catalonia spreads it will close completely the European mink population, hindering its recovery.

Although this specie is difficult to remove and conservation should specially focus on European mink direct conservation (Zuberogoitia et al. 2006b), we advise to design the trapping campaigns for the American mink taking into account the home range sizes used by minks and the variables pointing to the preferred areas in order to be more successful in the control of mink populations. Following our results, most of the captures occur within core areas. Therefore, since we do not know where core areas are located, beforehand we should locate traps every 150–200 m, which are core area sizes obtained to maximize capturability. This roughly represents doubling the trapping effort (currently eradication campaigns set traps every 300 to 500 m). In this way, we might increase the capture rate of resident animals, including breeding females (which normally show lower capture rates). Moreover, traps should be placed preferably near helophytic vegetation since it had a positive effect on space use. In its absence, traps should be located near any kind of vegetation providing coverage for mink. Regarding human activity, we advice to check how mink behaves in each area to place the traps either far from human activity (as in our study area) or close (as in Gerell 1970 and Zuberogoitia et al. 2006a).

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All animal procedures comply with the current laws of the country and were done with permission from the Environment Department.

References

Barreto GR, Rushton SP, Strachan R, Macdonald DW (1998) The role of habitat and mink predation in determining the status and distribution of water voles in England. Anim Conserv 1:129–137

Birks JDS (1981) Home range and territorial behaviour of the feral mink (*Mustela vison* Schreber) in Devon. Ph.D. dissertation, Exeter University, Exeter, UK

Birks JDS, Linn IJ (1982) Studies if home range of feral mink, *Mustela vison*. Sym Zool Soc Lond 49:231–257

Birks JDS (1986) Mink. Antony Nelson, Oswestry, Shropshire, UK

Bonesi L (1996) Spatial organization and feeding ecology of the American mink (*Mustela vison*) in a coastal habitat. M.Sc. thesis, University of Durham, Durham, UK

Bonesi L, Palazón S (2007) The American mink in Europe: status, impacts, and control. Biol Conserv 34:470–483

Brainerd SM, Hellding JO, Lindström ER, Rolstad E, Rolstad J, Storch I (1995) Pine marten (*Martes martes*) selection of resting and denning sites in Scandinavian managed forests. Ann Zool Fenn 32:151–157

Clode D, Macdonald DW (1995) Evidence for food competition between mink (*Mustela vison*) and otter (*Lutra lutra*) on Scottish islands. J Zool 237:435–444

Craik JCA (1999) Long-term effects on North American mink *Mustela vison* on seabirds in western Scotland. Bird Study 44:303–309

Doadrio I (2001) Atlas y libro rojo de los peces continentals de España. Departamento de Biodiversidad y Biología Evolutiva. Museo Nacional de Ciencias Naturales, CSIC

Dunstone N, Birks JDS (1983) Activity budget and habitat usage by coastal-living mink (*Mustela vison*). Act Zool Fenn 174:89–191

Dunstone N (1993) The mink. T and A D Poyserd Ltd., London, UK

Erlinge S (1972) Interspecific relations between otter (*Lutra lutra*) and mink (*Mustela vison*) in Sweden. Oikos 23:327–335

Erlinge S, Sandell M (1986) Seasonal changes in the social organisation of male stoats, *Mustela erminea*: an effect of shifts between two decisive resources. Oikos 47:57–62

Ferreras P, Macdonald DW (1999) The impact of American mink *Mustela vison* on water birds in the upper Thames. J Appl Ecol 36:701–708

Garin I, Zuberogoitia I, Zabala J, Aihartza J, Clevenger A, Rallo A (2002) Home range of European mink (*Mustela lutreola*) in southwestern Europe. Acta Theriol 47:55–62

Generalitat de Catalunya and MMA (2006) Proyecto LIFE-Naturaleza (2002-2005) para la conservación del visón europeo (LIFE 02/ NAT/E/8604), Madrid, Spain

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

Gerell R (1970) Home ranges and movements of the mink *Mustela vison* Schreber in southern Sweden. Oikos 21:160–173

Gill FP, Wolf LL (1975) Economics of feeding territoriality in the golden-winged sunbird. Ecology 56:333–345

Halliwell EC, Macdonald DW (1996) American mink *Mustela vison* in the upper Thames catchment: relationship with selected prey species and den availability. Biol Conserv 76:51–56

Ireland MC (1988) The behaviour and ecology of the American mink (*Mustela vison* Schreber) in a coastal habitat. Ph.D. dissertation. Durham University, Durhan, UK

IUCN (2007) Red list of Threatened Species. www.iucnredlist.org

Lindström ER, Brainerd SM, Helldin JO, Overskaug K (1995) Pine marten–red fox interactions: a case of intraguild predation? Ann Zool Fenn 32:123–130

Loukmas JJ (1998) Criteria for quantifying mink (*Mustela vison*) habitat quality in great lakes basin. PhD dissertation, Southern Illinois University at Carbonade, USA

Loukmas JJ, Halbrook RS (2001) A test for habitat suitability index model for riverine systems. Wildlife Soc B 29:821–826

Macdonald RA, Strachan R (1999) The mink and the watervole: analyses for conservation. Wildlife Conservation Research Unit and Environment Agency, Oxford

Macdonald DW, Rushton S (2003) Modelling space use and dispersal of mammals in real landscapes: a tool for conservation. J Biogeogr 30:607–620

Maran T, Macdonald DW, Kruuk H, Sidorovich NV, Rozhnow VV (1998) The continuing decline of the European mink *Mustela lutreola*: evidence for the intraguild aggression hypothesis. In: Dunstone N, Gorman ML (eds) Behaviour and ecology of riparian mammals. Cambridge University Press, Cambridge, UK

McCulloch CE, Searle SR (2001) Generalized, linear, and mixed models. Wiley, New York

McNab BK (1963) Bioenergetics and the determination of home range size. Am Nat 97:133–140

Nosdström M, Korpimäki E (2004) Effects of island isolation and feral mink removal on bird communities on small islands in the Baltic Sea. J Anim Ecol 73:424–433

Palazón S (1998) Distribución, morfología y ecología del visón europeo (*Mustela lutreola* Linnaeus, 1761) en la Península Ibérica. PhD thesis, Universitat de Barcelona

Palazón S, Ruiz-Olmo J (1995) Tracking of a female American mink (*Mustela vison*, Schreber, 1777) in NE Spain. Doñana Acta Vertebrata 22(1–2):97–102

Palazón S, Ruiz-Olmo J (1997) El visón europeo (*Mustela lutreola*) y el visón americano (*Mustela vison*) en España. Serie Técnica ICONA, Madrid, Spain

Palomo J, Gisbert J (2002) Atlas de los Mamíferos terrestres de España. Organismo Autónomo de Parques Nacionales. DGCNA_MIMAM, Madrid, Spain

Robitaille JF, Raymond M (1995) Spacing patterns of ermine, *Mustela erminea* L., in a Quebec agrosystem. Can J Zool 73:1827–1834

Ruiz-Olmo J, Aguilar A (2002) Els grans mamífers de Catalunya i Andorra. Lynx editions

Sandell M (1989) The mating tactics and spacing patterns of solitary carnivores. In: Gittleman JL (ed) Carnivore behaviour, ecology, and evolution. Chapman & Hall, London, pp 164–182

Stevens RT, Ashwood TL, Sleeman JM (1997) Fall–early winter home ranges, movements, and den use of male mink, *Mustela vison* in eastern Tennessee. Can Field Nat 111:312–314

Strachan R, Jefferies DJ (1993) The water vole *Arvicola terrestris* in Britain (1989–1990): its distribution and changing status. Vincent Wildlife Trust, London, UK

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

Yamaguchi N, Macdonald DW (2003) The burden of co-occupancy: intraspecific resource competition and spacing patterns in American mink, *Mustela vison*. J Mammal 84:1341–1355

Yamaguchi N, Rushton S, Macdonald DW (2003) Habitat preferences of feral American mink in the Upper Thames. J Mammal 84:1356–1373

Zabala J, Zuberogoitia I, Garin I, Aihartza JR (2003) Landscape features in the resting site selection of the European mink (*Mustela lutreola*) in south-western Europe. J Zool 260:415–421

Zabala J, Zuberogoitia Z, Martínez-Climent JA (2007b) Winter habitat preferences of feral American mink *Mustela vison* in Biscay, Northern Iberian Peninsula. Acta Theriol 52:27–36

Zabala J, Zuberogoitia I, Martínez-Climent JA (2007a) Spacing patter, intersexual competition and niche segregation in American mink. Ann Zool Fenn 44:249–258

Zalewski A (1997a) Factors affecting selection of resting site type by pine marten in primaveral deciduous forests (Bialowieza National Park, Poland). Acta Theriol 42:217–288

Zalewski A (1997b) Patterns of resting site use by pine marten *Martes martes* in Bialowieza National Park (Poland). Acta Theriol 42:153–168

Zuberogoitia I, Zabala J, Martínez JA (2006a) Diurnal activity and observations of the hunting and ranging behaviour of the American mink (*Mustela vison*). Mammalia 2006:310–312

Zuberogoitia I, Zabala J, Martínez JA (2006b) Evaluation of sign surveys and trappability of American mink: management consequences. Folia Zool 55:257–263