Decline in Endangered Species as an Indication of Anthropic Pressures: The Case of European Mink *Mustela Lutreola* Western Population

THIERRY LODÉ*
JEAN-PAUL CORMIER
DOMINIQUE LE JACQUES
Laboratoire d'Écologie Animale
UFR Sciences
Campus Belle-Beille
2 bd Lavoisier
Université d'Angers
49045 Angers, France

ABSTRACT / Populations of threatened species, especially predators at the top of the food chain, may be affected by anthropic pressures.The endangered western population of European mink *Mustela lutreola* has shown a large decline over 50% of its natural range.*M. lutreola* disappeared from north-western France between 1984 and 1997 and the decline was associated with an increase in mustelid trapping, changes in watercourse quality, and habitat modifications due to agricultural practices.The pattern of decline showed a fragmentation restricting the minks into very small areas.Trapping was the first known cause of mortality. Although feral American mink *Mustela vison* may compete with autochthonous carnivores, *M. lutreola* had disappeared from streams before the introduction of the American species, suggesting that competitive inter-actions were not responsible. Furthermore, American mink has never been found or has remained rare in 62.4% of the area from which *M. lutreola* has disappeared. During the 25 last years, permanent grassland surfaces were reduced by 40% whereas fodder culture in-creased by 470%, causing considerable habitat changes.Furthermore, 55.7% of water courses were classified as being of bad quality or polluted. Therefore, our data suggests that a conjunction of intensive trapping, alterations in water quality and habitat modification was critical for the European mink's decline.Although there are difficulties in ascribing specific cause to distribution changes in a top-predator, this decline can be regarded as an indication for anthropic pressures on natural habitats.

No one can predict how the extinction of one single species will affect natural ecosystems, but the decline of a species could be regarded as a possible indicator of habitat degradation. During the last decades, modifications of agricultural practices have considerably changed the landscape in Europe. The bioaccumulation of toxicants in trophic webs could have a considerable impact on animal communities (Primack 1993), but habitat changes could also affect wildlife by fragmenting populations and by reducing available habitats (Frankel and Soulé 1981). The search for bioindicators allowing the assessment of the effects of these pressures constitutes a real challenge for environmental preservation. Because of their high sensitivity, some species can be regarded as good bioindicators. This is especially the case of top predators acting as keystone species in freshwater ecosystems according with Paine's original definition (Paine 1969). Thus, mustelids, such as otters or minks, were both at the top of the food chain and required precise habitat qualities. Furthermore, only with difficulty these territorial mustelids could avoid bad environmental conditions.

KEY WORDS: Decline; Endangered species; Habitat change; Mustelid; *Mustela lutreola.*

*Author to whom correspondence should be addressed.

Populations of European mink, *Mustela lutreola* L. 1761 (Carnivora, Mammalia), have suffered a decline all over Europe (Youngman 1982). The species has been extinct in central Europe since the beginning of the century (last data from Germany 1948:Saint-Girons 1991; from Hungary 1952: Szunyoghy 1974) and the mink's range is actually fragmented into two population units:an eastern population unit ranging from the Urals and Estonia to the Black sea (Maran and Henttonen 1995), a population that is already subdivided into small units, and a western population (Youngman 1982, Saint-Girons 1991). Observed since 1820 in the Poitou region (Didier and Rode 1935), the European mink's western population was actually restricted to the Atlantic sea board (from Brittany to the Pyrennees) until 1984 (Bree and Saint-Girons1966, Youngman 1982, Saint-Girons 1991), although some individuals were mentioned for the first time in northern Spain in 1951 (Ondarra 1955). Since then, the species has disappeared from the northern half of its range (Maizeret and others 1998). In Brittany, the last known mink were found in 1992 and in 1997 in Vendée (Lodé 1999a). Currently, the western mink population only occupied south-western France (Maizeret and others 1998, Lodé 1999a) and some areas of northern Spain in the Ebro valley (Ruiz-Olmo and Palazon 1996). However, the mustelid is now considered as one of the most endangered mammal species in the world (Schreiber and others 1989).

Inhabiting mainly forest brooks, the European mink occupies an intermediate semi-aquatic niche between the polecat *Mustela putorius* and the otter *Lutra lutra* (Youngman 1982). Numerous reasons for European mink extinctions have been listed by Schröpfer and Paliocha (1989), Saint-Girons (1991) and Rozhnov (1993). These authors hypothesized that habitat changes, trapping and the presence of competitors such as the feral American mink *Mustela. vison* have caused the decline. Reviewing the pattern of the decline in Europe, Maran and Henttonen (1995) considered changes in river banks, due to small river channeling, and modern forestry, to be the major cause of the European mink's decline. Four animals examined by Lopez-Martin and others (1994) were contaminated by PCBs and DDTs, so they proposed that pollution could be partly responsible for the mink's decline. A note for natural processes in the extinction of the European mink has been also articulated (Rozhnov 1993). However, few detailed cases of study were documented. Because invasive species can have a considerable impact on autochthonous fauna, the European mink's decline in eastern Europe is now chiefly attributed to competition with American mink (Maran and others 1998a, Schröpfer and Jordan 1999, Sidorovich 1999).

The recent extinction of European mink from its northern half of the western range provided an unique opportunity to study the causes for the decline of this endangered species. The aim of this study was to analyze whether habitat changes, the pollution of water courses, or competition with *M.vison* could have influenced the decline in the species' north-western range. This study thus provides valuable information on the influence of human activities on an endangered species.

Methods

We analyzed the pattern of population decline focusing on four main reasons for the decline in the northern range of the western European mink population: (1) causes of mortality, (2) influence of the introduction of the feral American mink; (3) water pollution, and (4) habitat modification.

We studied the known causes of mortality of 88 *M. lutreola* considering trapping, road kills, drowning in eel fyke nets, diseases and other causes (hooks, riparian engineering). Cases were classified into three periods: (i) 1965/75, (ii) 1976/86, and (iii) 1987/97. The European mink was protected by law in 1976. Known causes of mortality of mink were compared with causes of mortality of 558 *M. putorius* and 64 *L. lutra* between 1976 and 1997 in western France, using χ^2 test, considering three classes, trapping, road kills and other causes. Mortality causes were also compared with known mortality between 1992 and 1997 in weasel *M. nivalis*, a mustelid trapped as a pest ($n = 351$) and stoat *M. erminea*, a species protected by law ($n = 83$).

The mink current distribution was based on a capture design carried out by live-trapping on every demographic basin from Brittany to Pyrenees between 1992 and 1997 revealing the decline in the north-western range (see Ruiz-Olmo and Palazon 1996, Maizeret and others 1998). Because of the rarity of data since 1987 and because most ancient data were inaccurate, we investigated the effect of competition with the feral mink, water pollution and habitat modification on the base of reliable data obtained from 1976 to 1997 for 37 sites (see Figure 1).

We estimated the influence of the introduction of feral American mink *M. vison* on the regression of *M. lutreola* by noting the date of the first observation of American mink to evaluate their simultaneous or successive use of watercourses. Numerous carnivore and rodent species considered as pests were trapped all the years by hunting societies and the first mention of feral American mink was accurately noted for 37 watercourses frequented by the European mink between 1976 and 1997 considering two periods (1976-86 and 1987-97). All trapped animals were directly identified by observation or skull examination.

Estimates of the pollution of water courses in the northern range was based on a map published by Agence de Bassin Loire-Bretagne in 1985–this date approximately coincided with the mink's decline. The study focused only on water bodies, which formerly have been frequented by *M. lutreola*. The water quality parameters resulted from the analysis of urban, Industrial or agricultural pollutants during the lowest water level. Water courses were classified into four categories from best quality to most polluted water considering oxidizible and organic matters, nitrates, other nitrogenous matters, phosphorus concentration, and hydrobiological quality measured in 307 watercourses (Agence de l'Eau Loire-Bretagne 1985). The proportion of watercourses for each category was compared with watercourses in Aquitaine, where the European

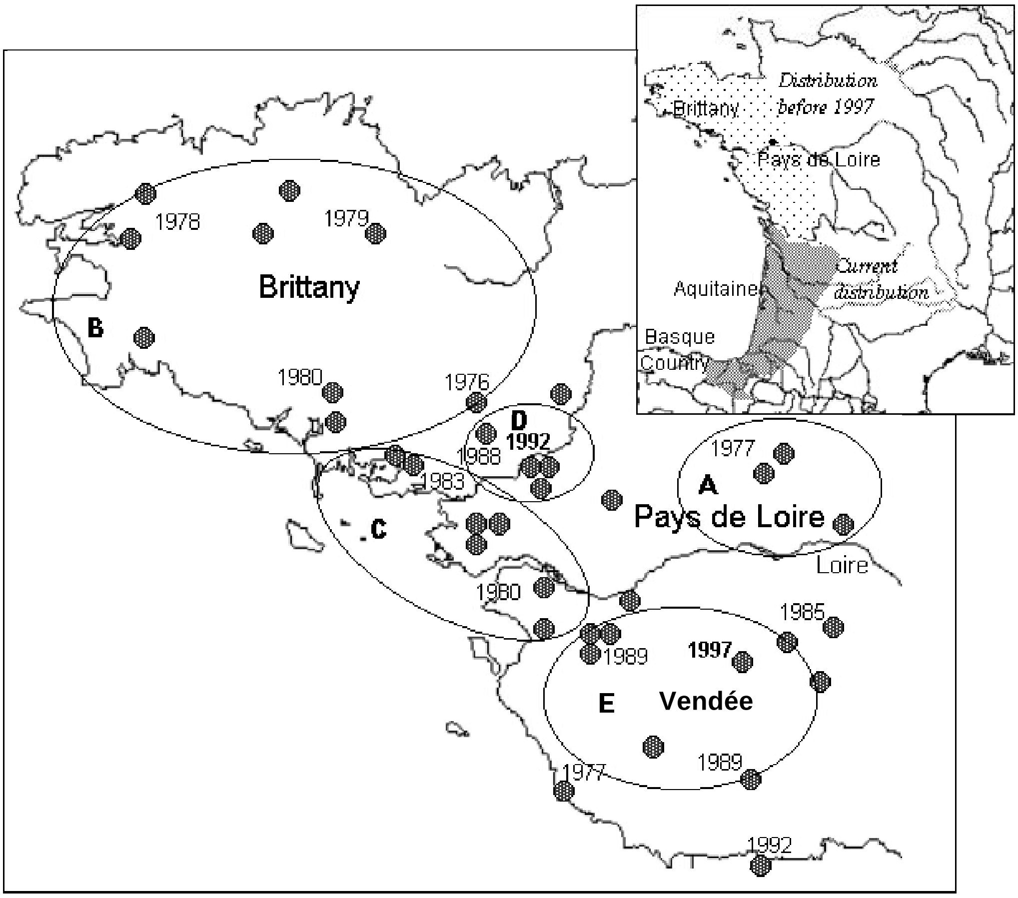


Figure1. Distribution of European mink sites between 1976-97 and dates of last data. (Insert : decline and current range of mink western population based on Palazon and Ruiz-Olmo 1993, Maizeret and others 1998, Lodé 1999).

mink is currently present (Maizeret and others 1998). Measures of the level of nitrates in water and water consumption for irrigation were based on data provided by the Agence de Bassin, but data were not available for all years.

The analysis of habitat modifications focuses on habitat features relevant to *M. lutreola* ecology such as forest surfaces, wetlands and hedges (see Maizeret and others 1998). The habitat modifications were assessed between 1970 (when the European mink was still present) and 1990 (at the end of the mink's decline) by comparing hedge length in 1970, 1981 and 1997, forest surfaces between 1972 and 1997, and agricultural and grass land surfaces between 1970 and 1996. These data were based on Agriculture and Forestry Administration (DRAF, SCEES-INSEE recensement agricole 1970, 1988, 1995-1997), and Environment Regional Administration (DIREN Bretagne and DIREN Pays de Loire). The proportion of natural meadows changed to fodder may constitute a good indicator of modifications to agricultural practices and of anthropic pressures exerted upon landscapes. In addition, the increase of irrigation between 1993 and 1996 was included (source DRAF).

Results

Pattern of Decline

In France, the European mink has disappeared from the northern half of its previous range since 1997 (52.7%, Figure 1). The species mainly frequented small rivers with wooded banks and some marsh areas. First, the mink deserted the north of the Loire river before 1977 (Figure 1, area A). Similarly, the decline occurred in western Brittany before 1980 (Figure 1, area B). Then, the European mink was declining in the southwestern Brittany (Figure 1, area C). At that time, minks only occupied a very restricted area in the Vilaine Valley (Figure 1, area D), the last data being found on a small forest brook "le Moulin" in 1992 (at the crossing of the Vilaine and Isac rivers, 47°34N-2°50W). From this date, the mink has never been recorded except in Vendée in 1997, revealing the survival of the last minks on the Lay River (46°48N-0°57W), a forest stream (Figure 1, area E). Thus, last minks mainly occupied small forest rivers with dense riparian groves (willows *Salix fragilis* and *Alba* and ashes *Fraxinus excelsior*).

Table 1. Known causes of European mink *M. lutreola* mortality in northwestern France from 1965 to 1997

%	1965-75	1976-86	1987-97	Average
Trapping	76,5	73,1	72,7	75
Road kill	11,8	15,4	9,1	12,5
Drowning	5,9	3,8	9,1	5,7
Disease	1,9	3,8	0	2,3
Others	3,9	3,8	9,1	4,5
n	51	26	11	88

Known Causes of Mortality

Out of 88 cases, only 12.5% were found since 1987 in north western France (Table 1). The main known causes of mortality were trapping with 75% and road casualties with 12.5% while drowning, diseases and others causes, respectively reached 5.7%, 2.3% and 4.5%. Differences among the three periods were not significant ($c^2 = 0.66$, df = 4, $p > 0.05$). Between 1976 (when the species started to be protected) and 1997 (last data), of 37 causes of mortality of *M. lutreola*, trapping totaled 73%, road-kills 13.5% and others 13.5% (Figure 2A). Since 1976, causes of mortality ($n = 64$) of otter *L. lutra* populations were mainly road kills (68.7%) while trapping only represented 14.1% and other causes 17.2%. By contrast, the polecat was extensively trapped as a pest by hunting societies and mortality was chiefly due to trapping (76.5%) and road collisions (17.7%). Mortality in *M. lutreola* significantly differed from that of otter ($c^2 = 37.7$, df = 2, $p < 0.0001$) but did not differ from polecat mortality ($c^2 = 3.8$, df = 2, $p > 0.05$). Furthermore, the same trend was found when comparing *M. lutreola* mortality with mortality causes in *M. erminea* ($c^2 = 30.2$, df = 2, $p < 0.0001$) and weasel *M. nivalis* mortality ($c^2 = 4.23$, df = 2, $p > 0.05$) (Figure 2B).

Feral American Mink Introduction

The American mink *M. vison* farming was beginning in 1926 in France but most of fur farms closed during the war. Between 1970 and 1990, the Agriculture and Forestry Administration encouraged the setting up of numerous fur farms, mainly in central Brittany. During this period, some animals escaped and colonized several streams. From 1987, the American mink (considered as a pest) was extensively trapped in Brittany while only six individuals were found in Pays de Loire. Nevertheless, occurrences of American mink were only reported in 37.6% of the area formerly frequented by *M. lutreola*, whilst the American mink has always been absent or rare in 62.4% of *M. lutreola*'s previous range.

Furthermore, occurrences of American mink were found after the decline of *M. lutreola*. Since 1976, out of 37 observations on *M. lutreola*, the simultaneous presence of American mink and European mink was only attested in 14.9% of watercourses while 25.2% of watercourses were only occupied by *M. lutreola* (Figure 3) with no significant differences between the periods 1976-86 and 1987-97 (Wilcoxon $T = 0.0$, $p > 0.05$). Conversely, 59.9% of watercourses first exploited by the European mink ($n = 37$) were then colonized by the American mink 7.7 years on average (SD 3.15, range 3-12) after the extinction of *M. lutreola*. The delay of *M. vison* introduction after *M. lutreola* disappearance did not significantly vary between 1976-86 (mean 8.5 years, SD 3.1) and 1987-97 (mean 6.9 years, SD 3.1) (Welch approximate *t-test* = 1.05, $p > 0.05$). In fact, *M. lutreola* has disappeared from numerous watercourses although *M. vison* has never been found on these waterways or marshes, notably in Pays de Loire.

Water Quality

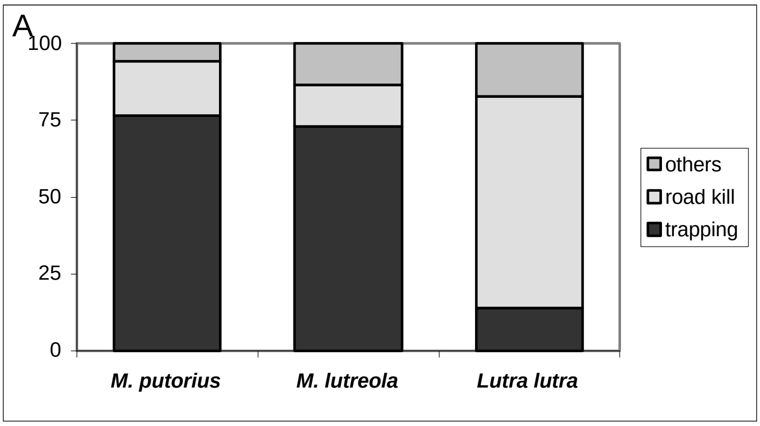
Considering only water bodies formerly frequented by *M lutreola* at least once, the waterways in 1983 appeared to be rather unfavorable, since 55.7% of them were qualified as bad or polluted (Table 2). The quality of watercourses notably differed between northwestern France in 1983 and southwestern France (Aquitaine) where European mink is still present ($c^2 = 15.1$, $p < 0.002$, Table 2).

Between 1971 and 1994 the proportion of water catchments polluted by nitrates varied from 4% to 40% (Figure 4). Water consumption for agricultural needs increased by 55.8% (from 260 millions m^3 to 405 millions m^3) while domestic consumption was only augmented by 16.1% (from 310 millions m^3 to 360 millions m^3) between 1981 and 1990.

Habitat modifications

The structure of habitats changed between 1970 and 1996. The reorganization of agricultural practices entailed an increase of the size of plots, wetland drainage, and a destruction of hedges. There were 383,448 km of linear hedges in 1970, 164,385 km in 1981 and 166,092 km in 1997. Hence, in 1997 the loss was 56.7% (217,356 km of linear hedges) and even reached 57.1% in 1981.

Forest areas extended to 634 600 ha in 1997 in north-western France, showing an increase of 15.2% from 1972 (550,995 ha), mainly due to coniferous plantation (coniferous +30.7%, deciduous +6.1%). In contrast, permanent grassland was considerably reduced from 2,910,000 ha in 1970 to 1,728,400 ha in 1996 (a loss of 40.6%), whereas fodder culture increased by



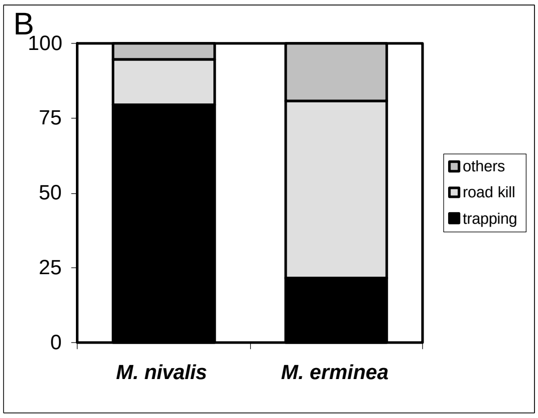


Figure 2. A: Known causes of mortality in *M.putorius, M. lutreola* and *Lutra lutra* from northwestern France between 1976 and 1997. B: Known causes of mortality in *M.nivalis* and *M. erminea* from northwestern France between 1992 and 1997.

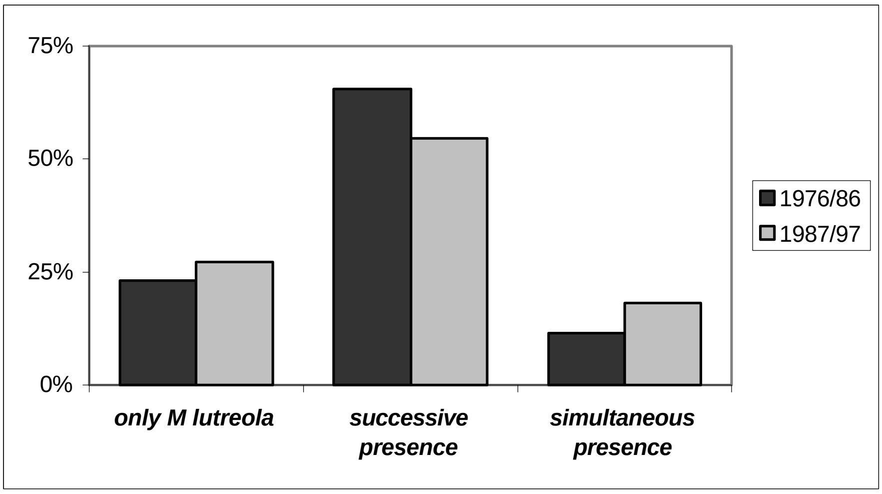


Figure 3. Frequency of watercourses used by *M. lutreola* between 1976 and 1997 in northwestern France considering either the absence, the successive or the simultaneous presence of the feral *M. vison*

470%, from 200 000 ha in 1970 to 1,139,900 ha in 1996 (Figure 5). Today, 55.9% of French maize is produced in western France. Furthermore, this landscape modification has been also associated with the augmentation of irrigation drawn directly from watercourses (+20.9%, from 78,780,000 m^3 in 1993 to 95,214,000 m^3 in 1996), mainly small streams (86%).

Discussion

Conserving populations of rare species requires detailed information for understanding the effect of the factors that affect their survival. The analysis of the decline in European mink western population provides a suitable case study for demonstrating that the distri-

Table 2. Occurrences of watercourses according to the water quality in northwestern France (in 1983 when *M lutreola* was still present) and in south western France (1995, actual range of European mink)

	Good quality	Average	Polluted	Excessively polluted	*n Water courses*
Brittany	45.9	24.6	18.0	11.5	183
Pays de Loire	41.9	37.9	16.1	4.0	124
Total NW France	44.3	30.0	17.3	8.5	307
South western France	72.9	20.8	4.2	2.1	48

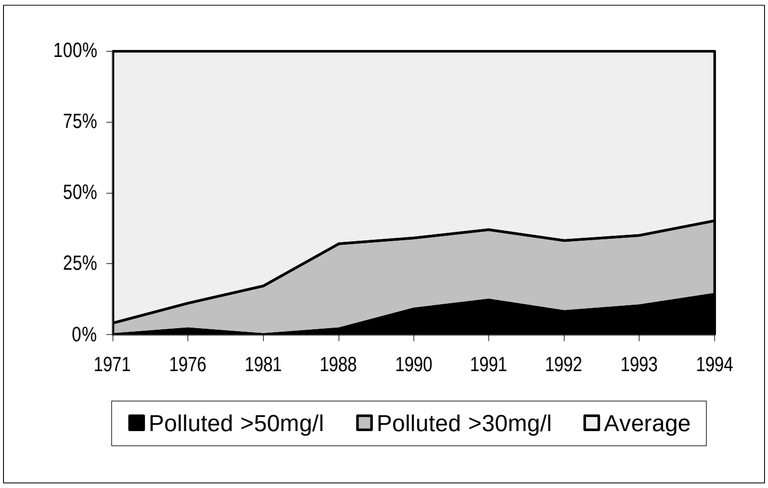


Figure. 4. Alteration of the water quality by NO3 as measured by the proportion of polluted water catchments between 1972 and 1994.

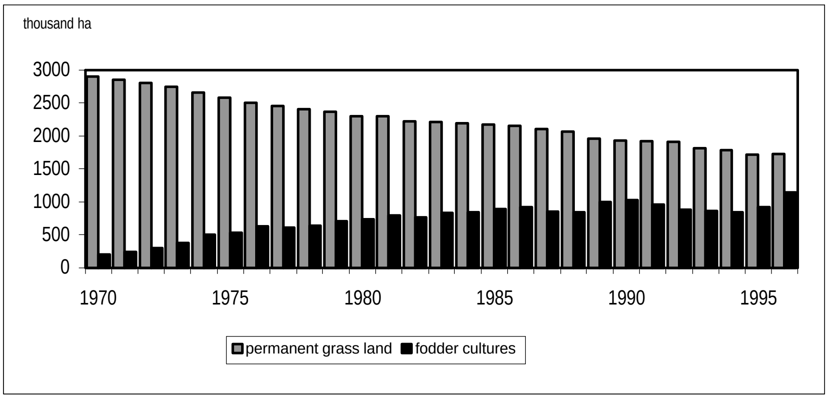


Figure. 5. Variations in permanent grass land surfaces and fodder cultures in north western France between 1970 and 1995.

bution change of top-predators was affected by anthropic pressures. The European mink western population has disappeared from the half of its range in 20 years. The European mink did not exhibit a regular pattern of decline from the north to the south, refuting the common opinion on the existence of a decline front. The population showed a fragmentation restricting the minks into very small areas. Such a decline emphasized the influence of several combined factors.

First, trapping was the main known accidental cause of mortality of *M. lutreola*. In fact, even after 1976, European mink was continuously trapped, although this trapping may be accidental and result from confusion with European polecat or with feral American mink. The dark phenotypes of polecat and European mink were both called "water polecats" by French trappers (Lodé 1995) and were heavily persecuted because they could prey on game species. Known causes of mortality of European mink (protected species) were rather similar to those of polecat (regarded as a pest), whereas they greatly differed from those of otter (protected species). The lower risk of confusion between otters and other mustelids results in lower mortality due to trapping. By contrast, trapping was one of the main causes of otter mortality before its legal protection in 1976 (Bouchardy 1986). Furthermore, *M. lutreola* known cases of mortality were comparable to known cases of mortality in weasels, (another species considered as a pest) whilst they differed from those of *M. erminea*, a protected and easily distinguishable species. Although natural mortality is probably underestimated for all species, these data suggest the dramatic impact of trapping on mustelid populations. Reviewing the distribution of polecat and Pine marten in Great Britain, Langley and Yalden (1977) stressed the role of persecution in the decline of carnivores. Trapping not only lessened the number of mink but also led to the fragmentation of population units.

Second, although feral American mink may compete with autochthonous carnivores (Erlinge 1969, Lodé 1993a, Kauhala 1996, Schröpfer and Jordan 1999), their direct influence on the European mink's decline remains unclear in western Europe. In spite of the introduction of *M. vison*, many stable populations of *M. lutreola* were found in the zone of sympatry of the two species in northeast Russia (Saveljev and Skumatov 1999).In Belarus, *M. lutreola* body size decreased after the introduction of feral American mink (Sidorovich 1999, Sidorovich and others 1999) and the diet of the American species tends to change after *M. lutreola*'s disappearance in Estonia (Maran and others 1998b) supporting the hypothesis of strong competitive interactions (Maran and others 1998a). Exhibiting a pectoropelvic paddling like terrestrial carnivores, the locomotory behavior of the European mink differs only slightly from that of the polecat (Lodé 1999b) whereas the American mink swims more efficiently (Dunstone 1978, Williams 1983). Nevertheless, in northernwestern France, *M. lutreola* disappeared from watercourses several years before the introduction of the feral American mink in 60% of cases. Moreover, 25% of waterways from which the European mink disappeared were not until now occupied by the American species. The inopportune introduction of *M. vison* could affect the presence of *M. lutreola* in only 15% of cases even though the simultaneous presence of both mustelids did not prove to be a decisive argument for negative interactions. Furthermore, *M. vison* has either never occurred or has remained extremely rare in 62.4% of the area from which *M. lutreola* has disappeared. Therefore, in western France it would be unreasonable to attribute the main role in the European mink's decline to competition with American mink.

Third, the quality of watercourses was deteriorating between 1971 and 1994 mainly due to input of nitrates. The European mink actually occupied watercourses of a better quality than those available in the northwestern range. Our results suggest that European mink needs good quality streams and this pollution could be partly responsible for the regression. In American mink, reproduction failed when levels of PCBs exceeded 50 µg g^{-1} on a lipid basis (Jensen and others 1977) and Lopez-Martin and others (1994) found levels on average 122.5 µg g^{-1} in four European mink from Spain. Conversely, although otter populations have shown a relative decline (Lodé 1993b) most watercourses deserted by European mink were still frequented by otters and of pesticide residue concentrations remained low (Mason and Lodé 1992). Thus different hypotheses may be put forward to explain this difference: (1) *M. lutreola* needs higher water quality than otter. (2) the deterioration of water quality has not had a decisive impact. Data were insufficient to allow rejection of either hypothesis. However, European mink do seem to be spreading in Spain despite a variable level of toxicants (Lopez-Martin and others 1994). Despite small differences in habitat selection (Kruuk personnal communication), feral *M. vison* populations showed a substantial regression in water bodies in Brittany, and the presence of American mink mainly resulted from numerous escapes from fur farms.

Fourth, in northwestern France, forest areas changed slightly between 1972 and 1997 in spite of an increase in coniferous plantations. In contrast, the destruction of hedges considerably modified the landscape, previously characterized by a patchwork of small fields surrounded by hedge-topped banks of oaks and ashes, called the "bocage". Hedges made a mosaic habitat in which distinct habitat types were interspersed and favored connections between biotopes (Mwalyosi 1991, Lindenmayer and Nix 1993). However, the major change in habitat structure resulted from the considerable increase of fodder culture between 1970 and 1996, restricting permanent grassland areas. This modification of agricultural practices led to a reduction of water levels, due to the increase of irrigation, and a reduction of prey availability. Because of its semi-aquatic way of life, the European mink may be affected by this lowering of water levels as mainly small streams were pumped out. The European mink needs to accumulate energy resource for surviving in winter (Tumanov and Sorina 1999). In otter, mortality mainly occurs during times of low food availability (Kruuk and Conroy 1991). Similarly, the transformation of habitats is often evoked for the decline of species. Thus, the transformation of meadows in rearing areas entailed the destruction of the black-footed ferret (Miller and others 1990; Biggins and others 1998). Furthermore, the modification of forests intervenes on the situation of the marten (Bright 2000).

Since the disappearance of genetically distinct populations is a major factor increasing a species' extinction risk (Pimm and others 1988, Primack 1993, Hughes and others 1997), the conservation of European mink's western population constitutes an important goal for preservation of the species. Nevertheless, the actual system of protected areas (mainly devoted to bird protection) remains inadequate. Despite the founding of 26 protected reserves in the mink's range since 1970 (source Muséum National d'Histoire Naturelle) *M. lutreola* only occupied 10 of them (38%). The clear coincidence between environmental changes, alteration of water quality and European mink decline suggested that anthropic pressures contributed to the decline. But the western population has also been affected by trapping and legal protection measures were proved to be inefficient. Furthermore, the western population was already threatened by inbreeding (Lodé 1999a, Lodé and Le Jacques 1999) worsening the loss in genetic diversity (Lande 1988, Frankham 1995, Frankham and Ralls 1998, Saccheri and others 1998). Genetic depletion revealed that breeding exchanges were disrupted and can affect the immune response to pathogens (Bergstrom and others 1999), worsening the vulnerability of Mink to diseases. Some cases of Aleutian disease were reported from the southern range (Beaulieu, personnal communication).

Although the regression of European mink was chiefly attributed to competitive interactions (see Maran and others 1998a), the introduction of American mink could not constitute the determining cause for the disappearance of *M. lutreola* in northwestern France. Nonetheless, there are difficulties in ascribing a single cause to the European mink decline. The conjunction of intensive trapping, of alteration of water quality and habitat modification was the critical factor for the decline. Anyway, concrete measures of European mink conservation are needed to curb the decline.

Acknowledgements

We especially appreciated the helpful criticisms from Prof. H. Kruuk on the earlier draft. We thank Dr. Bojorquez-Tapia and Dr Westrum for their comments improving the manuscript. We thank F. André, J. Bayer, M. Belin, J.L. Carrère, M. Chauvet, J.P. Chusseau, M., Ferron, A. Gloaguen, O. Grosselet, J. Hedin, F. Ibanez, D., A. Le Beller, F. Leger, P. Lemaire, M. Madec, C. Maizeret, M. Mercier, M. Monbert, D. Monfort, G. Perais, Y. Philippeau, M. Pichard, M. Poirier, M. Pondaven, J. Pourreau, J.F. Raymond, M.C. Saint-Girons, M. Thomas, Y Trotoux-Hardy and C. Weben.

Literature Cited

Bergstrom, C.T., P. MacElhamy, and L. A Real. 1999. Transmission bottlenecks as determinants of virulence in rapidly evolved pathogens. *Proceedings of National Academy of Sciences USA* 96:5096-5100.

Biggins, D.E., J. L. Godrey, L. R. Hanebrury, B. Luce, P. E. Marinari, M. R. Matchett, and A. Vargas. 1998. The effect of rearing methods on survival of reintroduced black-footed ferrets. *Journal of Wildlife Management* 62:643-653.

Bouchardy, C. 1986. La loutre. Sang de la Terre, Paris, 174 pp.

Bree Van, P. J. H., and M. C. Saint-Girons. 1966. Données sur la répartition et la taxonomie de *Mustela Lutreola* (Linnaeus 1761). *Mammalia* 30:270-291.

Bright, P. W. 2000. Lessons from lean beasts: conservation biology of the Mustelids. *Mammal Review* 30:217-226.

Didier, R., and P. Rode. 1935. *Mustela lutreola* L. le vison. Pages 302-305 *in* R. Didier and P. Rode eds. Les Mammifères de France. Archives d' Histoire Naturelle, Paris.

Dunstone, N. 1978. The fishing strategy of the mink (*Mustela vison*): time budgeting of hunting effort ? *Behaviour* 67:157-177.

Erlinge, S. 1969. Food habits of the otter (*Lutra lutra* Linnée) and the mink (*Mustela vison* Schreber) in a trout water in southern Sweden. *Oikos* 20:1-7.

Frankel, O. H., and M. E. Soulé. 1981. Conservation and Evolution. Cambridge University Press, Cambridge.

Frankham, R. 1995. Conservation genetics. *Annual Review of Genetics* 29:305-327.

Frankham, R., and K. Ralls. 1998. Inbreeding leads to extinction. *Nature* 392:441-442.

Hughes, J. B., G. C. Daily, and P. R. Ehrlich. 1997. Population diversity: its extent and extinction. *Science* 278:689-692.

Jensen, S., J. E. Kihlström, M. Olsson, C. Lundberg, and J. Örberg. 1977. Effects of PCB and DDT on mink (*Mustela vison*) during the reproductive season. *Ambio* 6: 239.

Kauhala, K. 1996. Distributional history of the American mink (*Mustela vison*) in Finland with special reference to the trends in otter (*Lutra lutra*) populations. *Annales Zoologica Fennica* 33:283-291.

Kruuk, H., and J. W. H. Conroy. 1991. Mortality of otters (*Lutra lutra*) in Shetland. *Journal of Applied Ecology* 28:83-94.

Lande, R. 1988. Genetics and demography in biological conservation. *Science* 241:1455-1460.

Langley, P. J. W., and D. W. Yalden. 1977. The decline of the rarer carnivores in Great Britain during the nineteenth century. *Mammal Review* 7:95-116.

Lindenmayer, D. B., and H. A. Nix. 1993. Ecological principles for the design of wildlife corridors. *Conservation Biology* 7:627-630.

Lodé, T. 1993a. Diet composition and habitat use of sympatric polecat and American mink in western France. *Acta Theriologica* 38:161-166.

Lodé, T. 1993b. The decline of otter *Lutra lutra* populations in the region of Pays de Loire (western France). *Biological Conservation* 65:9-13.

Lodé, T. 1995. Convergence morphologique du putois *(Mustela putorius*) et du vison américain *(M. vison*) avec le vison d'Europe *M. lutreola). Gibier Faune sauvage* 12:147-158.

Lodé, T. 1999a. Genetic bottleneck in the threatened western population of European mink *Mustela lutreola*. *Italian Journal of Zoology* 66:351-353.

Lodé, T. 1999b. Comparative measurements of terrestrial and aquatic locomotion in *Mustela lutreola* and *M. putorius. Zeitschrift für Säugetierkunde* 64:110-115**.**

Lodé, T., and D. Le Jacques. 1999. Heterozygosity and bottleneck in the Endangered mink *Mustela lutreola* western population. Third Internartional Symposium of Semiaquatic Mammals, Osnabrück.

Lopez-Martin, J. M., J. Ruiz-Olmo, and S. Palazon. 1994. Organochlorine Residue Levels in the European Mink (*Mustela lutreola*) in Northern Spain. *Ambio* 23:294-295.

Maizeret, C., P. Migot, H. Galineau, P. Grisser, and T. Lodé. 1998. Répartition et habitats du Vison d'Europe (*Mustela lutreola*) en France. *Arvicola "Actes Amiens"* 67-72.

Maran, T., and H. Henttonen. 1995. Why is the European mink (*Mustela lutreola)* disappearing ? A review of the process and hypotheses. *Annales Zoologica Fennica* 32:47-54.

Maran, T., D. W. Macdonald, H. Kruuk, V. Sidorovich, and V. V. Rozhnov. 1998a. The continuing decline of the European mink Mustela lutreola : evidence for the intra-guild competition hypothesis. *Symposium of Zoological Society of London* 71:297-323.

Maran, T., H. Kruuk, D. W. Macdonald, and M. Polma. 1998b. Diet of two species of mink in Estonia: displacement of *Mustela lutreola* by *M. vison*. *Journal of Zoological of London* 245:218-222.

Mason, C. F., and T. Lodé. 1992. Analyse de la concentration des résidus de pesticides organochlorés et PCBs dans les fèces de la Loutre *Lutra lutra*. *Bulletin de la Société des Sciences Naturelles de l'Ouest de la France* 14:109-113.

Miller, B., C. Wemmer, D. Biggins, and R. Reading. 1990. A proposal to conserve Black-Footed ferret and the prairie dog ecosystem. *Environment Management* 14:763-769.

Mwalyosi, R. B. B. 1991. Ecological evaluation for wildlife corridors and buffer zones for lake Manyara National Park, Tanzania and its immediate environment. *Biological Conservation* 57:171-186.

Ondarra, P. R. 1955. Hallazgo, en Guipuzcoa, de un mamifero no citado en la "Fauna Iberica" de Cabrera, el *Putorius lutreola*. *Munibe* 7:201-207.

Paines, R. T. 1969. A note on trophic complexity and community stability. *American Naturalist* 103:91-93.

Pimm, S. L., L. H. Jones, and J. Diamond, J. 1988. On the risk of extinction. *American Naturalist* 132:757-785.

Primack, R. B. 1993. Essentials of Conservation Biology. Sinauer Associates, Sunderland.

Rozhnov, V. V. 1993. Extinction of the European mink: ecological catastrophe or a natural process ? *Lutreola* 1:10-16.

Ruiz-Olmo, J., and S. Palazon. 1996. Situation actuelle du vison d'Europe en Espagne et perspectives de recherche. *Cahiers d'Ethologie* 15:425-434.

Saccheri, I., M. Kuussaari, M. Kankare, P. Vikman, W. Fortelius, and I. Hanski. 1998. Inbreeding and extinction in a butterfly metapopulation. *Nature* 392:491-494.

Saint-Girons, M. C. 1991. Le Vison sauvage *Mustela lutreola* en Europe. *Collection Sauvegarde Naturelle* 54, European Council, Brussels.

Saveljev, A., and D. Skumatov. 1999. Recent status of the European mink *Mustela lutreola* in the north-east of its area of distribution. Third International Symposium of Semiaquatic Mammals, Osnabrück.

Schreiber, A., R. Wirth, M. Riffel, and H. Rompaey. 1989. Weasels, Civets, Mongooses and their relatives. An action plan for the conservation of mustelids and viverrids. IUCN & NR, Gland.

Schröpfer, R., and M. Jordan. 1999. Niche analysis of the Mustela species lutreola, putorius, and vison by craniometry and direct observation in enclosures. Third International Symposium of Semiaquatic Mammals, Osnabrück.

Schröpfer, R., and E. Paliocha. 1989. Zur historischen and rezenten Beständerung der Nerze *Mustela lutreola* (L. 1761) und *Mustela vison* Schreber 1777 in Europa-eine Hypothesendiskussion. *Wissenschaft Beitung Univität Halle* 37:303-321.

Sidorovich, V. 1999. Study on the decline in the European mink populations in connection with American mink expansion in eastern Europe: review of results and research priorities. Third International Symposium of Semiaquatic Mammals, Osnabrück.

Sidorovich, V., H. Kruuk, and D. W. Macdonald. 1999. Body size, and interactions between European and American mink (*Mustela lutreola* and *M. vison*) in Eastern Europe. *Journal of Zoology of London* 248:521-527.

Szunyoghy, J. 1974. Eine weitere Angabe zum Vorkommen des Nerzes in Ungarn, nebst einer Revision der Nerze des Karpatenbeckens.*Ver Hungarian* 15:75-82.

Tumanov, I. L., and E. A. Sorina. 1999. Seasonal changes in nutrition and some physiological parameters in the European mink *Mustela lutreola* L. and in the American mink *Mustela vison* Schreb. Third Internatioanl Symposium of Semiaquatic Mammals, Osnabrück.

Williams, T. M. 1983. Locomotion in the North American mink, a semi-aquatic mammal. I. Swimming energetics and body drag. *Journal of Experimental Biology* 103:155-168.

Youngman P. M. 1982. Distribution and the systematics of the European mink Mustela lutreola Linnaeus 1761. Acta Zoo- *logica Fennica* 166:1-48.