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Review Article

The European Mink's Paradox: Near Extinction but Colonizing New Habitats

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Abstract

Following known historical occurrences of endangered European mink (*Mustela lutreola*), it seems that western population came from Black sea gradually ascending the Danub, passing through the north of the Alpine arc, and then following the Loire river toward western France. The western range of mink extended from Brittany to Aquitaine. Nonetheless, the western population suffered a dramatic decline, restricting in range by half. Analysis of known causes of mortality showed that trapping and loss of habitat were involved in the decline. Paradoxically, and despite a severe bottleneck, the western population of European mink has colonized rice paddy fields and garrigue Mediterranean areas, new habitats never used before, emphasizing the decisive role of peripheral populations for conservation biology. Such an unexpected colonisation pattern chiefly results from the long-distance breeding strategy usually used by mustelids, but clearly complicates the conservation in restricted natural reserves. Until now, mink remains the only known case of an endangered species capable of colonizing new habitats.

INTRODUCTION

During their dispersal, many species encounter novel environments but exploration can entail costs due to predation, road mortality or bad environmental conditions [1,2]. Despite the potential fitness consequences of finding habitats, most species are known to reject unfamiliar sites and return to the source site, showing homing behaviors [3]. Understanding dispersal and breeding strategies can provide biological insights and are needed for wildlife management, future conservation and reintroduction projects. In addition, species near extinction generally exhibit both a decline in their range and depletion in genetic diversity [4]. Ecological factors were mostly recognized as having a major impact on the decline of populations but the loss of genetic stochasticity is regarded as a process restricting the evolutionary potential of wildlife species [5]. Genetic depletion through a bottleneck can reduce species' ability for persistence in a changing environment by depressing its reproductive fitness [6,7].

Formerly spread all over Europe, populations of European mink *Mustela lutreola* L 1761 have suffered a severe decline resulting in the isolation of a western population in western France from an eastern one from the Ural Mountains to the Black sea since the beginning of the century [8-10]. The European mink has been experiencing a drastic and ongoing reduction of its distribution range for about 40 years resulting in a brutal bottleneck [10-12], and is now recognized as one of the most endangered animals in the world. Furthermore, the western population actually has contracted in range by half in France [9,11].

The rapid decline in Europe has been mainly attributed to habitat loss due to intensive agriculture and forestry exploitation [13,14]. The competition with *Mustela vison* was also suspected having worsened the decline [15,16]. Despite its legal protection, *Mustela lutreola* was often confused with feral American mink and European polecat which were still persecuted as pest.

Actually, a critical aspect of endangered species recovery is to estimate the viability of a population. Rarity is a major component of species vulnerability and carnivores, as top predators, are basically found in fairly low densities even in optimal [17].

Surprisingly, and despite its general decline, the European mink has paradoxically been found in new habitats revealing a new facet of its ecology. Traditionally regarded as a semi-aquatic mustelid inhabiting mainly mixed forest brooks [8,13,18], the European mink was recently observed to exploit new Mediterranean areas. Thus, a large part of the total western population today occupies Mediterranean habitats along the Ebro River, up to the delta.

It seems very interesting to investigate the reason why an endangered species could show such a change in its natural area.

METHODS

Here, 170 cases of mortality in the northern part of the western population's range, from where the species recently disappeared were documented. The last record in Brittany was in 1992 and 1997 in Vendée (Figure 1). We collected credible evidence supported by photos, skulls or pelts and the known causes for mortality were classify into five categories: trapping, road-kills, drowning, diseases and others (killed by dogs, accidental crushing during riparian engineering works, swallowing a hook etc…). This species has been protected by law since 1976 and consequently the data were classified into four periods between 1) before 1964, 2) 1965 to 1975, 3) 1976 to 1996 and 4) 1997 to 2007. Because some periods and categories had only few records, they were combined to perform a χ^2 test between trapping and other causes of death between only two periods before 1976 and after 1976. Analysis of variance by rank (Kruskall-Wallis) was made among the four periods comparing trapping with all other causes. Further, 64 causes of mortality in otter Lutra populations were also collected in western France between 1976 and 2004. In order to compare with mink data, a χ^2 test was performed between otter and mink data after 1976 considering three categories, trapping, road kills and other.

Finally, we conducted a critical analysis of the historical distribution and habitat of the western population based on literature and the 170 records were collected.

RESULTS & DISCUSSION

Causes of mortality

Surprisingly, although the species has been in France protected since 1976, in 170 cases of mink mortality known between the beginning of the century and 2007, trapping was the major cause representing 83.5% of the whole mortality (Figure 2). The number of trapped individuals regularly decreased but the number of casualties did not significantly differ either before 1976 (115 trapped mink, 18 others) and after 1976 (27 trapped mink, 10 others) (χ^2=2.9, df=1, p>0.05) or among four considered periods comparing trapping and other causes (KW = 2.17, p>0.05) indicating that trapping remained the main cause of mortality. One male (VE076) was still trapped in Vendée, in August 1997 (Petit Lay River).

The other causes totalled 16.5% of mortality. Road-kills represented 8.2% of mortality. Drowning accidents (4.7%) were mainly due to eel fyke nets in marsh areas and two cases (1.2%) of parvoviral disease were suspected.

In western France since 1976, causes of mortality (n=64) of otter Lutra populations were mainly road-kills 68.7% while trapping represented 14.1% and others 17.2% (including drowning 6.3%). Since 1976 on 36 causes of mortality in *Mustela lutreola*, trapping totalled 75%, road-kills 11.1% and others 13.9% and significantly differed from otter mortality (χ^2=39.9, df=2, p<0.0001).

In fact, even after 1976, European mink was repeatedly trapped by accident because it remained poorly known and confusion is often made between this species and the feral American mink *Mustela vison* or especially the dark phenotype of European polecat *M. putorius*, which was persecuted as pest. During the same period, the otter was protected and the lower risk of confusion with unprotected species meant that few otters were accidentally trapped.

By contrast, accidental trapping clearly may be one of the main causes of the probable extinction of the European mink in north-western France. Documenting the decline in the distribution of polecat, pine marten Martes martes and wild cat Felis sylvestris in Great Britain, Langley and Yalden [19] stressed that direct persecution was involved. Allee effect hypothesis [20] predicts that poor habitats through habitat deterioration may result in such extensively scattered home-ranges that low densities prevent most females from finding mates. Indeed, fitness could be strongly affected by a decrease in population density. The species could lost partially its breeding ability as shown by hybridization events [21].

Colonization scenario

Historical data showed that the western range of European mink extended from Brittany to Aquitaine although some scattered data were present up river in the Loire Valley (Figure 1a). Following known historical occurrences of mink in the modern period, it could be hypothesized that western population of mink came from Black sea gradually ascending the Danub and passing through the north of the Alpine arc, and then following the Loire River toward western France (Figure 1b). Yougman [8] noticed that mink from Romania resembled French more than Russian or Baltic mink, supporting this hypothesis.

In France, the European mink, has disappeared from the northern half of its previous range. The decline was not regular but showed a fragmentation restricting the mink into very small areas in twenty years. First, the decline occurred in the north of the Loire River before 1997. The last European mink from north-western population was found in a very restricted area on a small forest brook in 1992 (47°34N-2°50W) and on the Lay River in 1997 (46°48N-0°57W) [9]. Then, the pattern of decline exhibited subdivision into undersized areas restricting the mink into very small subpopulations between the Gironde and the Pyrenees. The population continued to fragment into several subpopulations, the main ones being in Charente-Maritime and in the south of the Gironde. Thus, the general decline in mink western population does not occur in south peripheral range but in the centre and the north of the range.

There are three PNR (PNR Armorique 65000ha, PNR Brière 7000ha and PNR Marais poitevin 70000ha) in the area deserted by the mustelid while only one PNR exists in the actual range (PNR Landes de Gascogne 206140ha). But, although habitats were relatively protected in these PNR, both hunting and trapping were allowed. Despite the founding of 26 protected reserves since 1970 in the mink range *Mustela lutreola* only occupied 11 of them (42.3%). Strategies for habitat protection in the general pattern of a MAB-reserve (UNESCO) stressed the importance of preserving a core strictly protected area considering that peripheral zones could endure a moderate human impact [22]. The buffer zone surrounding an undisturbed core area constitutes a transition zone which may favour animal dispersal [23].

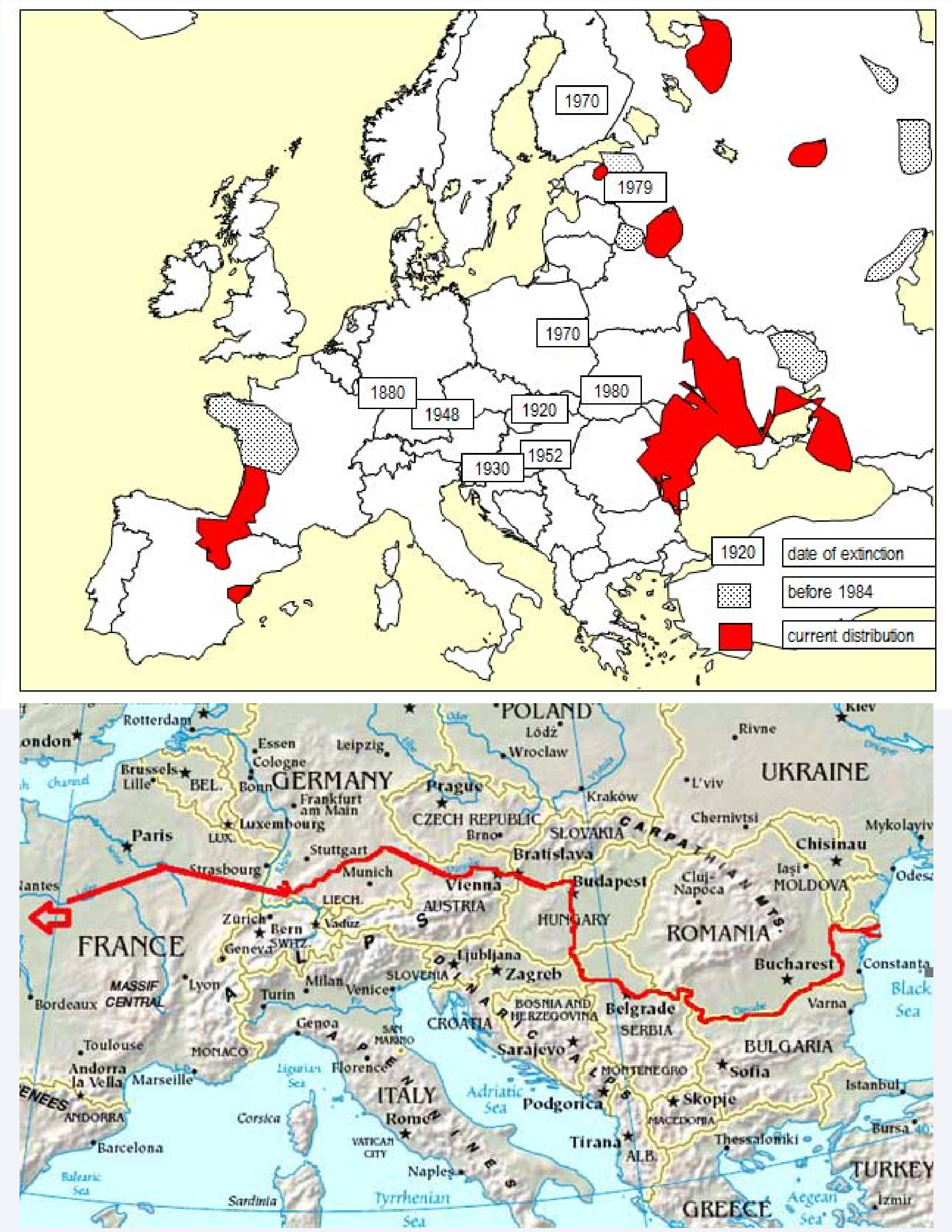

Figure 1 A: Last occurrences and current distribution of *Mustela lutreola* in Europe, **B:** Dispersion scenario of *Mustela lutreola* colonizing Europe from Black sea.

Habitat change

That some habitat types may favour a good reproduction forms a key factor for species conservation and environmental management [24] but here novel habitats never used before are occupied. The first mention of the species in northern Spain was in 1955, slowly followed by 85 other records [18]. European mink data have not been recorded in other Mediterranean areas, either in western Europe (southeastern France and Italy) or in eastern Europe (Albania, Croatia, Greece and Turkey), although an unique record was reported from Vojvodina, Serbia in 1941 [25]. These data support the conclusion that the Mediterranean areas in Spain were very recently colonised from the European mink's western population. Mink exploited river banks near the river Ebro but were also found in typical garrigue Mediterranean habitat and rice paddy field [18]. The change in the western range thus support the conclusion that the Mediterranean areas were very recently occupied from the European mink's western population.

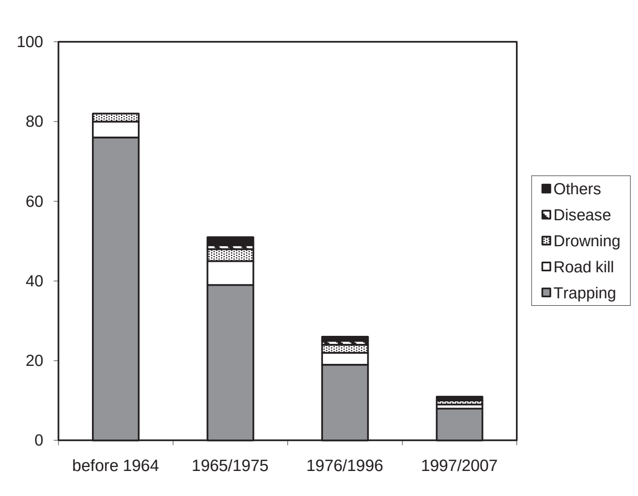

Figure 2 Known causes of European mink mortality between the beginning of the century and 2007 in north-western France.

The reasons for this colonisation of Mediterranean areas were poorly known but for the first time an endangered species shows both a decline and a colonisation new habitats. Displacement in Mustelids were usually characterized by a succession of small movements and of longer journeys towards profitable sites revealing area-restricted predatory tactics and favouring solitary habits [26]. Although mustelids exhibited individualistic habits, it is known that male mink breeding strategies occurs via long-term breeding excursions so that they could move farther away searching for mates [27-29]. Thus, polecat made also frequent breeding excursions away from familiar ranges [28,30]. The very low population density therefore led to a shift in the area so that individuals ventured along the Ebro River. This recent colonization of Mediterranean areas was realized from the southern of the range while mink populations are declining in northern and central ranges. In any case, the modern history of the mink advancing regularly along the Danube valley seems to demonstrate a peculiar aptitude for such colonization.

CONCLUSION

The "Mink paradox" consists in that the endangered European mink exhibits a capacity to colonize new habitats demonstrating a relative level of plasticity in habitat use despite a recent severe bottleneck. Paradoxically, this endangered species is proved to exploit new habitats, Mediterranean garrigue and rice paddy field, never used before. Until now, mink remains the only known case of an endangered species capable of colonizing novel habitats.

The recent colonization of Mediterranean areas occurred from marginal population units in the southern of the range, resulting from a strategy of breeding excursions away from familiar ranges. Little is still known about interactions between carnivores and what favours their coexistence [31]. In fact, very low densities of mink in western population might prevent most females from finding mates. Mink and polecats have cohabited in sympatry for a long time. That the mink hybridized with polecat in its northern range suggests the species could lose partially its breeding ability and may viewed as a response to decreasing potential mates [21]. Moreover, mink avoidance from polluted watercourses might result in a greater subdivision of populations but mink can coexist in habitat still frequented by polecat and otters [14].

Although a bottleneck may alter more the number of polymorphic loci than the heterozygosity [32], Ralls et al. [33], building a model of a long-term bottleneck in sea otter Enhydra lutris populations, predicted a loss of 12 to 23% of heterozygosity. The bottleneck effect could differ from a species to another but this predicted loss allowed estimating a pre-bottleneck heterozygosity reaching 0.0251 in *Mustela lutreola*. Endangered animals can be recognized by rate of genetic diversity loss. Nonetheless, genetic diversity in European mink western population remained weak but in the average of others mustelids and was clearly higher than that of endangered black-footed ferret Mustela nigripes populations (Table 1). Genetic diversity was slightly higher in some studied mustelids than in the mink, for instance, Ho = 0.033 in Stoat M. erminea and ranged from Ho =0.018 to Ho = 0.032 in River otter Lontra canadensis [34]. Analysing 8 microsatellite data in Polecat and European mink from southwestern France, Peltier & Lodé [12] demonstrated a comparable genetic diversity in both species although the significant heterozygote deficit revealed that inbreeding affected mink populations. Similarly, Michaux et al. [10], also found a mean genetic diversity.

So, it could be hypothesised that an unexpected ability to colonise a different habitat chiefly results from the long-distance breeding strategy usually used mustelids but could be favoured by the retention of a certain fitness and a strong adaptive potential. I reason that this habitat change may result from the maintenance of genetic diversity in marginal population units showing ability to reply to new environmental constraints. In turn, long-distance dispersal events may significantly reduce inbreeding depression

Table 1: Comparison of genetic diversity (number of polymorphic loci and level of heterozygosity) in some mustelids.

	M. lutreola	*M. putorius*	*M. erminea*	*M. nivalis*	*M. putorius*	*M. nigripes*	*Martes americana*	*Enhydra lutris*
Polymorphism P (0.95)	7.9%	25.8%	7.5%	22.5%	10%	4.3%	33.0%	19.4%
Heterozygosity	0.020	0.057	0.033	0.064	0.029	0.008	0.17	0.046
N. loci studied	38	31	40	40	40	46	22	31
N. individuals	*12*	*49*	*3*	*19*	*16*	*17*	*10*	*64*
Population	Western France	Western France	Austria	Austria	Austria	Central USA	Wyoming	California
Authors	[11]	[36]	[37]	[37]	[37]	[38]	[39]	[40]

and are biologically very important for small population survival. Our results provide an understanding of the factors governing a vulnerable species to cope with a novel environment and clarify the potential fitness consequences of finding habitats. Indeed, that marginal population units of a threatened species were able to colonise distinct new habitats constitutes a clear challenge for conservation biology. The long-distance breeding strategy of *Mustela lutreola* complicates the conservation of the species in restricted natural reserves. Different models for how to conserve carnivores were proposed, but new researches are however needed to incorporate breeding strategies in population dynamics and habitat requirements of endangered species [35]. Anyway the mink's paradox emphasises the decisive role of peripheral population in conservation of endangered species.

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