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Review

The American mink in Europe: Status, impacts, and control

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ABSTRACT

We examine the distribution of American mink *Mustela vison* in 28 European countries, and we review the impacts of this invasive species and the efforts made so far in controlling it. Our study reveals that, although mink farms are mostly concentrated in northern countries, mink are widely distributed across Europe, and that in some countries mink are apparently declining, although in most cases the causes are unknown. Countries for which the impact of mink on native species has been studied show that mink can have a significant effect on ground-nesting birds, rodents, amphibians and mustelids. The overall economic impact of feral mink seems to be relatively small but can be significant in specific regions. Recently, a number of eradication and local control projects have been carried out throughout Europe, indicating that these actions could be effective to protect native species. A consistent body of knowledge is starting to accumulate on issues concerning the American mink as an invasive alien species, but, as this review highlights, for most European countries there is currently a limited knowledge about its distribution or impacts. Taking all these observations together, we present some of the actions that have recently emerged as effective for dealing with this species and discuss which considerations may further encourage competent European authorities to take action to prevent and mitigate impacts of American mink.

Contents

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1. Introduction

The American mink *Mustela vison* is one of the five species of non-native mammals that have established feral populations following introduction to Europe from North America (Jeschke and Strayer, 2005). American mink have been introduced for the purpose of fur farming and, as a result of escapes and their intentional release in Russia and other countries, the species is now naturalised in many parts of Europe (Mitchell-Jones et al., 1999). Feral populations of American mink have been reported also in Asia and South America (Medina, 1997; Previtali, 1998).

Mink, as an alien introduced species, can be detrimental to native species and to economic activities (Harrison and Symes, 1989; Moore et al., 2000; Macdonald and Harrington, 2003). It is therefore crucial to establish the impacts of the American mink in Europe and the best strategies that may be available to control their populations.

In this paper, we first review the status of mink as an invasive species in 28 European countries. We then consider some of the actions that have recently emerged as suitable for dealing with this species and discuss which factors may further encourage competent European authorities to take action to prevent and mitigate the impacts of American mink.

2. The status of mink in European countries

This review was compiled by searching published and grey literature, and, in the cases for which there was no available information in the public domain, we reported personal communications from researchers in individual countries (see Acknowledgments). For each country we aimed at gathering the following information: (1) the extent of mink farming; (2) the extent of mink distribution; (3) the impact of mink on the native fauna; (4) the attempts at dealing with the problem of mink. An overview of the results for each country is described in Box 1 and this information is also partly summarised in Tables 1–4; a map of the relative abundance of mink in each European country can be found in Fig. 1, and a map of mink distribution in Europe is provided in Fig. 2.

Box 1. Summary of the status of mink country by country

*Austria:*Fur farms have been made illegal in Austria, but they were present until 1994. Escapes from these farms and immigration of mink from the Czech Republic have given rise to some feral mink populations starting from the mid-1990s (Andreas Kranz, personal communication). These populations can be found north of the Danube in Lower and Upper Austria and also along the Danube Lowlands, south of the Danube. Moreover there is a population in south-eastern Styria and neighbouring province of Burgenland (Andreas Kranz, personal communication). The impacts of mink on native species have not been studied in Austria.

Belarus: Mink farms are present in Belarus and the American mink is widespread, possibly thanks to the high prey biomass that can sustain mink and other mustelids of the same guild (Sidorovich, 1992; Sidorovich et al., 1996; Sidorovich et al., 1998). In Belarus, it has been shown that the American mink has a negative impact not only on the water vole *Arvicola terrestris* and on the European mink *Mustela lutreola*, but also on the polecat *Mustela putorius* (Sidorovich and Macdonald, 2001; Macdonald et al., 2002b). Studies are being carried out to verify the impact of mink on the root vole *Microtus oeconomus* and waterfowl (Vadim Sidorovich, personal communication). American mink are in turn limited by otter distribution, especially in habitats where their trophic niches are more similar (Sidorovich, 1997b). Removal of American mink carried out between 1998 and 2001 in an area of 12×23 km in north-east Belarus suggests that local and sustained control may be helpful to protect the European mink (Sidorovich and Polozov, 2002).

Belgium: Fur farms are present in Belgium, but no feral population breeding in the wild has been recorded so far, even though there have been occasional escapes of mink from the farms (Roland Libois, personal communication) and mink have been found in the wild (Libois, 1996). A survey of traffic kills all over Flanders supports the observation that mink are rare in Belgium (Koen Van Dan Berge, personal communication). One of the hypotheses for the scarcity of mink in Belgium, especially in the northern part, is that high levels of pollution may prevent mink from building viable populations (Koen Van Dan Berge, personal communication).

Czech Republic: Mink farms are present in the Czech Republic and mink populations have established in the wild since at least the 1960s (Mazák, 1964). A survey using questionnaires in 1991–1992 confirmed the occurrence of this species over 5% of the area of the Czech Republic (Andìra and Hanzal, 1996); this occupation had increased to 27% by the end of the 1990s (Cervený and Toman, 1999; Èervený et al., 2001) and the population is still expanding (Martin Šálek and František Sedláček, personal communication). An experimental study of mink removal has shown that it has a notable impact on waterfowl and the stone crayfish *Austropotamobius torrentium* (Sálek et al., 2005). It has also been observed that mink can impact populations of the dice snake *Natrix tesselata* (Lukas Polednik, personal communication). No systematic action of mink eradication has been attempted in the Czech Republic, but this option has been evaluated by the Czech Agency of Nature Protection (Lukas Polednik, personal communication).

Denmark: In Denmark, there are more than 2000 mink farms and feral mink are widely distributed across the country. In one region of Denmark, it has been found that most of free-ranging mink (79%, $n = 213$) were born in a farm and subsequently escaped indicating that farms can act as a true source for the wild populations, maintaining high levels of mink abundance (Hammershøj et al., 2005). In Denmark, there are some endangered species of amphibians and, as mink preys on amphibians, there is the possibility that mink might have an impact on their populations (Hammershøj et al., 2004). However, a part from this theoretical possibility and from some local effects, a study of the diet of the American mink in winter

has not highlighted any particular wide-scale threat to native species posed by mink (Hammershøj et al., 2004).

Estonia: Although there is only one mink farm in Estonia, the American mink is widely distributed in the country due to farming activities in the past and to immigration from nearby countries (Tiit Maran, personal communication). Estonia is part of the natural range of the European mink, but this species is now extinct on the mainland (Maran, 2003). To create a sanctuary for the European mink, in 1998–1999 the American mink has been successfully eradicated on Hiiumaa Island, an island c. 1000 km^2 located in the Baltic Sea 22 km from the coast of Estonia (Macdonald et al., 2002c; Maran, 2003). Nowadays, the American mink is a concern especially where it can colonise islands where the European mink has been or is going to be re-introduced and park officials have expressed concern about its impacts on waterfowl in bird sanctuaries (Tiit Maran, personal communication). There are claims among the hunters that the American mink has declined remarkably during the last few years, but no hard evidence has yet been collected to support this (Tiit Maran, personal communication).

Finland: Mink farming is relatively important in Finland and a study based on game enquires revealed that the species was widespread in the country in the early 1990s with their highest densities being in eastern Finland (Kauhala, 1996). The impact of mink on birds, small mammals and amphibians has been studied in detail on Finnish islands of the Baltic Sea (Nordström et al., 2002; Nordström et al., 2003;Nordström and Korpimäki, 2004; Banks et al., 2005). An experimental approach showed that the breeding densities of 15 of 22 species of ground-nesting birds increased upon the removal of mink and two species already extinct in one of the removal areas returned to breed (Nordström et al., 2002; Nordström et al., 2003). However, there was also a number of bird species that were unaffected by mink (Nordström et al., 2002; Nordström et al., 2003). Mink also had a significant impact on the bank vole *Clethrionomys glareolus*, field vole *Microus agrestis*, and common frog *Rana temporaria* (Banks et al., 2004; Banks et al., 2005).

France: Most of the mink farms in France are concentrated in Brittany where the largest feral population of American mink can also be found (Léger and Ruette, 2005; Xavier Grémillet, personal communication). Mink populations are present also in other areas of France, in the central-west (Charente) and in the south-west (Léger and Ruette, 2005). The population in the south-west constitutes a threat to the remaining fragmented population of European mink (Léger and Ruette, 2005), although anthropogenic factors, mainly changes in habitat quality and trapping, are recognised as the main cause of the decline of the European mink in France (Lodé et al., 2001). Culling of American mink has been conducted in the past and is currently being carried out as a conservation measure to protect the European mink (Xavier Grémillet, personal communication).

Germany: Despite the fact that mink farming is not widespread in Germany, a recent study, partly based on questionnaires, has revealed that mink are present in three regions (Zschille et al., 2004) and possibly in further five of the 16 regions of Germany, mostly in the eastern an northern part of the country (Jana Zschille, personal communication). The American mink has also recently established in the Northwest German Lower Plain where re-introduction projects of the European mink are being attempted (Rüdiger Schröpfer, Osnabrück, personal communication). Studies of mink's diet have found no evidence of a strong negative impact of the American on native prey populations in Germany (Zschille et al., 2004) and research is currently ongoing to further investigate possible impacts on prey (Jana Zschille, personal communication).

Greece: There are only few mink farms in Greece but since the early nineties the American mink has established a feral population in the Ramsar Wetland of Mikri Prespa (Maragou and Mantiziou, 2000; Irene Koutseri, personal communication). A part from the existence of this population, we have found no other information the distribution and impacts of the American mink in Greece.

Hungary: There is little information on mink in this country. Up to the 1970s large farms were present, but nowadays only smaller farms survive and the number of mink in these farms is estimated between few hundreds up to a maximum of 5000 (Sandor Holdas and Gabor Nechay, personal communication). In the area of Godollo, east of Budapest, where most farms are located, feral mink can be observed occasionally in winter (Sandor Holdas and Gabor Nechay, personal communication). However mink must not be common in this country, indeed Dr. Miklós Heltai (personal communication) who collects information on a nation-wide scale from hunters and monitoring programmes based on live trapping, has never been reported with records of mink. Large-scale field surveys for otters conducted in South-West Hungary have never detected mink either (József Lanszki, personal communication).

Iceland: Here American mink have been established since at least 1937 and are now present throughout the country but limited by the extent of ice-free areas (Skírnisson and Petersen, 1980; Hersteinsson, 1992; Hersteinsson, 1999). In spite of extensive culling measures through the set up of bounty schemes, the population appears to be still increasing in size (Hersteinsson, 1999). Recently, the Icelandic Parliament has approved to finance an eradication trial to be carried out in 2–3 areas in 2006–2008 to help determine future action (Pall Hersteinsson, personal communication). The impact of mink on native species is largely unknown, but they have been implicated in the demise or extinction of some bird species, which were either ground-nesting species living in large colonies on islands, or wetland species (Hersteinsson, 1999).

Ireland: The American mink is widespread in Ireland (Smal, 1988) but not particularly abundant (Smal, 1991) and its abundance seems to be linked to that of white-clawed crayfish *Austropotamobius pallipes*. The main taxa and species affected by mink in Ireland are waterfowl, island-nesting birds and terns (*Sterna* spp.), however impacts appear to be localised and hence only local control has been advised (Smal, 1991).

Italy: Fur farming is limited in Italy (less than 30 farms in 2005 – Piero Genovesi, personal communication) and such activity is also relatively recent compared to that in the northern countries. There is no systematic study of the species, but feral populations are known to be present in the wild mainly in central and north-east Italy, although they are probably relatively small (Lapini, 1991; Angelici et al., 2000). No attempt has been made to contain these populations apart from the attempts to re-trap individuals following intentional releases of large numbers of mink from animal liberation groups (Luca Lapini, personal communication). A small population is also present in Sardinia (Spagnesi et al., 2002) and is currently the target of an eradication project by the competent local authorities (Piero Genovesi, personal communication).

Latvia: Mink farms are present in Latvia and the American mink was widespread in the country in the first half of the 1990s as revealed by field surveys and questionnaires (Ozolinš and Piläts, 1995). Mink have been hunted in the country since at least the 1970s and a reduction of game bags was observed between 1985 and 1993, probably due to a fur market decline rather than to an actual decline of mink (Ozolinš and Piläts, 1995). Predation by American mink on birds is a problem in some wetland areas and indeed the species is particularly abundant along estuaries and coastal lakes rich in waterfowl (Ozolinš and Piläts, 1995). In Latvia the presence of beavers *Castor fiber* is thought to favour the American mink by increasing foraging and denning opportunities (Ozolinš and Piläts, 1995).

Lithuania: Mink farms are present in Lithuania and the American mink was widespread in the country in the early 1990s (Mickevicius and Baranauskas, 1992), and, although no field survey has been carried out in the past 10 years, recent questionnaires have confirmed that mink is still widespread today (Balciauskas et al., 1997; Edvardas Mickevicius, personal communication). There is evidence of the negative impact of the species on ground-nesting birds and it is possible that there is a negative impact on the water vole as well (Edvardas Mickevicius, personal communication). At the end of the 1980s it became possible to hunt mink in the wild and this is believed to have caused a decline in numbers (Bluzma, 1990 cited in Mickevicius and Baranauskas, 1992).

Luxembourg: There are no mink farms in Luxembourg, but an individual American mink was found in the wild in 1993, the origin of which is not known (Schley, 2001). There is currently no evidence of the presence of established feral populations of American mink in Luxembourg (Laurent Schley, personal communication).

Malta: In 1972 the Department of Agriculture attempted unsuccessfully to start a mink fur industry in Malta but currently there are no mink farms on the island and no feral mink populations (C.Savona-Ventura http://www.geocities.com/RainForest/3096/animal.html).

Norway: Mink farms are relatively abundant in Norway and a questionnaire to local authorities carried out in 1993 suggests that the Norwegian mainland is now fully colonised with only some islands mink-free (Bevanger and Henriksen, 1995).

Poland: Mink farms were not very abundant in Poland in 2000, but their number has probably increased in later years, as it becomes cheaper and less constraint by legislation to farm in Eastern Europe (Tiit Maran, personal communication). Mink have been present in Poland at least since the 1960s (http://www.iop.krakow.pl/ias/), and they have colonized over half of the Polish territory (Brzezinski and Marzec, 2003). The arrival of mink in some areas has coincided with a decline of muskrat *Ondatra zybethicus* and waterfowl populations (Bartoszewicz and Zalewski, 2003; Brzezinski and Marzec, 2003).

Portugal: There are no mink farms in Portugal (Margarida Santos-Reis, personal communication) and mink are a relatively recent invasive deriving from escapes from a mink farm in Spain (Vidal-Figueroa and Delibes, 1987). At the moment there is reliable evidence of mink presence in the north-western region of Portugal on the rivers Minho, Coura and Lima (Santos-Reis and Petrucci-Fonseca, 1999; Queiroz et al., 2005). Mink are probably expanding their range in Portugal but no country-wide survey has yet been carried out (Margarida Santos-Reis, personal communication). The impact of mink on native species has not been studied, but the existing understanding of the species predation habits leads to suspect that the American mink may have a negative impact on the European desman *Galemys pyrenaicus*, the Iberian water vole *Arvicola sapidus*, and possibly amphibians (Margarida Santos-Reis, personal communication).

Slovakia: Mink farms have been present in Slovakia since the 1950s and mink have been found in the wild, especially in the central part of Slovakia, although the presence of populations that reproduce in the wild has not yet been confirmed (Maria Bodova, personal communication). Studies are currently being carried out to assess the status of the species in Slovakia.

Slovenia: Mink farming was present in Slovenia in the 1960s with at least one known farm near the capital Ljubljana (Kryštufek et al., 1994). In spite of recorded escapes from this farm, mink have not established feral populations in the country (Kryštufek et al., 1994). Currently there are no farms and no recorded mink (Boris Kryštufek, personal communication).

Spain: Mink farming started in Spain at the end of the 1950s and the number of farms reached a peak in the 1980s with about 400, mostly concentrated in the region of Galicia (Ruiz-Olmo et al., 1997). The origin of the populations of feral mink was related to massive escapes by accident or deliberate liberation (Ruiz-Olmo et al., 1997). The expansion of the populations has been more rapid in those areas where there were no competitors, such as otters and polecats (Ruiz-Olmo et al., 1997). Six populations of feral mink are now found in Spain, the largest three being in Central Spain, Catalonia and Galicia (Ruiz-Olmo et al., 1997; Palazon, personal observation). The impacts of mink on native species have not been studied experimentally in Spain, but the American mink is thought to affect the remaining populations of European mink, and a study of the diet of coastal living mink in

north-western Spain suggests that they could potentially have an impact on rocky intertidal communities (Delibes et al., 2004). Experimental removals have been carried out in Catalonia where the density of mink is particularly high (Yolanda Melero, personal communication).

Sweden: Mink were introduced to Sweden at the end of the 1920s (Gerell, 1999). At present, mink farms are relatively abundant in Sweden and the species is known to be present in the wild, although its current distribution is not known. Reported catches of mink have decreased markedly in recent years (Gerell, 1999), but it is not known whether this is due to decreased number of mink or reduced trapping intensity (Sam Erlinge, personal communication). No native species in Sweden has been exterminated by the introduced mink (Gerell, 1999).

Switzerland: There are no mink farms in Switzerland and no mink have ever been reported (Darius Weber, personal communication).

The Netherlands: In spite of the presence of a relatively high number of mink farms in Holland, mink have not been reported to have established feral populations (Thissen and Hollander, 1996). One of the hypotheses to explain this observation is that mink are trapped as a side-effect of the intensive trapping campaigns for the coypus *Myocastor coypus* and the muskrat (Hugh Jansman, Alterra, personal communication). The effects of the American mink on the native fauna have not been studied in Holland (Hugh Jansman, Alterra, personal communication).

UK: In the UK, including Northern Ireland, mink farming has been banned since 2003 (Fur Farming (Prohibition) Bill, 2000). Because of fur farms being relatively numerous in the past, reaching a peak of about 700 in the 1960s (Thompson, 1962; Thompson, 1967), mink are now widespread. In England, mink distribution has been monitored systematically since the 1970s (Crawford, 2003); their population appears to have recently declined probably due to competition by the larger otter that is in the process of re-colonising (Jefferies, 2003; Bonesi et al., 2006b). Surveys of mink on rivers in Northern Ireland indicate that mink are found at only 30% of sites despite being present for over 50 years (Aughley et al., 2005). In Scotland, mink occupy over 50% of the region (Green and Green, 1995), but although widespread their densities in freshwater habitats are probably relatively low.

With the exception of Finland and Belarus, perhaps most of the studies on the impact of American mink on native wildlife have been carried out in Britain, where mink are known to have an impact on a number of native species, in particular the water vole, which has declined by 97% since 1900 (Woodroffe et al., 1990; Jefferies, 2003), but also on ground-nesting seabirds, especially in Scotland and on small islands (Craik, 1997), and waterfowl (Ferreras and Macdonald, 1999). Their activities, including surplus killing, have been linked to almost complete breeding failure amongst colonies of terns and gulls, including some rare species (Craik, 1997). In Northern Ireland, there is no evidence that mink have any excessive impact on prey populations (Aughley et al., 2005).

There are not many studies on the economic damage by mink and most of them have been carried out in the UK. Mink can inflict damage to poultry runs, reared game birds and fisheries (Harrison and Symes, 1989; Moore et al., 2000; Sheail, 2004). However, in a study conducted in England and Wales, Harrison and Symes (1989) concluded that feral American mink are a relatively minor problem and hence it is difficult to justify widespread mink control based on economic grounds, apart from local attempts at control. Moore et al. (2000) discussing the economic impact of mink on the Outer Hebrides, recognised that the animals could cause considerable damage to salmon farming interests, to free ranging chickens and to the eco-tourist industry through predation on ground-nesting birds. It is difficult to assess and quantify economic damage by mink and to generalise, as damage is peculiar to the kind of activity and also the kind of protection granted. However, in the UK prevention of economic damage by trapping and proofing appear to be satisfactory for most types of damage caused by mink (Harrison and Symes, 1989).

Due to its wide distribution, it is now too late to envisage the eradication of the American mink on mainland Britain, although this may be possible in smaller islands. A five-year project to eradicate the species from the Uists and reduce numbers in Harris is ongoing in the Western Isles, off the coast of Scotland (Moore et al., 2003). On the main island, the serious decline of the water vole has prompted a call for at least local control (DoE, 1995), and control campaigns are currently ongoing on a number of rivers such as, for example, the river Itchen (Rob Strachan, personal communication) and the Upper Thames by the local Wildlife Trusts (Lauren Harrington, personal communication). An experimental removal is also being carried out on the Upper Thames (Lauren Harrington and David Macdonald, personal communication). On the river Itchen mink control has been going on for a long time and an increase in the water vole population following mink culling has been observed, especially after the introduction of mink rafts as a method of culling mink (http://www.gct.org.uk – Jonathan Reynolds, personal communication).

By reviewing the situation in the 28 European countries considered in the present study (Box 1) the following aspects emerge:

(1) Mink farms are concentrated in northern countries (Table 2), where the activity is more profitable because the climate favours the growth of fur of high quality.
(2) Although in most countries the mink is currently present, there is great variability in terms of its abundance between, as well as within, countries (Figs. 1 and 2).
(3) In some countries, such as Sweden, Lithuania, Estonia and the UK, mink are apparently declining, but in most cases the causes are unknown.

Table 1 – Date of the first observation in the wild and impacts of the American mink in the European countries considered in this study

Country	First record	Impacts	Source
Austria	1980s	NS	Andreas Kranz, personal communication
Belarus	–	R, E	Sidorovich and Macdonald (2001), Macdonald et al. (2002b)
Belgium	1990s	NS	Libois (1996)
Czech Republic	1960s	B, C	Mazák (1964), Sálek et al. (2005)
Denmark	1940s	NS	Hammershøj (2003)
Estonia	1970s	B, E	Maran (1991)
Finland	1930s	B, R, A	Westman (1966), Nordström et al. (2002)
France	1960s	E	Henry, 1927, Léger and Ruette, 2005
Germany	1950s	NS	Heidemann (1983), Schröpfer (1999), Zschille et al. (2004)
Greece	–	NS	Maragou and Mantiziou (2000); Irene Koutseri, personal communication
Hungary	–	NS	József Lanszki, personal communication
Iceland	1937	B	Hersteinsson (1999); Pall Hersteinsson, personal communication
Ireland	1956	B	Smal (1988)
Italy	1980s	NS	Lapini (1991)
Latvia	1940s	B	Ozolinš and Piläts (1995)
Lithuania	1950s	B, R	Mickevicius and Baranauskas (1992)
Luxembourg	1990s	NS	Schley (2001)
Malta	–	–	http://www.geocities.com/RainForest/3096/animal.html
Norway	1950s	NS	Bevanger and Henriksen (1995)
Poland	1960s	B	Ruprecht et al. (1983), Brzezinski and Marzec, 2003; http://www.iop.krakow.pl/ias/
Portugal	1980s	NS	Vidal-Figueroa and Delibes (1987)
Slovakia	1950s	NS	Maria Bodova, personal communication
Slovenia	1960s	–	Kryštufek et al. (1994)
Spain	1970s	NS	Delibes and Amores (1978)
Sweden	1920s	B	Gerell (1967), Gerell (1971)
Switzerland	–	–	Darius Weber, personal communication
The Netherlands	1957	NS	Thissen and Hollander (1996)
United Kingdom	1950s	B, R	Thompson (1968), Macdonald et al. (1999), Crawford (2003)

The date in the column 'First record in the wild' indicates the year or the decade in which mink were first known to be present in the wild, but does not necessarily mean that mink were reproducing in the wild; '–' indicates that the year is not known or mink were never found in the wild. Under the column 'Impacts' there is a list of species and taxa that are thought to be negatively influenced by mink in each country as suggested by anecdotal or experimental evidence. Island-nesting birds and waterfowl (B); Rodents (R); European mink (E); Amphibia (A); Crayfish (C); not studied (NS).

(4) In two countries, Belgium and The Netherlands, apparently very few mink are present in spite of the existence of a relatively high number of mink farms and of the proximity of countries with widespread populations of mink.
(5) Local and regional studies on the impact of mink on native species have shown that the American mink can have a significant effect on ground-nesting birds, rodents and amphibians as well as on the European mink and the Eurasian polecat (Table 4).
(6) The impact of feral mink on economic activities such as fish farming seems to be relatively small on a national scale but it can be locally important.
(7) For most countries there are no published studies on the national distribution of the American mink and no comprehensive reviews on the impacts of this species.

3. Strategies and actions

Three main strategies can be applied for the control of alien invasive species depending on the level of their diffusion: (1) prevention, (2) early detection, and (3) assessment and management of established species (Wittenberg and Cock, 2001). We review the results of the applications of these strategies and associated actions in the case of the American mink in European countries. We identify four scenarios in Europe for the actual and potential diffusion of American mink taking into account mink farms, which are the source of mink, and the presence and distribution of feral mink populations (Table 2, Figs. 1 and 2):

(1) Countries where mink farming is not currently present and have no populations of mink, e.g. Malta and Slovenia.
(2) Countries where mink farming is present and have relatively small and localised populations of mink, e.g. Italy and Spain.
(3) Countries where mink farming was diffuse in the past and where the activity is no longer occurring or is very reduced, but where mink are already widespread, e.g. the UK and Estonia.
(4) Countries where mink farming is present and that have widespread populations of mink, e.g. Denmark and Sweden.

Table 2 – Farming activities in Europe

Country	No. of farms	Average no. breeding females per farm
Austria[3]	0	–
Belgium[1]	26	1125
Denmark[1]	2200	951
Estonia[1]	1	2145
Estonia[2]	1	NK
Finland[1]	600	629
France[1]	22	1372
Greece[1]	7	1752
Germany[1]	32	2130
Hungary[3]	few	NK
The Netherlands[1]	208	2750
Iceland [3]	25	1340
Italy[1]	35	1240
Ireland[1]	5	5283
Latvia[2]	4	NK
Lituania[2]	few	NK
Luxembourg[3]	0	–
Malta[3]	0	–
Norway[1]	170	355
Poland[3]	9	5500
Portugal[3]	0	–
Slovenia[3]	0	–
Spain[1]	50	1132
Sweden[1]	187	1210
Switzerland[3]	0	–
United Kingdom[1]	13	1740
United Kingdom [3]	0	–

Number of farms and calculated number of breeding females for: (1) European countries in the year 2000 from Dantzer et al. (2001), (2) Baltic countries in 2005 (http://www.baltkurs.com/rille/archive/01/manuf.htm); (3) Other countries in 2005 (Sandor Holdas, Andreas Kranz, Boris Kryštufek, Pall Hersteinsson, Tiit Maran, Gabor Nechay Lukas Polednik, Margarida Santos-Reis, Laurent Schley, Darius Weber personal communications); NK indicates that no data were available regarding the average number of breeding females.

In countries not yet invaded by mink and where there are no mink farms, prevention is the most appropriate strategy (Wittenberg and Cock, 2001). In this case probably the most important action is preventing the establishment of mink farms, especially in areas where there are native species that could be vulnerable to mink predation and competition. For example, in Spain, regions that have endorsed the Conservation Plan for the European mink now forbid the establishment of American mink farms. Small islands are areas of particular concern because the impact of mink is likely to be great partly because island species are less adapted to withstand novel predators (Courchamp et al., 2003). A proactive approach may include licensing mink farming only in areas where the habitat is not favourable to mink and hence feral populations are less likely to establish. These areas are characterised by a scarcity of water bodies (Linscombe et al., 1982) and by a low abundance of mink prey (Dunstone and Birks, 1985) and could be identified by means of GIS suitability models.

Where mink farms are already present, but feral populations have not yet established, or in countries that have no mink farms themselves and no mink, but that are adjacent to countries in which the species is present, the main activity should be focused on early detection and early intervention by eradication (Wittenberg and Cock, 2001). The successful establishment of invasive alien species is frequently characterised by a lag phase during which the populations persist in low numbers in fixed areas before rapidly increasing and invading nearby sites (Crooks and Soule', 1999). Typically the best opportunity for control or reduction of impact of an invasive is during this lag phase or early spread before it occupies a large area or achieves high densities (Byers et al., 2002). In the Nordic countries, where snow cover is present for several months of the year, early detection of mink can be achieved by searching for mink tracks in the snow (Tiit Maran, personal communication). Early detection of American mink has recently become more feasible also in areas without snow cover

Table 3 – List of programs of American mink eradication, local control or hunting carried out in Europe for which there is published material or for which we have had direct information

Country	Year	Method	Outcome	Reference
Belarus	1992-onw	Control	Successful	Sidorovich and Polozov (2002)
Estonia	1998–1999	Eradication	Successful	Macdonald et al. (2002c)
Finland	1993–2001	Eradication	Successful	Nordström et al. (2003)
Iceland	1940s-onw	Hunting	Mink population overall increasing	Hersteinsson (1999)
Lithuania	1980s-onw	Hunting	Believed to have caused decline of mink	Bluzma (1990) cited in Mickevicius and Baranauskas (1992)
Spain	2003–2005	Control	Not known yet	Yolanda Melero, personal communication
UK – England	1964–1970	Eradication	Not successful	Sheail (2004)
UK – Itchen	1990s-onw	Control	Successful	Rob Strachan, personal communication
UK – Thames	2002-onw	Control	Successful	L. Harrington and D. Macdonald, personal communication
UK – Western Isles	2001-onw	Control/ Eradication	Successful	Moore et al. (2003)

Eradication indicates that it was attempted to remove all mink from a designated area; *control* indicates that the aim was to keep mink numbers down but not to eradicate them; *hunting* indicates that mink were hunted as part of a game bag scheme or for the fur industry. The column 'effects' indicates whether the eradication or control campaign achieved its aims, which were usually a decline of mink and/or a stabilisation or increase of native species threatened by mink (a list of mink management projects can be found at http://www.issg.org/database/).

Table 4 – Verified impacts of mink on native European species

	Species	Country	Reference
Predation			
Mammals	Bank vole (*Clethryonomis glareolus*)	Finland	Banks et al. (2004)
	Field vole (*Microtus agrestis*)	Finland	Banks et al. (2004)
	Water vole (*Arvicola terrestris*)	Belarus, UK	Strachan and Jefferies (1993), Macdonald et al. (2002b)
Birds	Arctic suka (*Stercorarius parasiticus*)	Finland	Nordström et al. (2003)
	Arctic tern (*Sterna paradisaea*)	Finland	Nordström et al. (2003)
	Black guillemot (*Cepphus rille*)	Iceland, Sweden	Olsson (1979), Petersen (1979), cited in Hersteinsson (1999)
	Black-headed gull (*Larus ridibundus*)	UK, Sweden	Landgren (1996) cited in Nordström and Korpimäki (2004), Craik (1997)
	Common eider (*Somateria mollissima*)	Iceland, Sweden	Hersteinsson (1999), Andersson (2002)
	Common gull (*Larus canus*)	Finland, UK	Craik (1997), Nordström et al. (2003)
	Common tern (*Sterna hirundo*)	UK	Craik (1997)
	Coot (*Fulica atra*)	UK	Ferreras and Macdonald (1999)
	Gadwall (*Anas strepera*)	Finland	Nordström et al. (2002)
	Mallard (*Anas platyrhynchos*)	Finland	Nordström et al. (2002)
	Moorhen (*Gallinula chloropus*)	UK	Ferreras and Macdonald (1999)
	Northern shoveler (*Anas clypeata*)	Finland	Nordström et al. (2002)
	Razorbill (*Alca torda*)	Finland, Sweden	Olsson (1979), Nordström and Korpimäki (2004)
	Ringed plover (*Charadrius hiaticula*)	Finland	Nordström et al. (2003)
	Rock pipit (*Anthus petrosus*)	Finland	Nordström et al. (2003)
	Shelduck (*Tadorna tadorna*)	Finland	Nordström et al. (2002)
	Slavonian Grebe (*Podiceps auritus*)	Iceland	Nielsen (1998), cited in Hersteinsson (1999)
	Tufted duck (*Aythya fuligula*)	Finland	Nordström et al. (2002)
	Turnstone (*Arenaria interpres*)	Finland	Nordström et al. (2003)
	Velvet scoter (*Melanitta fusca*)	Finland	Nordström et al. (2002)
	Water Rail (*Rallus aquaticus*)	Iceland	Skarphendinsson (1998) cited in Hersteinsson (1999)
	Wheatear (*Oenanthe oenanthe*)	Finland	Nordström et al. (2003)
	Pintail (*Anas acuta*)	Finland	Nordström et al. (2002)
	Red-breasted merganser (*Mergus serrator*)	Finland	Nordström et al. (2002)
Amphibia	Common frog (*Rana temporaria*)	Finland	Banks et al. (2005)
Crustacea	Stone crayfish (*Austropotamobius torrentium*)	Czech Republic	Sálek et al. (2005)
Competition			
Mammals	European mink (*Mustela lutreola*)	Belarus, Estonia	Maran et al. (1998), Sidorovich and Macdonald (2001)
	Eurasian polecat (*Mustela putorius*)	Belarus	Sidorovich and Macdonald (2001)

This table reports a list of species where it has been possible to verify that the American mink has a negative impact by reducing significantly their overall density, or at least their breeding density. However, for some of these species, mink was a compounding factor and not the main cause of the decline. Moreover, there are a number of prey species and competitors upon which mink seems to have no effect (e.g. Nordström et al. (2003); Bonesi et al. (2006b)).

with the development of a survey method based on floating rafts that detects mink footprints and that can be used also to trap mink (Reynolds et al., 2004). These rafts reveal mink presence even in areas where they are found at low densities and where they are difficult to detect by other means, such as trapping and systematic searches for field signs (Reynolds et al., 2004). Early detection may lead to successful eradication in areas where mink are at their initial stages of colonisation or on small islands. These actions of early detection and eradication may still be feasible even on the mainland in countries like Italy and Greece where the species is not yet widespread.

Where feral mink are already widespread, as in most European countries, there are at least five different actions that could be undertaken to minimise their impacts.

3.1. *Local control or eradication*

A number of projects have shown that it is possible to control and eradicate the American mink through mechanical control (*sensu* Wittenberg and Cock, 2001) provided that there are enough resources and manpower (Table 3). Eradications of this species have been or are being carried out on relatively small islands (less than 1500 km sq) in Finland, Estonia and the Western Isles in the UK (Macdonald et al., 2002c; Moore et al., 2003; Nordström et al., 2003), while projects of local control have been or are being carried out in Belarus and on the mainland in the UK, as well as on the Western Isles (Macdonald et al., 2002c, Lauren Harrington and David Macdonald, personal communication; Sidorovich and Polozov, 2002; Moore et al., 2003). Several smaller projects of local control have been conducted in other European countries, such as the Czech Republic, France, Germany, Italy, and Spain, although little information is available on the outcomes of these efforts. In some countries, such as Iceland, Lithuania and Latvia, mink are actively hunted (Bluzma, 1990 cited in Mickevicius and Baranauskas, 1992; Ozolinš and Piläts, 1995; Hersteinsson, 1999). Harvesting is bound to change the age structure of mink populations (Whitman, 2003; Bonesi et al.,

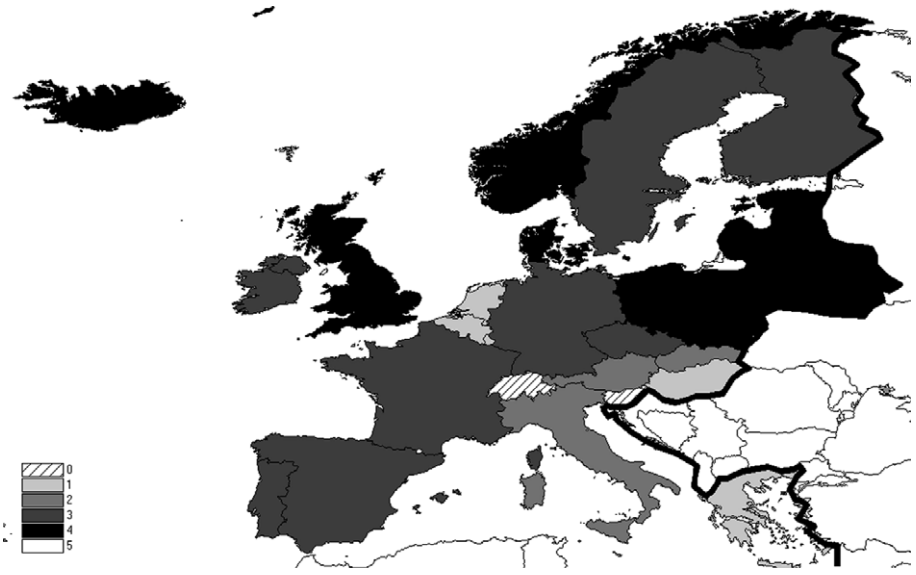

Fig. 1 – Presence of mink in each of the 28 European countries considered in this study: 0 = mink absent, 1 = found sporadically in the wild but no established population confirmed; 2 = localised distribution in a few areas; 3 = widely distributed but over less than 50% of the national territory; 4 = widely distributed over 50% of the national territory; 5 = status not determined. The dark line identifies the eastern border beyond which we did not determine mink status.

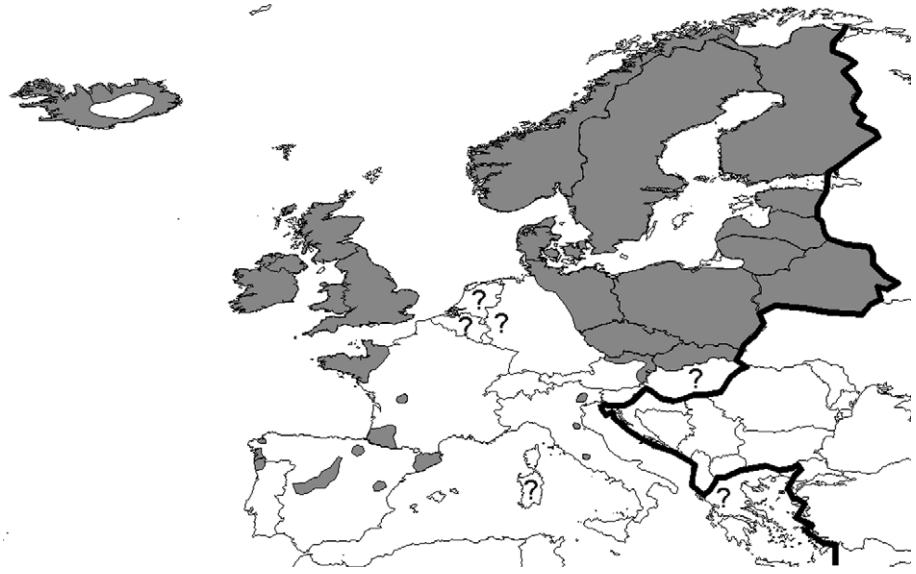

Fig. 2 – Distribution of mink in Europe. Only established populations are reported. A question mark indicates those countries and areas for which it was not possible to assess with certainty the presence of established populations because of lack of data. The map was drawn using published maps (France, Finland, partly for Germany, Latvia, Lithuania, Poland, UK), published descriptions of mink distribution (Denmark, Italy, Luxemburg, Norway, Slovenia, Sweden) and from information provided directly by researchers and reported in the text (Austria, Belgium, Check Republic, Estonia, partly for Germany, Iceland, Slovakia, Switzerland, The Netherlands). All the information refers to mink's distribution since 1990. The distribution of mink was represented as continuous in those areas where they were relatively abundant and widespread even if there were gaps in their range.

2006a), but it is not clear yet what is the level of harvesting above which the density and distribution of the species start to decline.

Not all the attempts to reduce mink populations were successful (Table 3). The projects resulted to be most effective in the long-term were carried out on relatively small islands away from areas from which mink could re-colonise (Nordström and Korpimäki, 2004). Some of these projects have also shown that that the reduction of mink numbers can have positive effects on the native fauna (e.g. Sidorovich and Polozov,

2002; Nordström et al., 2003) and have also started to give some indications about best practices in mink culling. For example, the culling project in the Western Isles has shown that the use of dogs to locate active den sites and mink signs may be crucial in removing the last animals of a low-density population, that are usually difficult to trap (Moore et al., 2003). In Iceland, hunting with dogs to locate active dens in early spring has also proved useful at reducing damage to bird colonies during the nesting season (Hersteinsson, 1999). The project in Estonia showed instead that the ability of the trapper is very important in determining trapping success (Macdonald et al., 2002c). Currently models are being developed to help improve the success of control strategies for mink (Moore et al., 2003; Bonesi et al., in preparation).

3.2. *Restoration and manipulation of habitat*

The ability of prey species to persist in the presence of mink may depend on the characteristics of the habitat in which the two species coexist. In favourable cases, habitat management can be considered as a potential action to minimise the impacts of mink on its prey. In the case of the water vole, it has been established that vulnerability to mink predation is exacerbated by habitat loss (Barreto et al., 1998; Jefferies, 2003), but, under certain habitat configurations, it has also been observed that the coexistence of water voles and American mink is possible. For example, since reedbeds have been shown to provide a refuge from mink predation, the restoration of this particular type of habitat is currently being implemented in the UK as a conservation measure for the water vole (Carter and Bright, 2003). In pristine wetlands in Belarus, enclaves of water voles survived in isolated and small still-water sites away from large, running-water sites where mink were most active (Macdonald et al., 2002b). Levels of habitat fragmentation have been shown to be important in determining presence or absence of water voles at given sites and the persistence of their populations (Lawton and Woodroffe, 1991; Aars et al., 2001; Telfer et al., 2001; Bonesi et al., 2002). The observations indicate that not only the habitat type, but also its distribution within the landscape should be important factors to consider when restoring or manipulating habitat for increasing the viability of water vole populations.

3.3. *Promotion of the natural recovery of native mink competitors*

The establishment and persistence of significant populations of American mink are likely to depend on the abundance and seasonality of preys and on the presence of other competitors with overlapping trophic niches (Birks, 1989; Sidorovich, 1997a; Bonesi and Macdonald, 2004a). So far, the only mustelid recognised to have a negative effect on the distribution and abundance of mink in Europe is the Eurasian otter (Kauhala, 1996; Ruiz-Olmo et al., 1997; Sidorovich, 1997a; Jefferies et al., 2003; Bonesi et al., 2006b). Otters are able to reduce the density of mink upon their re-introduction (Bonesi and Macdonald, 2004b), to partly exclude mink from certain habitats (Sidorovich, 1997b), and to slow down mink colonisation (Ruiz-Olmo et al., 1997). In the past, otter populations have declined in many parts of Europe following persecution and pollution (e.g. Chanin and Jefferies, 1978; Lode, 1993), but are now recovering in some areas (Conroy and Chanin, 2003). Promoting the recovery of the otter may be a suitable strategy to reduce the impacts of mink. However, caution must be taken when implementing this strategy because otters have been observed to provoke a shift in the diet of mink from aquatic to terrestrial prey with possible consequences for endangered terrestrial prey species (Clode and Macdonald, 1995; Bonesi et al., 2004).

3.4. *Management of prey species*

There may be exceptional cases for which it may be possible to manage non-endangered prey species in order to protect endangered species that are vulnerable to mink predation or competition. There have been instances where the spread of mink has been aided by the presence of introduced alien prey species, such as the case of rabbits in the UK (although perhaps rabbits should now be considered part of the UK fauna), muskrats in Poland (Brzezinski and Marzec, 2003), and the American crayfish *Procambarus clarckii* in Spain (Santiago Palazon, personal observation). These species provide an abundant food source that may help mink establish feral populations. When this is the case, managing invasive alien prey of mink may be useful in order to reduce the likelihood of the establishment of mink in an area and to slow its colonisation front. However, one must always take into account that mink is very opportunistic and may feed on a wide range of species. Management of prey species may also be implemented directly on those native species that are threatened by mink. For example, in regions where mink are successfully removed, species like the water vole in the UK or the European mink in Estonia, can be re-introduced (Macdonald et al., 2002a; Maran, 2003).

3.5. *Prevention of further escapes and rapid response after releases*

In addition to intervening on feral populations of mink and on the biotic factors that affect them, it is important to focus management activities on the farms themselves by increasing fencing and security, as also recommended by the European Strategy on Invasive Alien Species (Genovesi and Shine, 2004). Reducing the number of individual released and the frequency of releases reduces the probability of mink establishing feral populations (Kolar and Lodge, 2001). Intervening on mink farms is very important, especially considering a Danish study that has revealed that as much as 79% of the mink caught in the wild were born on farms (Hammershøj et al., 2005). Following this report, Denmark has recently passed legislation to improve fencing and increase the security of fur farms (Madsen Aksel Bo, personal communication). Other countries, including Spain, Italy and Estonia, are currently in the process of improving their legislation and/or designing protocols to reduce the likelihood of mink escaping from the farms. For example, in Italy a series of guidelines to improve rapid response after releases from mink farms are being developed by Piero Genovesi at the Italian Wildlife Institute (I.N.F.S.) in collaboration with the Italian Association of Mink Farmers (A.I.A.V.). These guidelines advocate that contingency plans

for addressing escapes should be developed, and they recommend that: (1) a rapid communication system between the fur farmers and the competent authorities is set up; (2) a surveillance system is established for recording presence of minks around farms; (3) contingency plans are instituted by the competent authorities; (4) an emergency equipment (traps, baits, hand-nets) is set up and maintained; (5) emergency teams are assembled and trained to use capturing methods. The aim of these guidelines is to ensure a rapid response to escapes (ideally 2–3 h and not longer than 24–48 h, when most animals can be easily taken by hand or hand-nets) by establishing a clear communication procedure, defining an authorisation procedure for all needed actions, and improving the technical ability of the competent authorities to carry out the appropriate actions.

4. Conclusions

A consistent body of knowledge is currently being accumulated on issues concerning the American mink as an invasive alien species in Europe and on ways to mitigate its impacts. Several studies on methods of mitigating the effects of the presence of mink, such as, for example, those in the Czech Republic, Germany, Spain, and UK, are ongoing or have recently been completed and their results should soon be known (Box 1 and Table 3). In spite of this growing amount of information, there are still several countries and regions for which knowledge is very limited (Box 1 and Table 1). For some countries, including Belgium, Greece, Hungary, Portugal, and The Netherlands, it would be important to ascertain whether there are self-sustaining populations of feral mink and the extent of their distribution. In particular, in Belgium and The Netherlands, where mink are reported to be present in low numbers, it would be important to understand the reasons of this scarcity, given that these countries have several mink farms and are surrounded by countries with abundant mink. Another area of research that may provide interesting insights, potentially useful from a management perspective, is the assessment of whether and why mink are declining in countries like Sweden, Lithuania and Estonia, which would appear to provide favourable conditions for their diffusion. Finally, more should be known about the impacts of mink on species that may be particularly vulnerable, such as the European desman in Portugal and Spain. Knowing about the impacts of mink can also encourage competent authorities to take action. For example, in the UK, the realisation of the precarious status of the water vole has prompted several actions aimed at mitigating the impacts of mink (e.g. DoE, 1995). A detailed knowledge about the impacts of mink on native species should not, however, be considered an absolute prerequisite to taking action in terms of control or eradication, especially in those cases where mink are at the initial stages of their colonisation or when they have just escaped from a mink farm (Decision 6/23 COP6, 2002). The impacts of the American mink on the native biodiversity must be considered in a wider framework that prioritises interventions based on the impacts of all other invasive alien species and considering also all other threats to biodiversity (Wittenberg and Cock, 2001). This framework must also carefully consider welfare issues linked to culling American mink.

One of the reasons why several European countries have not yet started to deal with the problem of the American mink, not even in relatively inexpensive areas such as requiring adequate fencing in mink farms, appears to be the poor knowledge of the problems associated with the presence of this invasive species and the consequent lack of interest by the general public and the administrations. European citizens and their Institutions do not appear to be particularly sensitive to the problem of invasive alien species. European countries lag behind other nations that have developed strategic frameworks to address this problem in a comprehensive way (Genovesi and Shine, 2004), and their overall legal framework may be considered to be inadequate (Genovesi, 2005). Thus, even if experiences carried out so far have shown that it may be possible to manage the impacts of mink, the main obstacle to taking action is still probably a lack of awareness about the importance of doing so on the part of European administrations. It is interesting to note that the countries that have actively mitigated the impacts of mink are often those where mink and the problems that they cause are also better studied, such as the UK or Estonia, suggesting that the scientific community can play an important role in sensitising the general public and governments about invasive alien species.

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