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Abstract

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LIST OF PUBLICATIONS

This thesis is based on the following papers which are referred by the Roman numerals:

I Davidson, A., Griffith, H. I., Brookes, R. C., Maran, T., MacDonald, D. W., Sidorovich, V. E., Kitchener, A. C., Irizar, I., Villate, I., Gonzales-Esteban, J., Cena, A:, Moya, I. and Palazon Minano, S. 2000: Mitochondrial DNA and paleontological evidence for the origin of endangered European mink, *Mustela lutreola*. Animal Conservation 3: 345–357.

II Maran, T. & H. Henttonen 1995. Why is the European mink, *Mustela lutreola* disappearing? – A review of the process and hypotheses. Ann. Zool. Fennici 32:47–54.

III Maran, T., MacDonald, D. W., Kruuk, H., Sidorovich, V. & V.V. Rozhnov 1998. The continuing decline of the European mink, *Mustela lutreola*: evidence for the intra-guild aggression hypothesis. Behaviour and Ecology of Riparian Mammals. Symposia of the Zoological Society of London, Cambridge, 71: 297–324.

IV Davidson, A., Birks, J. D. S., Maran, T. MacDonald, D. W., Sidorovich E., & H. I. Griffith 2000: Conservation implications of hybridisation between polecats, ferrets and European mink (*Mustela* spp.). In: Mustelids in a modern world: management and conservation aspects of small carnivore: human interactions. Backhuys Publishers, Leiden: 153 –163.

V Sidorovich, V. & T. Maran 1997. Pollutant concentrations in the European mink and rivers with implications for the decline of its populations in Belarus. Mustelids in Belarus: Evolutionary ecology, demography and interspecific relationships. Minks, "Zolotoi Ulei": 245–248.

VI Maran, T. 1991: Distribution of the European mink, *Mustela lutreola*, in Estonia: A historical review. – Folia Theriol. Estonica 1: 1–17.

VII Maran,T., Kruuk, H., MacDonald, D. W. & M. Polma 1998: Diet of two species of mink in Estonia: displacement of *Mustela lutreola* by *M.vison*. J. Zool. Lond. 245: 218–222.

VIII Sidorovich, V. E. Kruuk, H. Macdonald, D. W. & T. Maran 1998. Diets of semi-aquatic carnivores in northern Belarus, with implications for population changes. Behaviour and Ecology of Riparian Mammals, Zoological Society of London, Cambridge University Press: 177–190.

IX Maran, T. 2003: European mink: setting of goal for conservation and Estonian case study. Galemys (Numero Especial) 15: 1–11.

The author's involvement in papers II, III, VI, VII and IX was substantial, including the generation of hypotheses, fieldwork, data analyses and the writing process. In paper I the responsibility was shared with other co-authors and the author's main activities consisted in participation in data collection and the writing process. In papers IV, V and VIII the responsibility was also shared and the author was mainly involved in the generation of hypotheses, data collection, data analysis and the writing process related to the specific field of this thesis.

Additional publication not included in the thesis:

Bonesi., L., Harrington, L. A., Maran, T., Sidorovich, V. E. & D. W. MacDonald 2006: Demography of three populations of American mink *Mustela lutreola* in Europe. Mammal. Rev. 36: 98–106.

Põdra, M., Kõlamets, L., Solovej, I., Sidorovich, V. E. & T. Maran 2006: Feeding ecology of released European mink in Hiiumaa Island 2000–2003. International Conference on the Conservation of European mink (*Mustela lutreola*). Proceeding Book. Logrono: 187–198.

Põlma, M. & T. Maran 2006. Interspecific aggressiveness of European mink (*Mustela lutreola*) and American mink (*M.vison*): provisional results of experiments in captivity. International Conference on the Conservation of European mink (*Mustela lutreola*) . Proceeding Book. Logrono: 199–207.

Maran, T., 2006. Conservation of the European mink in Estonia: an update 2001–2003. International Conference on the Conservation of European mink (*Mustela lutreola*). Proceeding Book. Logrono: 131–142.

Maran, T. & M. Põdra 2005: Reintroduction of carnivores as a tool of species conservation: principles and analyses of the reintroduction of the European mink (*Mustela lutreola*). In: Ecological Restoration. Yearbook of the Estonian Naturalists´ Society. Ed. Marek Sammul & Asko Lõhmus. 83: 229–253. Tartu (in Estonian).

1. INTRODUCTION

Conservation biology is acknowledged to advance in two concurrent and parallel lines of development stemming from different approaches to species extinction. These two prevailing ways of thinking have been formulated and elaborated by Graeme Caughley (1994, 1995) as two paradigms in conservation biology. The first conceptual basis is labeled as the "small population paradigm" and the second one as the "declining population paradigm". Researchers armed with the small population paradigm address, as a rule, the risk of extinction inherent to small populations because of their small size, while the representatives of the second, declining population paradigm are concerned with the processes by which populations are driven to extinction by external factors and not so much with the size of the population.

The small population paradigm has been promoted by studies in population genetics and population biology of small populations. These studies usually focus on the risk of extinction in small populations. The development of this paradigm is driven mainly by studies of restricted island and captive populations. The small population paradigm is well equipped with theory, incorporating ideas of the impact of demographic stochasticity, environmental stochasticity and genetic stochasticity on small populations, but also the concept of meta-populations and population viability analysis (PVA). Thus, the emphasis within the small population paradigm is on analyzing the stochastic factors influencing small populations. An analysis of most of these theoretical considerations is provided in several classical reviews, such as Soule & Wilcox, 1980, Frankel & Soule, 1981, Soule, 1987.

The declining population paradigm has a longer history and focuses on the ways of detecting, diagnosing and halting a population decline. This paradigm largely overlooks the danger of extinction caused by internal stochastic factors of a small population and sees the problem as a population in trouble because something external to it has changed. The research effort in the framework of this paradigm is aiming to identify the external factors causing the decline of the species and to find what can be done about it. As a rule, the population of being small is not recognized to be a cause/problem in itself. The declining population paradigm stems largely from empirical studies and its theoretical background has so far remained relatively undeveloped. The main possible underlying theoretical considerations are thought to lie in the causes of extinction and the means by which the agents of decline might be identified (Caughley, 1994). Diamond (1984, 1989) analyzed the extinctions and found that the agents of decline can be divided into four groups, which he termed as "The Evil Quartet": overkill, habitat destruction and fragmentation, impact of introduced species, and chains of extinction. Caughley (1994) reviews the very initial generalizations about these four groups. He summarizes that a species facing the hunting culture tend to be in grave danger if it is valuable, insular or large. For habitat destruction and fragmentation it has been shown that population size is clearly dominant among the numerous factors influencing the rate of local extinctions. The impact of alien species has been clearly shown in IUCN Red List analyses (for the most recent one see Baillie et al., 2004). Chains of extinction are secondary extinctions, where the extinction of one species is caused by the extinction of the species it depends upon. According to Caughley (1994), there are numerous examples of such secondary extinctions among predators and scavengers.

Summarizing his review on these two paradigms in conservation biology, Caughley (1994) concludes that (1) the declining population paradigm is in urgent need for more theory and the small population paradigm needs more practical evidence; (2) both paradigms have much to learn from each other and their cautious intermixing might well lead to a reduction in the rate at which the species are currently going extinct.

The two-paradigm understanding of conservation biology has remained largely the same since Caughley (1994), though the gaps highlighted in Caughley's review have been filled to a certain extent. For instance Krebs (2002) reviewed the approaches to the understanding of changes in population numbers and questioned the possibility of finding invariant relationships between population growth and some other variables, as it is usually multiple factors that determine the population density, thus lessening the predictability. He emphasizes the need for better experimental design for solving the practical problems in population management.

The vacuum of real data from the wild to support the small population approach is slowly being replaced with accumulating data. For instance, the negative impact of inbreeding and low genetic diversity in wild populations has been revealed in several studies and the importance of internal stochastic factors in small populations has been revealed also in the wild (Keller & Waller, 2002; Frankham, 2003, 2005). The overall theoretical basis of the small population paradigm has been further elaborated (Ballou, et al., 1995). An attempt has been made to merge the two approaches, the small population paradigm and the declining population paradigm: for instance the concept of habitat fragmentation (declining population paradigm) with the concept of small population (Young & Clarke, 2000).

The European mink, *Mustela lutreola*, is a European small carnivore (Fam. *Mustelidae*) once widely spread in almost the whole continent and presently surviving as fragmented populations in few enclaves. The drastic change in its number and distribution has placed the species among the most endangered mammals in Europe and in the world. Most of local and international listings have regarded it as an endangered species in need of action: (1) the IUCN Red List (2004; www.redlist.org) ranks it as an Endangered Species; (2) the IUCN Action Plan for Small Carnivores (Schreiber et al., 1989) regards it as a priority species for Europe and the world; (3) the Bern Convention on the Conservation of European Wildlife and Natural Habitats lists it in Annex II as a species in need of strict protection; (4) the European Union Habitats Directive has positioned it in Annex II (Member States are required to designate special areas of conservation) and in Annex IV (Member States are required to establish a system for strict protection). Furthermore, the European mink is also protected by national law of all range states.

The rapid decline of the species urges for effective conservation actions to prevent the species from total extinction or, if the ways how to preserve the species remain uncertain, to find at least the ways how to mitigate the effect of the agents operating the extinction until more effective conservation tools become available. Application of the most relevant preservation and/or restoration measures requires a lot of knowledge on the biology of the species. So far the decline has been described in single countries and the agents operating the extinction have been addressed only on the local scale. However, to adequately define the objectives as well as the actions needed, knowledge about the extent of decline and the agents operating the extinction needs to analyzed and generalized across the whole historical range of the species.

As the European mink has been in severe decline and currently exists only in small populations, the application of tools from both conservation biology paradigms is equally relevant. Application of the declining population paradigm can assist in diagnosing the causes of decline. The use of tools from the framework of the small population paradigm assists in formulating the goals of conservation management of the species.

The current thesis was prepared by aggregating the studies performed over a relatively long period: 1991–2003. The thesis applies both paradigms and aims (1) to identify and describe the process of the decline, (2) to analyze the hypotheses proposed to explain the extinction and (3) propose for discussion the goal for the conservation efforts of this species.

The thesis contributes to overall development of species conservation by providing a global description of the process of decline of the European mink (Articles II and III), analyses of single putative agents of decline (Articles I, III, IV, V, VII, VIII), a holistic analysis of the agents behind the extinction (Articles I, II, III) and analyses of appropriate ways how to proceed with conservation management of the species (Article IX). In addition, the thesis provides an up-to-date review of the status of the species by countries and regions (Russia).

2. MATERIALS AND METHODS

The materials for this study were collected during the period of 1985–2003.

Data on the historical range are based entirely on records from literature. The change and present status were assessed also on the basis of published data but also by questionnaires (to assess the changes in the protected areas of the former Soviet Union) and research in the field (especially in Estonia).

Multiple methods were employed to test and evaluate the proposed hypotheses in an attempt to explain the overall decline. Various "deterministic" causes of decline were considered. These include, among others, the decline of food resources, over-hunting, habitat loss, hybridization with closely related taxa, and introduction of exotic species (see section 3.3). The emphasis has been on comparison of the causes of decline in different regions and during different time periods.

The possible impact of *declining food resources* was tested by studying the diets of the European mink in Estonia and Belarus (**Articles VII, VIII**). Scats of the European mink, as well as of other close mustelids, were collected in the wild, the remains of prey were identified and compared with the food resources in nature, or with the scat contents of other mustelids present in the study area.

The *impact of hunting* was assessed mostly by retrospective analyses of literature in various regions (**Articles II, III, VI)**. The *impact of habitat loss*, too, was assessed by retrospective historical analyses of changes in landscape use and by comparing these changes with the shift in the status of the species (**Articles II, III, VI**).

The *possible impact of polecat*, *Mustela putorius*, through hybridization was assessed by studying the mitochondrial DNA of the European mink and polecat to reveal the origin of these species and the possible flow of genes between the two species (**Articles I, IV**).

The *impact of intra-guild aggression* between the American mink, *Mustela vison,* and the European mink, *Mustela lutreola*, was assessed by experimental studies on behavioral interaction of these species. Wild caught mink (n=8; 2 males and 2 females of both species) were housed in an outdoor L-shaped arena with three 5x5 m compartments. Observations on behavioral interactions were recorded every minute for 24 h during three consecutive days for each month between September 1989 and July 1990. (**Article III**).

The *overall goals for European mink conservation* were established (proposed for discussion in **Article IX)** by combining the evidence on "deterministic" causes of extinction with information about stochastic factors such as genetic, demographic and environmental fluctuations known to have a serious impact on the survival of small populations.

3. RESULTS AND DISCUSSION

3.1. HISTORICAL RANGE OF THE EUROPEAN MINK

Results

No special studies have been carried out by the author in regard to the historical range of the species. Consequently, no results of the studies can be shown. However, our analyses on the process of decline require a good overview of the historical range of the species. For this reason, all the known sources providing information on the historical spread of the species have been studied and a synopsis of this information is provided below.

Discussion

The first comprehensive review of the historical range was provided by Novikov (1939). Later, Heptner et al., (1967) and Youngman (1982) have adjusted Novikov's map to accommodate new data.

The historical distribution range of the European mink as provided by Novikov (1939) and Heptner et al (1967) is presented in Figure 1. While the historical spread of the species in the center of the European continent is clearly known, several questions remain concerning the border areas and opinions are often controversial.

The historical status of the European mink outside of the European continent deserves special attention. Novikov (1939) states that the European mink range remained to the west of the Ural Mountains until the mid-19th century and postulates that only thereafter the species invaded around 900 km east within a relatively short period (~60 years?!; Figure 2). Laptev (1958) doubts about this rapid spread over the Ural Mountains and proposes an alternative hypothesis to explain the scarcity of data on the presence of the European mink to the east of the Urals, but also the lack of older records. According to him, the abundance of the European mink remarkably decreases towards the eastern limit of the range due to harsh natural conditions and therefore the naturalists of the 19th century had better chances to describe the species close to the Urals than further east (Figure 3). As time passed and data collection efforts increased, records from also the eastern edge of the range gradually became available, forming an illusionary picture about the eastward expansion of the species. Heptner et al. (1967) describe both hypotheses but tend to regard it more likely that the European mink did not inhabit the biotopes east of the Urals until the 1870s and reached the easternmost edge of its range only in the 1930s. The validity of these two hypotheses is hard to judge. Therefore the question of whether the European mink was initially a purely European endemic species remains without an unequivocal answer unless the (still) possible genetic studies of the easternmost populations cast light on the origin of the population east of the Ural Mountains.

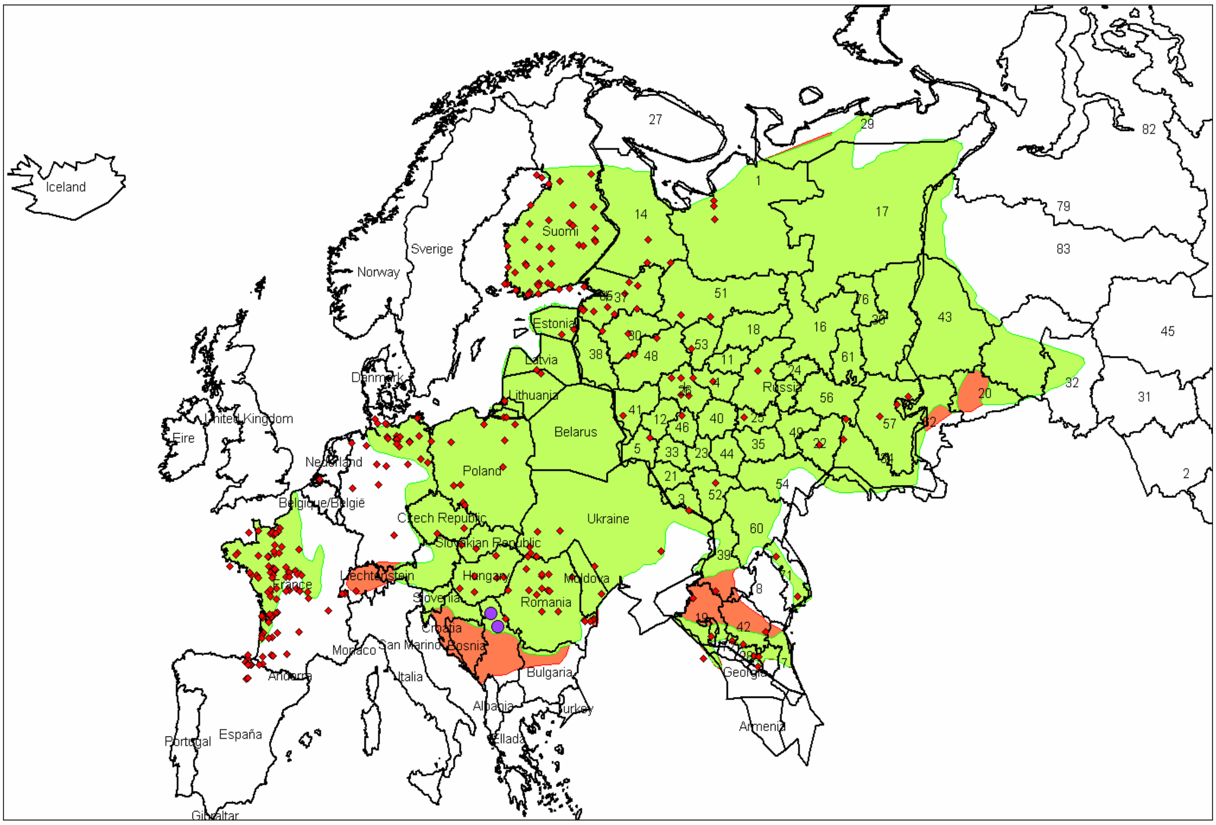

Figure 1. Data on the historical range of the European mink[1]:

1. Green area – After Novikov, 1939
2. Red area – Modifications to Novikov, 1939 by Heptner et al, 1956
3. Lilac dots – Records on the presence of the species in Northern Serbia (after Krustufek et al., 1994)
4. Red squares – Records on the presence of the European mink based on museum specimens and literary records (after Youngman, 1982)

Heptner et al. (1967) admit that, similarly to the eastern range, also the southern range of the species is not fully known. They partly correct Novikov (1939) and widen the range of the European mink southward of the Ural Mountains (Figure 1).

Novikov (1939) believes that the Caucasian population of the European mink was isolated from other populations and formed a natural enclave. Heptner et al. (1967), however, referring to several reports, show that the range was continuous up to the very south in the Caucasian area. Youngman's (1982) thorough study on museum specimens supports the continuous range in this area (Figure 1).

[1] The numbers in the map refer to the regions in Russia as specified in the table in Annex 1.

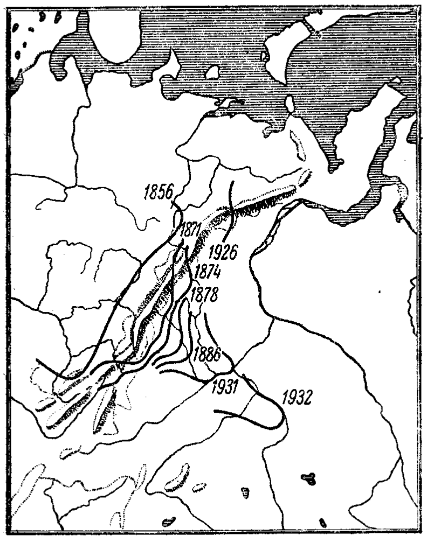

Figure 2. The invasion of the European mink, *Mustela lutreola* to the east from the Ural Mountains as suggested by Novikov, 1939

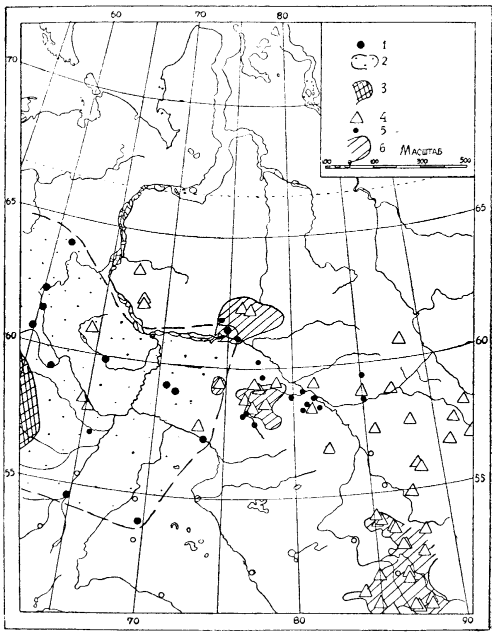

Figure 3. The presence of the European mink, *Mustela lutreola* and American mink, *Mustela vison* east of the Ural Mountains: European mink 1. single records; 2. single invasions and low abundances; 3. High abundance; American mink: 4. release sites, 5. single records, 6. high abundance. (Laptev, 1958)

Historical presence of the European mink in Austria remains unclear. Novikov (1939) states its historical presence in the northeast of the country and in Tirol Region. Altum (1876: ref. Novikov 1939) claims that in Tirol Region some 30 animals were caught annually. Greve (1895, ref. Novikov 1939[2]) reports the presence of the European mink in Mautern and Zonenburg(?) on the Danube River. Perkenshtein (1926, ref. Novikov 1939[3]) reports on the European mink on Lake Neusiedlersee. Rebel (1933, ref. Youngman 1982), summarizing the records on the European mink in Austria, refers to Tschudi (1913) and states the presence of the European mink at Wallsee. Ph. Youngman's (1982) concludes that the historical presence of the European mink in Austria is likely, though not entirely confirmed.

[2] Novikov (1939) does not provide the reference for Greve, 1985

[3] Novikov (1939) does not provide full reference for Perkenshtein, 1926

Data on the spread of the European mink on the Balkan Peninsula and in the republics of former Yugoslavia are controversial. Novikov (1939), Heptner et al., (1967) and Youngman (1982) provide different descriptions on historical distribution in this region (Figure 1). According to Novikov (1939), the range extended as far south as Croatia, Bosnia and Herzegovina. Novikov (1939) considers the presence of the species in the southeast of former Yugoslavia to be likely, though not confirmed by any data. Heptner et al., (1967), without providing any proof, shift the border of the range much further south and east including also Bulgaria, Serbia, Kosovo and Montenegro. Youngman (1982), without finding any proof on the presence of European mink in former Yugoslavia, leaves these countries out of the range. However, a relatively recent review (Krustufek et al., 1994) on historical presence of the European mink in former Yugoslavia refers to a record of the European mink in northern Serbia, evidencing historical presence of the European mink in the southern part of the Pannonian Basin. This gives us ground to regard Novikov's (1939) picture of the historical range as the most accurate with regard to former Yugoslavia.

Historical presence of the European mink in the western parts of Germany, in the eastern parts of France, Belgium, the Netherlands and Denmark remains unclear. For the Netherlands there is one known finding of the European mink, from a prehistoric site in Vlaardingen (2300 to 2100 B.C., Van Bree 1961a, 1961b; for other prehistoric evidence of the European mink see **Article I**). For other regions listed above there are no records of the European mink. As for France, the first records on the European mink are surprisingly recent – from the year 1839 (de Sélys-Longchamps, 1839, ref Youngman, 1982). The historical status of the mink in France is even more astonishing due to the fact that the European mink was discovered even more recently in Spain, with the first record dating back to 1951 (Rodriguez de Ondorra, 1955, ref Ruiz-Olmo & Palazon, 1990) and with all the subsequent records of the European mink ever since suggesting the invasion of the species to the northeast of Spain across the French border (Palazon et al., 2003; Zabala & Zuberogoitia, 2001). To explain the relatively late recognition of the European mink in French fauna, Youngman (1982) proposes three hypotheses: (1) the mink has been an old member of the fauna but has been overlooked; (2) the mink has been artificially introduced into France by man, (3) the mink spread into France from adjacent regions of Europe. The same hypotheses seem to be valid also for Spain. Youngman (1982) supports the third hypothesis for France. He postulates that the range extension to Western France, either from Western Germany or from Switzerland, began around the end of the 18th century, when the mink was disappearing from Central European countries. He connects the range extension with the end of the Little Ice Age in the 1850-s resulting in amelioration of the climate. Such casual connections do not seem to be likely. The species' range extended almost to the Arctic zone in the Ural region, which evidences the species' capability of adapting to much harsher climatic conditions than those in Central European countries. Thus the Little Ice Age could not have a noticeable impact on the species' survival there unless the populations in the south and west have less ability to adapt to cooler climate. The postulation of Youngman (1982) is partly supported by genetic studies of the eastern and French/Spanish populations (Lode, 1999, **Article I**, especially Michaux et al., 2005). The Spanish/French populations were found to possess an exceptionally low level of genetic divergence attributable to historical bottlenecks. The almost complete lack of genetic variation suggests that this population was established from very few individuals (possibly a single female) and possibly by anthropogenic introduction, but Holocene origin with establishment of a population from long-distant migrants from a refugium is equally plausible (Michaux et al., 2004). However, the prehistoric finding of the European mink in Vlaardingen (the Netherlands) from 2300–2100 BC (van Bree, 1961a,b) seems to indicate an alternative possibility: the European mink was historically widely distributed in Central and Western Europe but declined because of unknown reasons and thereafter partially recovered its range from a limited number of founders in more recent past.

3.2. COURSE OF EXTINCTION AND EVIDENCE ON THE CURRENT STATUS

Results

The status of the European mink in Estonia was studied retrospectively (**Article VI**). According to early literature, the European mink was common in Estonia before 1914. There are several reports claiming that the European mink was more common in Estonia than in the neighbouring countries (Curland & Livland). There are no reports on mammals on the Estonian islands, with the exception of a single report on the presence of the European mink on Saaremaa Island. However, as this report relies on a pelt bought from the local market, the origin of this specimen remains unclear. The reports on the period 1918–1940 indicate that the European mink was still common in Estonia, though a number of reports claiming regional decline of the species appear in this period. In 1980–1987, a survey on the status of the European mink and American mink was conducted, combining data from a questionnaire and fieldwork. The survey revealed that the American mink had invaded almost the entire southern and western Estonia. The European mink was detected only in the northeast of the country.

The status of the European mink in the protected areas of the former Soviet Union was studied by means of questionnaires (Maran 1992, **Article III**). The questionnaires were sent to 19 nature reserves in the ex-USSR in 1990. The same questionnaires were repeated in 1995. Thirteen of the questionnaired protected areas responded. Five of these reported extinction since 1990. Of the two reserves that reported abundance in 1990, one judged it to be in decline and the other one extinct in 1995. One protected area which reported the population to be in decline in 1990 reported it to be stabilised at a new low by 1995. No reserve reported a healthy population.

Discussion

The course of decline has been analyzed in several reports on global (**Articles II, III**, MacDonald et al. 2002) and on local scales (**Article VI**, Maran, 1992, Henttonen et al., 1991, MacDonalds et al., 2002, de Bellefroid & Rosoux, 1998, Lode et al., 2001, Tumanov & Zveryev, 1986, Tumanov, 1992, Savelyev & Skumatov, 2001, and others). According to the reports and analyses, decline and extinction was first (in the 19th century) recorded in Central European countries such as Germany, Switzerland and possibly also Austria. Thereafter the decline was observed in Eastern European countries – Poland, Hungary, Czech Republic, Slovak Republic and Hungary, where the mink disappeared in the 1930s–1950s. In Finland, Estonia, Latvia and Lithuania the mink vanished in the 1970s–1990s. In the former Soviet Union its decline was noticed in the 1950s, although the pattern of decline remains unclear and is not easy to describe. However, it is obvious that almost everywhere in the former Soviet Union the European mink has suffered an extensive decline and the species has disappeared from most of its historical range over the 20th century.

Although the pattern of change in distribution in Spain and France is clear for more recent periods (de Bellefroid & Rosoux, 1998, Ruiz-Olmo & Palazon, 1991, Palazon et al., 2003), the historical origin of the Spanish/French population remains unknown (see Chapter 3.1).

An overview of the recent status of the European mink by individual countries (and by regions for Russia) is provided in Annex 1. Data on the status of the species in regions (especially Russia) are quite fragmented and the quality of the data ranges from quantitative fieldwork to questionnaires and assessments. Often the literature sources even do not clearly state the basis of their conclusions about the status. For several regions, especially in Russia, no data are available at all. Also, the arrangement of data according to political and administrative borders is far from being a solid ground for comparison and analyses. All this makes it very difficult to draw any firm conclusions based on solid data. Yet, this is currently the best available dataset on the overall status of the species. The trend is obvious even from this data collection. The information collected in the table in Annex 1 clearly shows that the species is still extant in only a minor part of its former range and is in deep decline even in its currently remaining range enclaves. Only Romania and Vologotsk Region (Oblast) and Arkhangelsk Region (Oblast; Russia) can, perhaps, be regarded as exceptions. In Romania, the presence of the European mink in Danube Delta was confirmed relatively recently (Gotea & Krantz, 1999) and detailed studies still have to be undertaken to clarify its status and possible threats. In Vologodsk Region (Oblast), considering the rapid decline of the species in the neighboring regions and the presence of the American mink (look chapter 3.4), it is not likely that the European mink populations will hold there for long. In Arkhangelsk Region, the population seems to exist in the northwest of the region, which is close to the northern limit of the range and the presence of the American mink is likely to pose a serious threat to its long-term existence also there.

The American mink is present in most of the localities of the European mink. As the two species are very similar in their ecology, appearance, and also field signs (**Article III**, Sidorovich, 1994, Danilov & Tumanov, 1976), it is obvious that the replacement of mink species in the wild goes practically unnoticed, especially as such replacement may take place very quickly (like it did in North Estonia within some 5–10 years). Therefore, it is likely that in many areas the replacement between mink species has passed unnoticed and/or its extent has been underestimated. Also, observers (especially respondents to questionnaires) tend to consider the past status of the European mink to be still valid. Thus, the data aggregated into Annex 1 may well be an overestimate of the actual present distribution of the European mink.

3.3. HYPOTHESES ABOUT POTENTIAL CAUSES OF EXTINCTION

Different hypotheses aiming to explain the causes of decline have been put forth by a number of authors on the local scale (Cena, 2003, Cena et al., 2003, Lode, 2002, Lode, 2001, Fournier & Mazairet, 2003, Szunyoghy, 1974, Mošansky, 1998, Ozolinž & Pilats, 1995, Kiselyuk, 2002, **Article IX, Article VI**, Savelyev & Skumatov, 2001, Tumanov & Zveryev, 1986, Ginnev, 2002, Sidorov, 1999, Shashkov, 1977, and others). These hypotheses have also been analyzed and tested on a wider, global scale (e.g. **Articles II, III**). Also, several studies have proposed and/or evaluated specific causes of decline (see references in **Articles II & III**).

The following hypotheses have been proposed and analyzed (**Article II**, further elaboration in **Article III**):
Habitat loss [**Articles II, III, VI**] – Chapter 3.3.1.1.
Overhunting [**Articles II, III, VI**] – Chapter 3.3.1.2.
Pollution [**Articles II, III, V**] – Chapter 3.3.1.5.
Prey shortage [**Articles II, III**, see also **VII, VIII**] –.Chapter 3.3.1.4.
Introduced diseases [**Articles II, III**] – Chapter 3.3.1.4.
Inter-specific relations with American mink [**Articles II, III**; Maran, 1989] – Chapter 3.3.1.4.
Inter-specific relations with polecat [**Articles II, III, IV**] – Chapter 3.3.1.3.

3.3.1. Review of hypotheses

3.3.1.1. Habitat loss

Results

No experimental study has been conducted. The discussion is based on analyses of published reports. Habitat loss has been analyzed by comparing the literature about the loss of the riparian habitat in various periods (**Articles II, III, VI, Annex 1**) with the change in the status of populations.

Discussion

The European mink is a typical inhabitant of natural small rivers and streams with lush vegetation for shelter and abundant food resource available in the form of amphibians, fish, small mammals and crustaceans. Considering the extensive landscape transformation in Europe since the early 19th century, but especially the change in freshwater biotopes caused by overwhelming “land improvement” in Europe, it is clear that these changes in biotopes must have had an impact on the European mink populations, leading to severe fragmentation of the species’ distribution. The critical status of the species makes it very hard, if possible at all, to conduct a sound scientific experiment for identifying the habitat parameters that have a crucial effect on the survival of the species. The possibility of studying the vulnerability of the species to habitat change in an experimental setup is questionable as well.

Although the parameters describing the change in habitat quality have not been measured during the decline of the European mink, the high number of published reports (especially during the earlier period of decline) connecting the local extincttion of the species with extensive landscape transformation indicates that changes in the availability and quality of suitable habitats have had an important role in a number of areas (references in **Articles II, III, VI**, Shashkov, 1977, Shubnikova, 1982, Mošansky, 1998, Lode et al., 2001, Ginnev, 2002, Szunyoghy, 1974, Tumanov & Zveryev, Ozolinž & Pilats, 1995, and others).

Habitat destruction is considered a serious agent of extinction of the European mink, continuing to cause decline in several presently surviving populations. For instance, in Spain (Cena, 2003) the substitution of natural riparian plant communities with homogenous cottonwood (*Populus x hybrida*) plantations is expected to drastically decrease the capacity of such riparian habitats for mink. In France, a change in landscape structure in riparian zones caused by increasing fodder culture seems to have played an important role (along with other factors; Lode, et al., 2001).

Yet, despite convincing and numerous records about the historical impact of habitat loss in several regions, especially in the eastern part of the range, the European mink has disappeared also from regions with suitable habitats still available. Therefore, habitat loss cannot be regarded as a single factor responsible for the decline throughout its geographical range.

3.3.1.2. Overhunting

Results

The change of fur prices of fur animals has been analyzed for Russia as of the beginning of the 20th century and 1983 (**Article VI**). The change in prices is assumed to reflect a change in market demand and also in hunting pressure. The value of badger pelt was assumed not to have changed in time and was used for calculating comparable relative values. The value of mink pelt had changed 9.7 times over the period, which is high in comparison with the change in pelt price of polecat (4.7 times), stoat (2.1 times), otter (2.3 times), Indian marten (3.5 times), pine marten (1.2 times) and sable (0.2 times) pelt. The increase in the value of mink fur is considered to have resulted from starting mink farming and the spread of mink fur fashion in Europe since the 1920s –1930s.

The impact of hunting has been further analyzed on the ground of all known reports addressing this issue (**Articles II, III**).

Discussion

Hunting activities may have influenced European mink's distribution and abundance in two ways.

First, intentional hunting of the European mink has clearly had a serious impact on original mink populations in the eastern part of the range (analyzed in **Articles I, II, VI**). Although mink hunting has a long historical tradition (Shubnikova, 1982), hunting pressure is likely to have increased substantially in comparison with other similar fur species after American mink fur became a fashion in the early 20th century (**Article VI**). Indeed, as reported by Shashkov (1977) in Kostroma Region (Oblast), the actual annual harvest exceeded the expected annual productivity of the species almost twofold. That ultimately led to the plummeting of hunting statistics of the species in the region, but also in other central regions of Russia. Depletion of European mink populations as a consequence of hunting has also been described by Pavlov & Korsakova (1973) when explaining the need for introducing American mink into the European mink's historical range in the former USSR. Novikov (1939) reports two cases in the former Soviet Union where highly unsustainable hunting led to the imposing of a moratorium in the region to give the species time to recover.

Second, intensive trapping of other riparian small mammals with non-selective traps, such as muskrat trapping in the Danube Delta (Gotea & Kranz, 1999) or coypu trapping as pest control in France (Fournier & Maizaret, 2003), are reported to have a serious impact on the remaining populations in these countries. Also, though not completely classifiable as hunting, secondary poisoning with anticoagulants during rodent control campaigns seems to have a severe impact on the declining European mink populations in France (Fournier & Maizaret, 2003).

Although intensive and/or non-selective hunting have clearly had, and are still having, a serious impact on the European mink in a number of regions, there are other regions, e.g. Estonia, where the European mink disappeared despite a remarkably low hunting pressure throughout history. Consequently, overhunting is an important factor contributing to the decline but it cannot be regarded as the universal agent responsible for the extinction of the species in every case throughout its original geographic distribution.

3.3.1.3. Impact of the polecat, *Mustela putorius*

Results

In early 1990s, at the time of deep decline of the European mink, 6 mustelids with intermediate phenotypic characteristics between the European mink and European polecat were live trapped in Estonia. They were considered to be hybrids between these two species (Maran & Raudsepp, 1994). According to chromosome analyses, one of them had 39 and the others 40 chromosomes (the European mink has 38 and polecat has 40 chromosomes). The mitochondrial DNA of four of these putative hybrids was compared with that of morphologically "pure" polecat and "pure" European mink (**Articles I, IV**). These four animals had mitochondrial haplotypes which were otherwise not found in European mink (n=36) but were found in polecats (n=9).

Discussion

The mechanisms of the possible impact of the European polecat have been described in two main and mutually non-exclusive ways: (1) competition in human-transformed landscapes, which favors the polecat (Schröpfer & Paliocha, 1989); (2) hybridization (Granqvist, 1881). Both hypotheses were analyzed (**Articles I, II**) and the real role of the polecat in the decline of the European mink has been questioned. Still, reports of a higher number of hybrids during the phase of the European mink's rapid decline (Maran & Raudsepp, 1994; Sidorovich, 2000; but see also Tumanov & Abramov, 2002) indicate that hybridization may still, to a certain extent, accelerate the already ongoing process of extinction. Nevertheless, it is almost certainly not the key factor operating the decline but rather it may act synergistically with other factors (**Article IV**). However, hybridization may have an entirely different role in the evolution of the European mink, considering the likely recent speciation of these species and the possible frequent flow of genes between these species through hybrids (**Article I**).

3.3.1.4. Impact of the american mink, *Mustela vison*

Results

a. Competition for mates (**Article II**)

No special study has been undertaken about the competition for mates. The indirect evidence supporting and rejecting this hypothesis has been analyzed on the basis of literature.

b. Competition for food (**Articles VII, VIII**)

Diet of small carnivores in Belarus. The diet of small carnivores was analysed on the basis of scats collected (total 4312 faeces). The data shows that:
(1) the American mink feeds significantly more on small mammals than the European mink ($p<0,05$).
(2) the European mink feeds significantly more on amphibians ($p<0,05$).

The data on feeding was used as a basis for calculating the food niche overlap (Pianka index). The food niche of the two mink species largely overlaps and the index equals 0.83.

The diet of the European mink and American mink in Estonia. The diets of the two mink species in two different locations in Estonia were compared. The content of the diet differed substantially ($p<0.0001$). After the extinction of the European mink in the Altja River (North Estonia) and replacement of it with the alien mink, the scats of the latter were collected from the very same site. The diets of the two species in the same site were compared. No significant differences were detected ($P<0.5$).

c. Intra-guild aggression (**Article III**)

The role of interactions within species.

During the 6 days of observation of four specimens of the American mink, 45.3 (SE=13.35) behavioural events were recorded per day per animal, of which 10% were aggressive and 33% were approaching behaviour. In contrast, during the 5 days of observing four individuals of the European mink, only 23.4 (SE 4.66) behavioural events were recorded per animal. However, the quality of the interactions was similar, with aggressive behaviour making 11.7% and approach behaviour making 46% of the behavioural events. The American mink were markedly more active and more socially interactive than the European mink. There was no obvious difference between the species in terms of the proportion of intraspecific interactions involving the initiation of aggression. In the quartet of American mink, 5.2% of the 655 interactions initiated by females were aggressive, while amongst the European mink the respective figure was 3.7% of 241 interactions. In the quarter of American mink, 17.1% of the 432 interactions initiated by males were aggressive, while amongst the 230 interactions initiated by male European mink, 20.2% were aggressive. No striking difference between the species in terms of the flow of interactions was revealed in other categories of interaction.

The role of interactions between species.

Over the 10 months when both species were housed together, 5060 behavioural events were recorded during 22 days of observation, 4947 of which involved interactions between individuals. The remaining events were solitary play, which was more commonly observed in the males of both species. Overall, the behaviour of both species did not differ radically from that observed during the study on exclusive intraspecific interactions. In particular, the American mink continued to be significantly more active and the majority of interactions were intraspecific (of the 2751 behavioural events initiated by adult American mink, 76% were directed at conspecifics). In contrast, of the 1158 behavioural events initiated by European mink, only 21.8% were directed at conspecifics.

Male American mink were aggressive in 20.2% of their 1530 behavioural events. This aggression was largely directed at males, both conspecific and European mink. Of their interactions with male conspecifics, 31.1% were aggressive, as were 20.0% of their interactions with male European mink. For male European mink, 19.1% of the 733 recorded behavioural events involved aggression. They were more interactive with both male and female American mink than with either sex of their own species, and a greater proportion of the interactions with both sexes of American mink were aggressive than those involving either sex of conspecifics. American mink males frequently (24.1%) played with conspecific females but never played with European mink of either sex. European mink males interacted rather rarely. They were more aggressive toward conspecific females than were American mink males, while European mink females were more playful amongst themselves than were American mink females.

The general tone of interspecific relationships was hostile and did not differ signifycantly from intraspecific interactions. To elucidate the intraguild hostility hypothesis, evidence of male and female American mink dominating either sex of European mink was sought. The collected data showed that (1) male American mink did dominate male European mink, (2) male American mink dominated female European mink, (3) aggression flowed approximately symmetrically between female American mink and male European mink, with a slightly higher tendency of the latter to flee from female American mink than vice versa, (4) female American mink dominated female European mink.

As the study of interactions based only on one unreplicated trial (though very extensive) and can not therefore be used for any final generalizations, but can be used for designing further experimental studies.

d. Introduced disease (**Article III**)

Since 1983, 51 European mink and 40 American mink have been housed in close proximity at Tallinn Zoo. All these American mink were wild born or of F1–F2 generation in captivity. For 8 European mink we could retrospectively verify the number of different American mink kept in the adjoining cages. Despite up to four such exposures, there was not a single case of patent illness; all individuals survived and most of them subsequently bred. During 1987, eight European mink and nine American mink were involved in tests for interspecific aggression, during which two individuals of either species were observed in the same cage for a 15-minute sessions. In each of the 24 dyads, European mink were exposed to 15–75 min/day of direct contact with American mink for 34–62 days. During these observations (T. Maran, unpublished results), there was much physical contact and some fighting. However, no illness was observed subsequently in any of the experimental animals, and several became amongst the most successful breeders in the colony. In 1990, four European mink were housed in cages that had immediately beforehand housed wild born American mink, and none developed any illness.

Discussion

Although the American mink is very similar to the native European mink both in its ecology and morphology, these similarities seem to be the result of convergent evolution and the two species differ in numerous features of their ecology, morphology and reproductive biology. The American mink tends to be a more robust and ecologically more flexible species (**Article II**).

Introduction of the American mink to a number of countries in Europe in the early 20th century and its further spread in the wild seem to have influenced the native mink in a number of non-exclusive ways (**Article II**):

a. Competition for mates

(**Article II**). In contests for mates, assuming that there is inter-specific sexual attraction, the larger and more vigorous American mink males might exclude European mink males from their territories, thus increasing their own access to congeneric females. Furthermore, as American mink males become reproductively active earlier in the year than their European mink counterparts, and as hybrid embryos are resorbed as Ternovskij's (1977) records show, early inter-specific pregnancies would pre-empt European mink males' reproduction and make the female European mink reproductively ineffective for that year. There are evidences that inter-specific copulations of the two mink species can take place in experimental conditions but end with resorption of embryos (Ternovskij, 1977; Ternovskij & Ternovskaya, 1994). However, data about inter-specific fertilization in the wild are missing. Even more, the embryos of nine wild

European mink females studied in Belarus at the time of American mink expansion did not show any abnormal morphology which could have indicated their hybrid origin (provided that hybrid embryos have morphology features different from those of pure species; Sidorovich, 2001). In fact, there exist records evidencing the opposite. A report (Sidorovich et al., 2000) on encounters between mink species in the wild showed that these, almost exclusively aggressive contacts were always initiated by the alien mink and always resulted in a flight response of the native species regardless of its sex. Similar data are available from experiments in captivity as well (**Article III**). Even if hybrids do exist in the wild, the following questions need to be answered prior to deciding over their potential role in the extinction process of the European mink: (1) why should hybrids with the relatively distinct American mink reach higher frequencies in the wild than hybrids with the closest congeneric, the European polecat (*Mustela putorius)* and (2) why should the impact of hybridization with the alien mink be more detrimental than well-known hybridization with the European polecat (see Chapter 3.3.1.3.).

In summary, it is highly unlikely that inter-specific competition for mates could have any real role in the extinction of the European mink.

b. Competition for food

The robust build and confident character of the American mink may place it in a favorable position with regard to the use of resources such as food and habitat. This hypothesis has been tested both in Belarus (**Article VIII**) and in Estonia (**Article VII**). The Belarus study revealed that (1) the European mink is not a greater diet specialist than the polecat or the otter and is only slightly more specialized than the American mink; thus it is not likely that the decline of specific food resources could more significantly influence the status of the European mink, if at all, than that of the other species; (2) the European mink was declining in Belarus despite the fact that its most important food resource, the brown frog (*Rana temporaria*), was highly abundant in the study area; the same holds true for the less important prey item, the crayfish, *Astacus astacus*. There is no evidence linking the decline of the European mink in Belarus with changes in the biomass of the main prey species. If prey availability is not a limiting factor, competition for this resource between the species would be unlikely and could hardly lead to the displacement of the European mink. An Estonian study (**Article VII**) indicates that the selection of prey species in the American mink is not specialized but largely depends on the availability of food resources in the habitat. After the invasion of the American mink and displacement of the endemic mink in the study area, no significant difference was detected between the diets of the vanished species and the invader.

Although the shortage of biomass of available prey species could somewhere still result in competitive exclusion of the native species, our data indicate that competition for food has not been the cause of extinct-tion in Belarus. The same is true also for Estonia. Thus, competition for food cannot be regarded as a universal cause of extinction of the European mink throughout its range but it might have some effect in some areas.

c. Intra-guild aggression

The possibility that inter-specific aggressive encounters between the two mink, where the larger American mink is in a favorable position, could constitute pre-emptive competition for resources was partially tested by behavioral studies (**Article III**, Maran, 1989). The study about interactions between wild-caught mink of both species in experimental conditions (**Article III**) showed that: (1) American mink males tend to be more aggressive towards male European mink than *vice versa*; (2) American mink males tend to dominate European mink females; (3) American mink females tend to dominate female European mink. Despite the fact that the study is based on one replication only, it indicates that American mink tend to be more aggressive towards, and dominant over, European mink.

Although these studies reveal that the American mink is more aggressive than the European counterpart and thus dominates over the latter in an experimental setup, this cannot be regarded as a cause of decline of the European mink in the wild unless data on the occurrence of similar aggressive encounters in the wild resulting in suppression of the original mink species become available. A radio-tracking study of European mink, American mink, polecat and stoat in Belarus (Sidorovich et al., 2000; Sidorovich, et al., 1999) observed 14 cases of aggressive interactions between the two mink species. All of them were initiated by American mink (13 by males) and resulted in European mink fleeing off the riparian habitat. In case the European mink returned (recorded twice), the attack and chase was repeated.

The data indicate that intra-guild aggression is likely to be an important agent of European mink decline in the areas of American mink invasion. The higher reproductive capacity of the American mink (up to 7.6

embryos/female on an average) in an expanding population (Sidorovich, 1993) is likely to make the invasion very effective and quick, and it may explain why the switch of mink species is so quick, at least in some regions (e.g. in Estonia). However, in several regions, the decline and extinction took place before the invasion of the American mink. Therefore, intra-guild aggression cannot be regarded as a single universal agent leading to the extinction of the native mink species either.

d. Introduced disease

Along with the introduction of the alien American mink into Europe, also a contagious disease with detrimental impact on the native mink could have been introduced to Europe (**Article II, III**). This hypothesis has been partially tested in captive conditions (**Article III**) in Tallinn Zoo, where a number of wild-caught individuals of both mink species were kept in adjoining cages and were also used in a study of interspecific aggression, which involved keeping the individuals of both species in the same cages. Despite this, no sign of contagious disease was recorded and the European mink bred successfully in captivity.

Evidence from this breeding operation cannot be regarded as conclusive for rejecting an introduced disease as a possible cause of extinction. The lack of evidence on mink in the wild with obvious signs of illness is not convincing either. On the contrary, there is growing evidence that Aleutian mink disease parvovirus infection (ADV) is common among free-ranging riparian carnivores, including the European mink. (Sisco et al., 2003, Sisco et al., 2001, Skumatov, 2003). It could be that this agent possibly contributing to the extinction of the native mink may have been underestimated and deserves further studies. Although ADV was first discovered in farmed American mink in America in 1956 (Hartsough & Gorham, 1956), and soon thereafter (in 1959) also in farmed mink in Sweden in Europe (Obel, 1959), its origin remains largely unknown. However, if the American origin of ADV is ascertained, it may well fit with the proposed hypothesis that this disease with severe impact on the native mink was vectored into Europe by the American mink with the development of mink farming. This should mean also that the impact of ADV is more detrimental to the European mink than to its closest relative, the European polecat, which has seemingly not suffered from any substantial and otherwise unexplainable decline. Consequently, it is unlikely that ADV could be regarded as the main factor behind the decline.

3.3.1.5. Pollution

Results **(Article V)**

Heavy metal (Pb, Ag, Cr, Ni, Zn, Mo, Cu) concentrations were studied in the tissues of the European mink in the Lovat River in Belarus and compared with the concentrations of heavy metals in the American mink from unpolluted Drissa River and heavily polluted Svisloch River (Savchenko, Sidorovich, 1994). In 69% of the comparisons, the concentrations of heavy metals in the American mink from Drissa River were similar to these in the declining populations of the European mink inhabiting the upper reaches of the Lovat. In 25% of the comparisons, the concentrations of heavy metals in the American mink population at the Drissa River were significantly higher ($P<0.05$) and in 6% of the comparisons – lower that in the European mink populations. PCBs were detected in none of the three samples of the European mink inhabiting the study area nor in any samples of otter and the American mink. These contaminants were not found in the three water samples of the Lovat River either. Organochlorine pesticides were not found in the three water samples of Lovat riverhead. The concentrations of these contaminants in one sample of skin fat and two samples of muscle of the European mink were rather low in comparison with published data. These data do not support the hypothesis that pollution is one of the causes of recent decline of this species in the study area.

Discussion

The decline of the European mink has been attributed to pollution of water and riparian habitats (Schröpfer & Paliocha, 1989). There are some reports on the presence of the European mink in highly polluted biotopes (references in **Articles II, III**). Levels of organochlorine residues in the European mink at levels that could perhaps impair its reproduction have been reported from Spain (Lópes-Martin et al., 1994), though the report came from locations where the European mink was doing well at least at the time of reporting. Studies in France (Lodé et al., 2001; Lodé, 2002) have found a correlation between the decline of the European mink and freshwater quality. Water pollution seems to be one of the major factors responsible for decline of the species in France. However, pollution cannot be regarded as a key agent behind the extinction everywhere, as the European mink has experienced a rapid decline also in regions with relatively intact freshwater (**Article V**).

3.4. SYNTHESIS – SINGLE UNVERSAL CAUSE OR MULTIPLE CAUSES OF EXTINCTION

During the process of European mink decline, a high number of diverse hypotheses have been proposed in numerous reports. A plausible reason for this is the fact that the hypotheses have been constructed on the basis of local evidence and consequently they are well-suited in each respective locality. However, the attempts to use the same hypotheses to explain the extinction process elsewhere or in another time frame usually fail or are not applicable in full scale.

In most of Eastern European regions, the decline of the species, and even extinction, was noticed before the invasion of the American mink. This has led to the conclusion that the impact of the American mink cannot be regarded as operating the extinction. These earlier extinctions, as far as records available allow us to judge, have mostly been attributed to habitat loss and to a minor extent also to hunting. More recent extinctions have been connected also with the invasion of the American mink, beside the already mentioned factors.

In central parts of Russia, the demise of the species overlaps with increased hunting pressure and also with an extensive change of habitats in 1964–1970 (Shashkov, 1977). River dredging and forest reclamation have sometimes resulted even in the disappearance of several small rivers in these regions, but usually in highly changed riparian biotopes with impoverished food resources. This, combined with a drastically high hunting pressure, which at least in some regions (e.g. Kostroma Region) exceeded the species' yearly reproductive capacity almost twofold, could have been the factor which led the species to the brink of extinction (Shashkov, 1977)[4]. Obviously, fragmentation of the population further contributed to the extinction of the species.

In Estonia, on the other hand, over-hunting could hardly be the cause of extinction due to the fact that mink hunting has not been a tradition there and hunting pressure on mink was hardly higher than that on any other small mustelids, for instance the polecat. The first reports of the decline in Estonia in 1920–1940 were mostly connected with habitat changes. Large-scale river-dredging and draining of forests in the 1950s and 1960s, which had a great impact on most of the country's territory and its river basins, could not pass without a drastic impact on the status of the European mink. The concurrent invasion of American mink into the territory of Estonia must have had a cumulative effect on the species **(Article VI)**.

Similarly, in Belarus (Sidorovich, 1991), the European mink disappeared in several regions already before the spread of the American mink and its decline was attributed to an array of anthropogenic factors. However, the co-incidence of the spread of American mink with the final extinction of the species seems to confirm the crucial role of the alien mink.

In France (Lodé et al., 2001, Lodé, 2002, Fournier & Maizaret, 2003) the decline of the European mink is connected with the cumulative effect of several factors, such as high population fragmentation caused by patchy degradation of freshwater quality, habitat modification combined with secondary poisoning during rodent (mostly coypu) control with anticoagulants, but also non-selective trapping of coypus. The American mink has not been regarded to be responsible for the decline so far, although further spread of the alien mink is thought to pose a potential serious threat to the native mink (Fournier & Maizaret, 2003; but see also Lodé et al., 2001).

In Spain, the status of the European mink is somewhat odd. On one hand the species seems to have reached Spain only in the 20th century and is presently extending its range southwards (Palazon et al., 2003). Concurrently, the establishment of an American mink population inside the European mink's expanding range, along with the presence of ADV disease (see chapter 3.3.1.5.) and habitat loss, is believed to pose a serious threat to the species' survival there (Palazon et al., 2003, Cena, 2003).

In Finland, habitat loss and the impact of the American mink could not have been the main reasons for extinction. The decline of the species could only partly be connected with intensive muskrat trapping. However, it is obvious that the invasion of the American mink into the areas of fragmented and weak European mink populations prevented the recovery of the latter and worked towards its final extinction (**Article II** and references therein).

Also in Poland, the European mink started to disappear long before the invasion of the American mink (Ruprecht, 1982) and the extinction remains hard to explain. In fact, in several regions the European mink vanished so early that it has not been even discussed in literature.

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[4] However, see Skumatov, 2005. The author claims that hunting is not an agent of European mink demise but the decreasing in time hunting bag only reflects the decline of the species in the wild caused by other factors.

It seems obvious that the attempts to find one universal factor operating the extinction have failed. Explanations seemingly valid in one region do not hold in another region. This strongly supports the idea that there has been a set of various factors causing the extinction of the mink and the content of this set has varied in time and space.

In the European continent, human activities have resulted in large-scale alteration of landscapes, which has had a substantial impact on various habitats and their species. The European mink has proved to be sensitive to human-induced environmental change and disturbance. As the type and extent of human influence on the species and its biotope has varied in time and between regions in Europe, also the set of factors contributing to the extinction has varied.

Several factors have often been acting in concert with a cumulative effect. The course of decline in central regions of Russia is a perfect illustration to this. There, the effect of over-exploitation was noticed almost throughout the entire European mink range (this even resulted in a moratorium of hunting in several regions and even in reinforcement efforts in Gorky Region, where 133 European mink were translocated with the hope to recover the original, depleted population). In addition, extensive change of habitats in the mid-20th century further contributed to the decline. Thereafter, the invasion of the American mink posed a very serious threat to the endemic mink. Large-scale introduction of American mink in Russia, first planned to be conducted only in regions outside the European mink natural range, were ultimately performed also inside the native mink range. The reason for this was twofold: (1) the original mink has become too scarce for the fur-trapping industry, (2) higher value of American mink fur in the market (Pavlov & Korsakova, 1973). In the course of the introduction operation, 20,400 American mink were released in the USSR until 1971, with around 4000 of them being released into the range of the European mink (Pavlov & Korsakova, 1973). The intentional introduction of the alien species was strongly supported by rapidly developing mink fur-farming in the former Soviet Union – escapees from farms formed a continuous source of new founders for introduction. American mink farming started in the 1920s; in 1972, 1.9 million female American mink were kept in fur-farms and in 1973 4.9 million mink were raised in 146 farms in the former Soviet Union (Abramov, 1974). As the native mink populations were low-numbered and highly fragmented by over-exploitation and habitat loss, the fur-farm escapees, being ecologically more flexible (**Article III**) easily invaded into the freely available ecological niche, thus making it impossible for the depleted European mink to recover. Even more, the remaining European mink groups were an easy target for intra-guild aggression (**Article III**, 1998, Sidorovich et al., 2000, Sidorovich et al., 1999). The magnitude of the effect of mink-farming on the native mink is well illustrated by a recent study in Denmark (a country with a very high number of mink farms), which concludes that 86% of free-living American mink are escapees from farms (Hammershoj et al., 2005).

Local key factors have changed with time also in many other countries. For instance the impact of over-hunting and/or habitat change weakened the populations and accelerated the impact of the subsequent spread of the American mink and/or the impact of other factors. It might well be that sometimes the interchange of key factors in time and/or the concurrent impact of several factors has led to a synergistic effect on the European mink. Further, the time from the introduction of the threat to the extinction of the species can be highly variable, resulting in the so-called extinction or decline lag (Baillie et al., 2004). This along with the interwoven effect of numerous factors is likely to result in situations when it is hard or, in some cases, even impossible to identify the actual causes behind the extinction process.

The role of the alien American mink deserves a special attention. Its role has been noted in several reports as a secondary or not at all important factor, usually emphasizing that the decline of the European mink started before the invasion of American mink (Lodé et al., 2001, Lodé 2002, Rozhnov, 1992, Schubnikova, 1982 and others). Still, there are several records about local extinction of the European mink concurrent with rapid expansion of the American mink, e.g. in Estonia, Tver Region in Russia, Vittoria in Spain, Belarus. (**Article VI**, Katchanovsky, 2002, Cena et al., 2003, Sidorovich, 1991, 1993). Further, although there are "time-shot" records on the co-existence of the two mink species, no records of long-term sympatric co-existence of the two mink species are available. Numerous records reveal the local replacement of the European mink with the American mink but no opposite events have been reported. Records on replacement of the European mink with the American mink are further supported by studies of behavioral interactions between the two mink species in the wild and well as in experimental conditions (see section 3.3.1.3.). All this evidences that the American mink has played a special role in the demise of the European mink. While most of the other agents which have been operating the extinction are relatively easy to stop by conventional conservation management, there is very little one can do to prevent the spread of the alien mink. This means that the presence of the American mink in wide territories across Europe makes the efforts for species recovery a very complicated task.

The possible role of the Aleutian mink disease parvovirus infection (ADV) in the extinction of the European mink needs further investigation. Considering its close relation to American mink fur-farming, it may be quite plausible that this virus has been vectored to the European mink by the introduction of commercial mink farming and thus it can also be regarded as one of the ways how the introduction of the alien mink species has been contributing to the demise of the native mink species.

In conclusion, a number of factors, usually acting in concert, have been operating the extinction of the European mink. Although the impact of individual factors has varied in time and space, the three key factors are the impact of the American mink, degradation and loss of habitats, and over-hunting. The IUCN Redlist analysis on extinctions worldwide (Baillie et al., 2004) lists habitat destruction and fragmentation, invasive alien species, over-utilization, disease, pollution and contaminants, incidental mortality and climate exchange as the major human-induced impacts on biodiversity. In the case of the European mink, almost all these factors have also been blamed to play a smaller or greater role in the extinction process. The IUCN Redlist analysis concludes that the most pervasive threats that mammals face are habitat destruction combined with fragmentation, over-exploitation and invasive alien species. In addition, the analysis shows that often the combination of factors operating the extinction changes in time. The very same pattern can be observed also in the European mink case study: historically, over-hunting and change of habitats have been the main forces behind extinction but the present spread of the invasive American mink leaves little hope for the recovery of the European endemic in the continent.

3.5. STRATEGIC IDEAS FOR CONSERVATION: MANAGING A SMALL POPULATION TO PREVENT STOCHASTIC EVENTS AND ENSURE THE SPECIES' RECOVERY

Considering the critically endangered status of the European mink and the continuous spread of the American mink in extensive territories of Europe, it is likely that the native mink will completely vanish in Europe unless well-coordinated and effective conservation measures are taken. Also, the potential negative effects of mismanagement and faulty strategic decisions must be avoided (Maran, 2000).

To be successful in the conservation of the European mink, it is necessary to define the recovery goal, i.e. the status in which the species can be regarded as being safe from potential extinction. It is equally important to map the possible ways of reaching this target status.

Conservation biology follows largely two mutually supportive paradigms (Caughley, 1994): (1) the declining population paradigm (focusing on external agents of decline: deterministic factors) and (2) the small population paradigm (focusing on the risk of extinction because of too small a size of the population due to stochastic factors). The European mink is in serious decline and exists at present only in small fragmented populations. Therefore both (1) the deterministic causes of extinction together with the "prescription of the antidote" have to be identified (application of paradigm 1) and (2) serious attention has to be paid to its populations being jeopardized with extinction by stochastic factors due to their small size (application of paradigm 2).

(1) The analysis of the causes of decline indicates that the main factors behind the extinction have been loss and degradation of habitats, overly intensive hunting and the impact of the alien American mink, while the other agents (e.g., polecat's impact, pollution and road-kills) seem to have a minor significance. Therefore, these three major agents (usually acting in concert) have to be targeted when devising the conservation strategy and goals. Over-hunting and habitat loss can be addressed by conventional conservation measures (such as prohibition of hunting, habitat restoration and/or designation of protected areas), combined with effective public awareness campaigns. The impact of the spreading American mink is a far more complicated issue. Undoubtedly, it would be ideal for the European mink's survival if the alien American mink could be removed from the European continent. However, all currently available conservation tools are unlikely to achieve this goal even if the ever-haunting financial constraints in conservation and the rising ethical issues could be dealt with. Yet, without finding effective solutions to eliminate the negative impact of the American mink, protection of habitats and regulation of hunting will remain largely mistargeted conservation actions. This makes the negative impact of the American mink a priority issue to be addressed to ensure the European mink's survival.

Once it is agreed that overall removal of the alien American mink from Europe is an unachievable goal in foreseeable future, two options remain:

- To maintain the European mink's genetic diversity and fitness by means of a captive population via an intensive and well-coordinated conservation breeding program (*Ex situ* component).

- To ensure that at least some areas still having extant European mink populations will remain inaccessible for the American mink or, where this is not achievable, to establish new wild populations of the European mink in areas inaccessible to the alien mink (*In situ* component). This could be attained by means of creating island populations for the native mink, with the term "island" being used here in its broader meaning: a sufficiently large area of suitable habitats to maintain self-sustainable populations of the European mink, surrounded by barriers which make the area inaccessible for the American mink (for instance nature restoration areas within industrial landscapes) or landmasses separated from the continent by a body of water.

(2) Both of the above-mentioned components are derived from the paradigm of declining populations but lead also to intensive management of small populations. The need to secure the survival of these small populations raises the question of what must be the size of each of these island populations and captive populations to secure the survival of the species.

Under the small populations' paradigm (Caughley, 1994), three types of stochasticity (demographic, environmental, including random catastrophes, and genetic) are usually described as being likely to be detrimental for small populations.

The aim of *ex situ* conservation breeding is usually defined (Frankham et al., 2004, Soule et al., 1986; Ralls & Ballou, 1986) as maintenance of 90% of the present heterozygocity of the species for 200 (or 100) years. Such a goal will not be sufficient for retaining the evolutionary potential of the species in the long term but it is a practical compromise for effective use of captive space in zoos (Frankham et al., 2004). The need to divide the captive stock between a number of sites has also been emphasized as a means to avoid the impact of accidents (Foose et al., 1986).

There are very few *in situ* management plans for endangered species where genetic aims similar to the ones for conservation breeding have been defined, and even these tend not to be achievable (Frankham et al., 2004).

The "standard aim" for conservation breeding could probably also be used (with certain reservations) in defining the minimum size for mink populations both in islands and in captivity. It has to be admitted though that there are three fundamental differences between island and captive populations: (1) the natural environment is much harsher and less controllable than the artificial environment; (2) in islands, natural selection operates on the population, leading to the survival of the fittest to the natural environment, while in captive populations unintentional artificial selection leads to the survival of the fittest to captive conditions, thus supporting adaptations which most likely are not favorable for survival in the wild; (3) while captive populations and wild populations are likely have a more or less similar fecundity, mortality (due to predation, uncontrolled parasitism, environmental fluctuations, etc.) is obviously far higher in the wild than in captivity.

The size of the populations was evaluated using the computer model Capacity v.3, created by J. Ballou (1992)[5], and demographic and genetic data from the captive stock of the European mink EEP Program (Table 1) maintained in SPARKS (www.isis.org) database[6]. Captive breeding data cover the early periods in the EEP Program, when breeding in captivity was not entirely effective but every effort was made to gain success. In addition, they also cover the recent periods when at least part of the population has been intentionally managed to breed only to a certain extent so as not to exceed the available capacity of breeding facilities. Therefore it is obvious that application of this model to data from captive breeding operations will provide very conservative results. However, as no ideal data are available, this assessment still gives us a target size which is likely to yield success in captivity and provides approximate values for efforts with island populations. As it appears, in order to maintain 90% of the original heterozygocity with 30–50 founders (in general, 25 founders are considered to be an effective size, Ralls & Ballou, 1986) and with N/Ne ratio between 0.3–0.5, we need to maintain a population of 364–693 individuals for a 100-year period and 770–1483 individuals for a 200-year period. However, these figures are valid in the case of ideal management of the captive population. Reality is likely to make its own corrections because of several reasons. For instance, genetically important pairings may not be possible due to behavioral mismatch of mates or the transfer of animals needed for desired pairings may not be possible to perform due to logistic, financial or political reasons. Therefore, the final goal will need to be adjusted in the course of conservation breeding management.

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[5] Ballou, J. D. (1992) *Capacity*. Software to establish target population sizes for populations. Available from the Office of Zoological Research, National Zoological Park, Washington, DC. Accompanying software with the Single Population Analysis and Records Keeping System (SPARKS) available from www.isis.org

[6] One of the main shortcomings of the model used is its deterministic nature. The models which take into account of the stochasticity and enable to include the data from captive breeding program are recently developed and should be employed in the future for further development of the conservation goal. Such a model is the new version of Vortex v 9 (http://www.cbsg.org/ toolkit/vortex.php)

Demographic stochastisity tends to lead a population into extinction if the size of the population is less than 30–40 specimens (Caughley & Sinclair, 1994; Ralls & Ballou, 1986). Therefore, fulfilling the genetic requirements for population size will also satisfy the needs for survival from the demographic perspective.

Regarding *in situ,* the same projections could (in a situation where more adequate data from the wild are not available) be applied for genetic considerations. However, demographic considerations could be largely different, as the values of mortality (increased by predation, parasites, and environmental fluctuations) and fecundity are different from those characterizing the population in captive conditions. As there are no data on mortality and fecundity of wild populations and as genetic requirements, as a rule, tend to require far more individuals to be maintained than demographic considerations do, it seems reasonable to assume that fulfillment of genetic requirements will also satisfy demographic requirements.

Table 1. Actual carrying capacity required to maintain 90.0% of the original heterozygocity for different founders

Capacity v. 3 . by J. Ballou

Actual carrying capacity required to maintain 90.0% of the original heterozygocity for different founder #s under various Ne/N ratios

				No. of effective founders				
Table				**10**	**20**	**30**	**40**	**50**
Parameters			**0.20**	**90**	**70**	**70**	**70**	**70**
		N/Ne	**0.30**	**63**	**47**	**47**	**47**	**47**
Lambda:	1.31	Ratio	**0.40**	**48**	**35**	**35**	**35**	**35**
Generation length:	2.80		**0.50**	**38**	**28**	**28**	**28**	**28**
Time period:	**10 Years**		**0.60**	**32**	**23**	**23**	**23**	**23**

				No. of effective founders				
Table				**10**	**20**	**30**	**40**	**50**
Parameters			**0.20**	**2630**	**560**	**465**	**435**	**420**
		N/Ne	**0.30**	**1753**	**373**	**310**	**290**	**280**
Lambda:	1.31	Ratio	**0.40**	**1315**	**280**	**233**	**218**	**210**
Generation length:	2.80		**0.50**	**1052**	**224**	**186**	**174**	**168**
Time period:	**50 Years**		**0.60**	**877**	**187**	**155**	**145**	**140**

				No. of effective founders				
Table				**10**	**20**	**30**	**40**	**50**
Parameters			**0.20**	**7045**	**1290**	**1040**	**950**	**910**
		N/Ne	**0.30**	**4697**	**860**	**693**	**633**	**607**
Lambda:	1.31	Ratio	**0.40**	**3523**	**645**	**520**	**475**	**455**
Generation length:	2.80		**0.50**	**2818**	**516**	**416**	**380**	**364**
Time Period:	**100 Years**		**0.60**	**2348**	**430**	**347**	**317**	**303**

				No. of effective founders				
Table				**10**	**20**	**30**	**40**	**50**
Parameters			**0.20**		**2800**	**2225**	**2020**	**1925**
		N/Ne	**0.30**		**1867**	**1483**	**1347**	**1283**
Lambda:	1.31	Ratio	**0.40**	**8120**	**1400**	**1113**	**1010**	**963**
Generation length:	2.80		**0.50**	**6496**	**1120**	**890**	**808**	**770**
Time period:	**200 Years**		**0.60**	**5413**	**933**	**742**	**673**	**642**

Environmental stochasticity and unlikely but unpredictable catastrophic events may have a highly detrimental effect on a single island population. One way to avoid or reduce the effect of such a drastic scenario is to increase the number of island populations. Maintenance of ten such populations will reduce the probability of extincttion tenfold. Also, the impact of extinction in one island can be compensated by re-establishing the population there by means of translocations from other islands or re-introductions from breeding facilities.

On the ground of these considerations, I propose for discussion the overall target for European mink conservation in Europe consisting of the following elements[7]:

- **Establishment and maintenance of a pan-European captive population consisting of 200 effectively breeding individuals divided between a number of facilities (3–7).** This would secure the maintenance of 90% heterozygocity for 100 years and would require up to 693 individuals in captivity.
- **10 wild (or restored) populations in sites with a sufficient amount of suitable habitats inaccessible for the American mink and with protection measures applied to prevent the impact of other possible causes of extinction (hunting prohibited and habitats protected),**
    - **the total wild population consisting of, as a minimum, the total of 1500 individuals participating in breeding** (this would secure the maintenance of 90% of the initial heterozygocity for 200 years),
    - **at least 30–40 breeding individuals in each site (**a guarantee that these island populations will not vanish due to demographic stochasticity**),**
    - **10 populations situated as evenly as possible over the historical range of the species (**with 10 island populations the species is not likely to vanish due to environmental stochasticity and unpredictable catastrophic events).

It is noteworthy that the above goal-setting has reached a result very similar to the goals set up for the recovery of the black-footed ferret, *Mustela nigripes* (Black-footed Ferret Recovery Plan, 1978).

Clearly, reaching of this goal is not an easy task and could even be partly impossible due to the fact that reality constraints such as the lack of suitable sites or financial resources have their own role to play. However, I believe that the definition of an overall target for the conservation of the European mink will be of assistance in fine-tuning the goal-setting on the local scale and will thus contribute to the survival of the species on the global level.

[7] This attempt to define the conservation target is made under the assumption that the European mink can be regarded as a single Evolutionary Significant Unit, although studies, though they have not been able to detect remarkable genetic differences, suggest separate management of the eastern population and the French/Spanish population (Davidson et al., 2000b, Michaux et al., 2004). However, the very latest genetic study (Michaux et al., 2005) recommends to consider the eastern, southern and western European mink populations a single Evolutionary Significant Unit. Depending upon what the additional studies and evidences reveal and upon the availability of time and allocated funds, the definition of target should be applied to one ESU or to several ESU-s.

4. CONCLUSIONS

1. The historical range of the European mink is relatively well-studied but data on the evolution of the eastern and western distribution boundary of the species are somewhat controversial and leave room for different interpretations:
   a. Data on the range reaching over the Ural Mountains could indicate either a historical eastward extension of the range or the temporal pattern of discovery of this species east of the Urals at the end of the 19th and beginning of the 20th century. This leaves open the question of whether or not the European mink is to be regarded as a European endemic. Data suggest that at least presently the species is not extant east of the Ural Mountains.
   b. The historical range in the western parts of Germany, in the eastern parts of France, Belgium, the Netherlands and Denmark remain unclear. The available data suggest that the French and Spanish populations are relatively recent, with the French population first recorded in 1839 and Spanish population in 1951. The latter shows signs of expansion to the south since its discovery. Recent genetic data reveal an exceptionally low level of genetic divergence in the French and Spanish population, which supports the hypothesis of relatively recent invasion of the European mink into Western Europe, possibly as a result of anthropogenic introduction, or the establishment of a population from long-distant migrants from a refugium in Holocene. However, the prehistoric finding of the European mink from 2300–2100 BC in the Netherlands is not in line with the idea of recent invasion of the European mink into Western Europe. An alternative possibility, though also with open ends, could be that the European mink was historically widely distributed in Central and Western Europe but declined for unknown reasons and partially recovered its range later from a limited number of founders in more recent history.
2. The decline of the European mink was first recorded in the 19th century in Central European countries. A major decline took place by the end of the 20th century. By the beginning of the 21st century there is a more or less viable population in Danube delta in Romania, in Vologda and in Arkhangelsk Region in Russia. Small declining populations or remains of populations can be found in Spain, in France, in the Ukraine and in various Russian regions (oblasts).
3. A number of attempts have been made to explain the extinction of the European mink on the local scale as well in wider contexts. Analyses show that there is no single universal factor behind the extinction and there has been a set of several factors causing local extinction of the species everywhere. Also, the content of this set of factors has varied in time and space. Different factors acting in concert and/or in sequence often have a synergistic effect and thus strengthen each other’s impact. In several locations the reason of actual decline remains seemingly unclear. This might be attributable to the joint effect of several agents. None of the agents alone is likely to bring along the extinction of the species but in concert they are detrimental and also make it difficult to identify their individual role in the extinction process.
4. The most detrimental factors causing the extinction of the species both historically and at present are habitat loss, hunting pressure and the impact of the alien American mink. These main factors are usually combined which several other factors of secondary importance.
5. Full recovery of the European mink in continental Europe is not achievable due to the invasion of the American mink. Therefore, the goal proposed for conservation of the species foresees (1) maintenance of a viable captive population in the frame of a conservation breeding program and (2) establishment or maintenance of 10 isolated populations inaccessible for American mink all across the species’ historic range, which would form a viable meta-population capable of persisting in the long term.

EUROOPA NAARITS, *MUSTELA LUTREOLA*, (LINNAEUS 1761) LOODUSKAITSEBIOLOOGIA: LIIGI VÄLJASUREMINE JA SELLE PÕHJUSED.

Kokkuvõte

1. Euroopa naaritsa ajallooline levila on suhteliselt hästi uuritud. Siiski on olemasolevad andmed liigi levila ida- ja läänepoolsete piiride kohta mõneti vastuolulised ja jätavad võimalusi erinevateks tõlgendusteks:
   a. Andmed idapoolse levila ulatumise kohta üle Uurali mägede võivad peegeldada liigi levimist Euroopast Aasiasse või siis liigi avastamise käiku levila idaservas 19. sajandi lõpus ja 20. sajandi alguses. Lahtiseks jääb küsimus, kas euroopa naaritsa näol on tegemist Euroopa endeemse liigiga või mitte. Praeguseks on naarits Uuralitest ida pool hävinud.
   b. Ajaloolise leviku kohta Lääne-Saksamaal, Belgias, Hollandis ja Taanis pole küllaldaselt andmeid. Ajaloolised andmed Prantsuse ja Hispaania asurkondade kohta viitavad nende asurkondade suhtelisele noorusele. Prantsuse asurkond avastati alles 1839. aastal ja Hispaania asurkond 1951. aastal. Hispaania asurkond tundub laienevat lõuna poole. Hiljutiste geeniuuringute andmetel on Prantsuse ja Hispaania asurkondade geneetiline mitmekesisus erakordselt madal, mis paistab viitavat mõlema asurkonna hiljutisele tekkele. Nende asurkondade rajajad võisid olla kas inimese poolt sisse toodud või siis Holotseenis refuugiumidest sisse rännanud üksikisendid. Seda hüpoteesi aga ei toeta naaritsa eelajalooline leid 2300–2100 aastat eKr. Hollandis. Seetõttu on võimalik ka alternatiivne, kuid samas mitte puudusteta seletus naaritsa praeguse asurkonna tekkele Hispaanias ja Prantsusmaal: eelajalooliselt oli liik neil aladel laialdaselt levinud, kuid hääbus teadmata põhjustel suuremas osas Lääne-Euroopast ning asurkond taastus osaliselt 19. sajandi lõpus ja 20. sajandi alguses.
2. Euroopa naaritsa hävimist täheldati esmakordselt 19. sajandil Kesk-Euroopa maades. Suurem osa liigi levila kahanemisest toimus 20. sajandi jooksul, eriti selle lõpus. 21. sajandi alguseks püsivad enamvähem elujõulised asurkonnad veel vaid Doonau deltas Rumeenias, Vologda ning Arhangelski oblastites Venemaal. Väikesi tugevasti kahanevaid asurkondi või jäänukasurkondi leidub veel Hispaania kirdeprovintsides, Edela-Prantsusmaal, Ukrainas ning mitmetes Venemaa oblastites.
3. Naaritsa väljasuremist on uuritud ja analüüsitud nii lokaalses ulatuses kui ka globaalses kontekstis. Analüüsi tulemusel võib väita, et ühtainsat, kogu endise areaali piires universaalselt kehtivat väljasuremise põhjust ei ole. Kõikjal on olnud tegemist põhjuste kompleksiga, mille koostis on olnud regiooniti ja ajaliselt erinev. Sagedasti on eri põhjuste koosmõju ja/või üksteisele järgnemine kaasa toonud sünergilise efekti, mille tõttu koosmõju on tugevam kui üksikfaktorite summaarne mõju. Paljudes kohtades on osutunud väga keeruliseks selgitada liigi lokaalse väljasuremise konkreetseid põhjuseid. Seda võib samuti seostada mitmete tegurite koosmõjuga. Üksiktegurid eraldivõetuna ei tooks kaasa liigi hävimist, kuid paljude tegurite koosmõju viib liigi hävimisele. Koosmõju tõttu on sagedasti iga üksiku teguri mõju osatähtsust raske mõõta.
4. Kõige olulisemad liigi väljasuremisele viinud tegurid on olnud elupaikade kadumine, ülekütimine ja invasiivse võõrliigi ameerika naaritsa mõju. Enamasti toimivad need põhitegurid koosmõjus ning neid võimendavad mitmed teised mõjurid.
5. Euroopa naaritsa täielik taastamine kogu Euroopa ulatuses pole võimalik, kuna ameerika naarits on kas levinud või levimas enamvähem kõikjal Euroopas. Seetõttu pakutakse välja naaritsa liigikaitselise tegevuse eesmärk, mis näeb ette liigi säilitamist (1) tehisasurkonnana *ex situ* paljundusprogrammi kujul ja (2) minimaalse elujõulise loodusliku meta-asurkonnana, mis koosneb vähemalt kümnest isoleeritud, saarelisest, ameerika naaritsale kättesaamatust ning võimalikult ühtlaselt üle liigi terve ajaloolise levila paigutuvast asurkonnast.

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ANNEX 1

REVIEW OF DATA ON HISTORICAL DECLINE AND CURRENT STATUS OF THE EUROPEAN MINK.

The figures I, II, III, IV, etc. in columns entitled “Status”, “Proposed cause of decline”, “Comments” refer to the source of the information provided in column “Reference” under the same figures.

Country/ Region[8]	Status	Proposed cause of decline	Comments	Reference
Spain	I: Only in Basque country, Navarra, Rioja, north of Burgos, north of Soria; 900–1100 individuals estimated in 2001 II: 30% of decline in 1999–2000 IV: three enclaves distinguished: (a) north-west covering 8 UTM Squares in Basque country with American mink presence; (b) north-east enclave covering 15 UTM squares in the north-east of Basque country, heavily polluted rivers; (c) 62 UTM squares in southern Basque country and Navarra, La Rioja, north-west of Castilla-Leon. First records of American mink	II: not clear, possibly habitat destruction, III: American mink	IV: American mink present in two enclaves	I: Santiago, et al., 2002 II: Cena, 2003 III: Cena et al., 2003 IV: Palazon et al., 2003
France	I: 2002: Southwest of France on 978 km of watercourses, quick decline. III: in 17 departments of south-western France; quick decline. IV: Half of the range has disappeared in 20 years. At the turn of the 20th century mink was present in 38 departments; in the early 2000s only in 7 departments of the southern part of previous range. At present it can be found from Charente and Charente-Maritime to Spanish border. The densities are everywhere very low.	II: combination of water pollution, intensive trapping. Impact of the American mink not detected. III: ongoing population fragmentation, side effect of extensive rodent control with anticoagulants, American mink in future		I: Lodé, 2002 II: Lodé, 2001 III: Fournier & Maizeret, 2003 IV: Maizaret et al., 2002.
Switzerland	Extinct, historical presence not fully confirmed			Youngman, 1982 Novikov, 1939.
Belgium	No records			Youngman, 1982 Novikov, 1939.
The Netherlands	Extinct, only prehistoric records			Van Bree, 1961a,b. Youngman, 1982
Germany	Extinct, last records from early 20th century in the north and east of Germany	Habitat loss, land drainage (Claudius, 1866)		References in Novikov, 1939
Austria	Likely historical presence, extinct			References in Novikov, 1939 Youngman, 1982
Poland	Extinct, last records before World War II.			Ruprecht, 1983
Hungary	Extinct, last record 1952 at Lake Balaton	Former swamp habitats drained and transformed into farmlands		Szunyoghy, 1974
Check Republic	Extinct			Youngman, 1982
Slovakia	Extinct, last records from Oravska Kotlina basin, Slovenske Beskydy Mountains, Velka Fatra Mountains and the Vysoke Tatry Mountains in 1860–1886	Overhunting, interspecific relations with other carnivores (American mink, otter, polecat, stoat) parasite nose-fluke (?!)		Mošansky, 1998.
Romania	I, II, III: Viable population in Danube Delta. IV: 28 European mink trapped from 9 regions during 961 trapping nights. European mink probably widespread in the delta area.	I; II; III, IV: By-catch from muskrat trapping, feral dogs and cats, American mink population in the Ukrainian part of delta	I, II, III: American mink present in the Ukrainian part of Danube delta IV: Two skull records from Romanian part of the delta in Romanian museum collections.	I: A. Kranz & A.Toman, pers.com, 2003 II: Kranz et al., 2003 III: Gotea & Kranz, 1999 IV: Kranz et al., 2004.

[8] See Figure 1.

Country/ Region[8]	Status	Proposed cause of decline	Comments	Reference
Bulgaria	I, II: No records		III: Claims about presence in Bulgaria but do not provide any evidence	I: Novikov, 1939 II:Youngman, 1982 III: Heptner et al. (1967)
Serbia	Extinct, last specimen in the first half of 20th century (1941?) in northern Serbia			Krustufek et al., 1994.
Croatia	No records			
Slovenia	No records			
Latvia	Extinct, last specimen in 1993	Destruction of habitats and expansion of the American mink		Ozolinž & Pilats, 1995
The Ukraine	I: Only in the Carpathian region of the Ukraine in 2002. Elsewhere extinct[9]. In decline III: In early 1960s the number of European mink was estimated to reach 4000–5000 individuals; in 1968–1988 the number of European mink was estimated to be no higher than 200–250 individuals IV: The species is still present in the Carpatian region: Rakhivsky, Miszhgirsky and Tianchivsky district in Zakarpatska Region. General quantity is estimated to be about 60–80 species. V: In the 1970s the population amounted to 3000–4000 specimens, at the beginning of the 21st century 350–400 individuals. The most viable population in Danube Delta. (>200 individuals)	I: Impact of the American mink (competition and negative impact on reproductive efficiency of the European mink) II: The causes of extinction vary between regions. The most common causes are: (a) transformation of riparian biotopes; (2) intensive use of riparian areas for recreation and agricultural activities; (3) trapping of muskat (*Ondatra zibethicus*) with leghold traps; (4) death of mink in fish nets; (5) killing of mink by stray dogs and wolves; (6) acclimatization of American mink in the Ukraine); (7) reclamation of lands; (8) rafting of logs	I: The source does not provide any exact data but only claims the presence; The American mink present. II: The American mink population was formed by invaders from Belarus and escapees from fur farms V: No intentional release in the Ukraine.	I: Kiselyuk, 2002 II: Pavlov & Korsakova, 1973 III: Panov, 2002 IV: Bashta & Potish, in prep. V: Volokh, 2004
Belarus	I: Two small declining populations in the north-east and south of the country in 2004. Extinct elsewhere.	I: Intra-guild aggression by the American mink.	I: American mink present II: 895 American mink released in 1953–1958.	I: Sidorovich, pers. comm., 2004 II: Pavlov & Korsakova, 1973
Moldova	Present status unknown. Decline since the 1930s. In the 1980s the last populations had survived in the lower course of River Prut along the Romanian border.			Muntjanu (cited in Maran, 1994)
Lithuania	I: Extinct, last specimen in 1978–79		II: 113 American mink released in 1950–1953	I: Bluzma, 1990 II: Pavlov & Korsakova, 1973
Estonia	I: Extinct, last specimen in 1996	II: Destruction of habitats, American mink	II: American mink present in the continental part of the country. No intentional release performed. The wild population originates from escapees of mink farms and from animals invaded from neighboring areas.	I: Article IX II: Article VI
Denmark	No records			Youngman, 1982.

[9] Tumanov (1999) claims that only few individuals may be surviving in the south-western part of the Ukraine.

Country/ Region[8]		Status	Proposed cause of decline	Comments	Reference
Russia					
Adygeyskaya AO	77[10]	No data, probably extinct			Skumatov, 2005
Arkhangelskaya +Nenetskiy AO	1	I: The north-west of the region inhabited only by the European mink; in decline II: present in 2004		II: American mink present in the region (in rivers Severnaya Dvina and Pinegeya) II: 44 American mink released in 1957	I: Savelyev & Skumatov, 2001 II: Pavlov & Korsakova, 1973 III: Skumatov, 2005.
Astrahanskaya Oblast	71	I: Extinct by 1999 II: No data, possibly extinct by 2004:			I: Tumanov, 1999 II: Skumatov, 2005
Bashkirskaya ASSR	57	I: 1999: Extinct III: no data, possibly became extinct in the 1990s		II: 1245 American mink released until 1970.	I: Tumanov, 1999 II: Pavlov & Korsakova, 1973 III: Skumatov, 2005
Belgorodskaya Oblast	3	I: Single specimens in late 1970s, decline III: no data, possibly extinct by 2004			I: Tumanov & Zveryev, 1986 II: Skumatov, 2005
Bryanskaya Oblast	5	I: Common but rare II: Present in 2002			I: Tumanov, 1999 II: Skumatov, 2005
Checheno-Ingushskaya ASSR	10	No data			
Chelyabinskaya Oblast	62	I,II: Highly rare, last records from 2000, decline		I, II: Everywhere European mink and American mink po-pulations mixed, with the originnal species becoming rarer. III: in 1959/60 the ratio of mink species in overall hunting bag was 1:1; in 1970 75% were American minks.	I: Kiseleva & Potapkin, 2002 II: Kiseleva, 2003 III: Pavlov & Korsakova, 1973
Chuvashskaya ASSR	6	Extinct			Tumanov, 1999

[10] The numbers refer to the location of the region as indicated in the map in Figure 1.

Country/ Region[8]		Status	Proposed cause of decline	Comments	Reference
Dagestanskaya ASSR	7	No data, probably extinct			Skumatov, 2005
Ekaterinburgskaya Oblast/Sverdlovs-kaya oblast	43	I: Extinct, last records in the 1980s II: No data, probably extinct, last record from 2000	I: Main cause – American mink	I: American mink introduced in 1934–1970 (653 ind), replaced the original species	I: Savelyev & Skumatov, 2001 II: Skumatov, 2005
Gorkovskaya Oblast/Nizhnegorodskaya Oblast	9	II: Present, last record from 2003		I: 119 American mink released in 1957 –58	I: Pavlov & Korsakova, 1973, II: Skumatov, 2005
Hanty-Man-siiskiy AO	79	No data, probably extinct			Skumatov, 2005
Ivanovskaya Oblast	11	I: Common but rare in the 1980s II: Present, last records in 2004			I: Tumanov & Zveryev, 1986 II: Skumatov, 2005
Kabardino-Bal-karskaya ASSR	28	No data, probably present			Skumatov, 2005
Kaliningradskaya Oblast	68	I: Extinct II: No data, probably extinct			I: Tumanov, 1999 II: Skumatov, 2005
Kalmytskaya ASSR	8	I: Present status unknown, in decline II: No data, probably extinct			I: Ginnev, 2002 II: Skumatov, 2005
Kaluzhskaya Oblast	12	Present, last data from 2002			Skumatov, 2005
Karachaevo-Cher-kesskaya AO	72	No data			

Country/ Region[8]		Status	Proposed cause of decline	Comments	Reference
Karelskaya ASSR	14	I: Small population in late 1970s in the south-east of the oblast. Extinct elsewhere II. 1999 – extinct IV: No data, probably extinct		III: 328 American mink released until 1970	I: Tumanov & Zveryev, 1986 II: Tumanov, 1999 III: Pavlov & Korsakova, 1973 IV: Skumatov, 2005
Kirovskaya Oblast	16	I: 2001: Present in the west and north-west of the Oblast (in Rivers Pizhma, Cheptsa, Mlomo, Luza, Kobra inhabits small tributaries); decline II: present in 2002	I: Main cause – American mink	I: First American mink in early 1970s, invasion spread 20 km per year	I: Savelyev & Skumatov, 2001 II: Skumatov, 2005
Komi ASSR	17	I: 2001: European mink present, status unknown II: present in 2004.		I: American mink present in the region, probably widening its range and increasing in number	I: Savelyev & Skumatov, 2001 II: Skumatov, 2005
Komi-Permyatskiy AOK	76	No data			
Kostromskaya Oblast	18	I: In the western and central parts in small tributaries of Kostroma and Unzha Rivers common; in the south rare, in decline II: present, last records from 2004		I: Ratio 1:1 of the mink species in the western and central parts of the region	I: Savelyev & Skumatov, 2001 II: Skumatov, 2005
Krasnodarskiy Kray + Adygeyskaya AO	19	I: Remarkable decline, highly rare; isolated populations in the northern part of the region , found in 20 regions out 39 Decline between 1958/1959 and 1975/77 more than 30 times III: Present, last record from 2004	I: Transformation of landscapes, American mink, extensive hunting (also as bycatch)	I: American mink present II: in 1932 –36 626 American mink released, before 1970 1159 mink released	I: Ginnev, 2002 II: Pavlov & Korsakova, 1973 III: Skumatov, 2005
Kuibyshevskaya Oblast (Samarskaya Oblast)	22	I: 1999: single remaining individuals III: Probably extinct		II: American mink invaded from Tatarskaya Oblast in 1950s	I: Tumanov, 1999 II: Pavlov & Korsakova, 1973 III: Skumatov, 2005
Kurganskaya Oblast	20	Species extinct			Skumatov, 2005
Kurskaya Oblast	21	I: Single specimen in late 1970s, III: No data, probably present		II: American mink present	I: Tumanov & Zveryev, 1986 II: Tumanov, 1999 III: Skumatov, 2005
Lipetskaya Oblast	23	I: Single specimen in late 1970s, III: No data, probably present.		II: American mink present	I: Tumanov & Zveryev, 1986 II: Tumanov, 1999 III: Skumatov, 2005
Mariyskaya ASSR (El-Mari)	24	I: 2001: Small population surviving in the western part, in decline III: possibly present but recent data missing. Last data from 1998.	I: Main cause – American mink	I: Everywhere the American mink prevails II: 192 American mink released in 1948–1949	I: Savelyev & Skumatov, 2001 II: Pavlov & Korsakova, 1973, III: Skumatov, 2005

Country/ Region[8]		Status	Proposed cause of decline	Comments	Reference
Mordovskaya ASSR	25	No data, possibly extinct			Skumatov, 2005
Moskovskaya Oblast	26	I: Single individuals in late 1970s III: Present, last record from 2000		II: American mink present	I: Tumanov & Zveryev, 1986 II: Tumanov, 1999 III: Skumatov, 2005
Novgorodskaya Oblast (Nizhni-Novgorod)	30	I: Data only from Vettluga and Pizhma River basins (2001), in decline II: present, last data from 2000.	I: Main cause – American mink	I: Ratio 1:99 in favor of American mink	I: Savelyev & Skumatov, 2001 II: Skumatov, 2005
Omskaya Oblast	32	I: Extinct, supposed? last record in 1995	I: American mink	I: American mink present II: 771 American mink released in 1948 –1964	I: Sidorov, 1999 II: Pavlov & Korsakova, 1973
Orenburgskaya Oblast	34	I: 1999: few remaining individuals II: possibly present but no recent data; last record from 1992.			I: Tumanov, 1999 II: Skumatov, 2005
Orlovskaya Oblast	33	I: Single specimen in late 1970s III: Probably present, no data		II: American mink present	I: Tumanov & Zveryev, 1986 II: Tumanov, 1999 III: Skumatov, 2005
Penzenskaya Oblast	35	I: There were mink pelts in hunting bag in 1970. II: probably present, no recent data, last record from 1992.		I: 42 American mink released in 1964 (failure).	I: Pavlov & Korsakova, 1973 II: Skumatov, 2005
Permskaya + Komi-Permyatskiy AO	36	I: Only in the right bank of tributaries of Kama River of Komi-Perm AO in 2001. III: present in 2004.	II: American mink	II: American mink invaded in the 1960s and 1970s. In the 1990s re-placed the original species in left hand tributaries of Kama	I: Savelyev & Skumatov, 2001 II: Kiseleva & Potapkin, 2002 III: Skumatov, 2005
Pskovskaya Oblast	38	I: Populations in basins of rivers Velikaya, Shelon, Lovat, Polist, Msta II: 2003: only few individuals had remained in the study area III: Present, last records from 2003		II. American mink present	I: Tumanov, 1999 II: Sidorovich, 2003 pers. comm. III: Skumatov, 2005
Rostovskaya Oblast	39	Remarkable decline, highly rare; isolated populations in the northern part of the region, found in 20 regions out of 39 Decline between 1958/1959 and 1975/77 more than 30 times	Transformation of landscapes, American mink, extensive hunting (also as bycatch)	American mink present	Ginnev, 2002
Ryazanskaya Oblast	40	No data, probably present			Skumatov, 2005

Country/ Region[8]		Status	Proposed cause of decline	Comments	Reference
S.-Peterburgskaya Oblast (Leningrad Oblast)	37	I: Status unclear: possibly fragmented populations remaining, if at all. Quick decline III: no data, probably present, last records from 2002		II: American mink present and numerous	I: Tumanov, 1999 II: Pavlov & Korsakova, 1973 III: Skumatov, 2005
Saratovskaya Oblast	54	I: 1999: single remaining individuals II: present in 2003.			I: Tumanov, 1999 II: Skumatov, 2005
Severo-Osetins-kaya ASSR	50	I: No data, probably extinct		I: 56 American mink released in 1951–53	I: Pavlov & Korsakova, 1973 II: Skumatov, 2005
Smolenskaya Oblast	41	I: Common but rare in 1999 II: Present, last data from 2002			I: Tumanov, 1999 II: Skumatov, 2005
Stavropolskiy Kray + Kar.-Cherk.AO	42	I: Present status unknown, in the 1960s numerous in steppe rivers II: Possibly small populations left in some river basins, in decline III: Present, last record from 2003		II: American mink present everywhere	I: Ginnev, 2002 II: Tumanov, 1999 III: Skumatov, 2005
Tambovskaya Oblast	44	I: Single specimen in late 1970s II: No data, probably extinct			I: Tumanov & Zveryev, 1986 II: Skumatov, 2005
Tatarskaya Oblast	56	I: Extinct III: No recent data, probably extinct		II: 573 American mink released before 1970	I: Tumanov, 1999 II: Pavlov & Korsakova, 1973 III: Skumatov, 2005
Tschuvashkii AO		Present, last record in 2004			Skumatov, 2005
Tulskaya Oblast	46	I: Single specimen in late 1970s III: Probably present, last record from 2000		II: American mink present	I: Tumanov & Zveryev, 1986 II: Tumaonv, 1999 III: Skumatov, 2005
Tverskaya Oblast (Tver)	48	I: Single specimens can still be found III: Present, last record from 2003	I: American mink	I: The original species has been replaced in the 1990s almost everywhere. II: 60 American mink released in 1948	I: Katchanovsky, 2002 II: Pavlov & Korsakova, 1973 III: Skumatov, 2005
Tseljabinskaya Oblast		No data, probably present, last record from 1997			Skumatov, 2005

Country/ Region[8]		Status	Proposed cause of decline	Comments	Reference
Udmurtskaya Oblast (Udmurtya)	61	I: In 1997–1998 survived in small tributaries of Vyatka and Izh Rivers, and southeast of the Kama River III: Last data from 2002, probably extinct for 2004.	II: American mink	II: The ratio of European mink and American mink in the remaining sites 1:10	I: Savelyev & Skumatov, 2001, II: Kapitonov & Ukraintseva, 2002. III: Skumatov, 2005
Ulyanovskaya Oblast	49	I: 1999 – single remaining specimens can be found III: No reliable data but possibly still present.		II: American mink has occupied most of the habitats since the 1940s	I: Tumanov, 1999 II: Pavlov & Korsakova, 1973 III: Skumatov, 2005
Vladimirskaya Oblast	4	I: Common but rare in late 1970s III: No data, possibly present		II: American mink has not been released	I: Tumanov & Zveryev, 1986 II: Pavlov & Korsakova, 1973 III: Skumatov, 2005
Volgogradskaya Oblast	60	I: Extinct III: last record from 2001, present		II: 100 American mink released in 1959	I: Tumanov, 1999 II: Pavlov & Korsakova, 1973 III: Skumatov, 2005
Vologodskaya Oblast (Vologda)	51	I: In the south of the region pure European mink populations exist, in the northwest the species is mixed with the American mink with the ratio 7:3 in favor of the original species II: present in 2004		I: Viable populations exist in parts of the region. American mink present	I: Savelyev & Skumatov, 2001 II: Skumatov, 2005
Voronezhskaya Oblast	52	I: Single populations in late 1970s III: Probably still present, no recent data		II: 19 American mink released in before 1944 (unsuccessful).	I: Tumanov & Zveryev, 1986 II: Pavlov & Korsakova, 1973 III: Skumatov, 2005
Yaroslavskaya Oblast	53	I: Common but rare II: 1960–1964 the number pf pelts in hunting bag decreased threefold. III: last record from 2004, present	II: Overhunting	II: American mink has not been released.	I: Tumanov, 1999 II: Shashkov, 1977 III: Skumatov, 2005