Feral American mink Neogale vison continues to expand its European range: time to harmonise population monitoring and coordinate control

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Feral American mink (*Neogale vison*) continues to expand its European range: time to harmonize population monitoring and coordinate control

Summary

The American mink (*Neogale vison*) is considered an invasive alien species in Europe that threatens endemic biodiversity and may transmit zoonotic diseases. The last mapping of this species in the whole of Europe dates back to 2007. This study aimed to update the distribution of the American mink, by creating harmonized distribution maps with available data and identifying temporal trends. We gathered data out of a total of 34 databases from 32 countries. Data came from a range of sources, including open data repositories, institutional databases, and hunting bag data. The data were standardized and mapped onto a 10x10 km grid and trends were identified using changes in range size, hunting bag and capture statistics. We also reviewed the current situation of mink farming in the different European countries and identified population control schemes. The American mink is now widespread in The Baltic states, France, Germany, Iceland, Ireland, Poland, Scandinavia, Spain, and the United Kingdom. The species is reported absent from some areas of the United Kingdom, Iceland, and Norway. Data is deficient from several other countries, mainly in south-eastern Europe. These findings imply that during the last decade, the species has continued to spread across the continent, up to more than 13% in some countries. Our effort to collect and harmonize data across international borders highlights information gaps and heterogeneity in data quality. Monitoring efforts and data collection should be intensified in south-eastern Europe to improve data on the current distribution of this invasive species. Risk assessment and risk management policies would benefit from topical data on the species. This requires coordinated population monitoring of this species of conservation and zoonotic health concern. For effective control at continental level, objectives for American mink management should be approached across international borders.

KEY WORDS: Mustela vison, distribution, invasive species, Europe, risk assessment, species control

Introduction

According to the Inventory of alien invasive species in Europe (Genovesi et al. 2009), there are 64 Invasive Non Native mammal Species (INNS) in Europe, which have a marked ecological and economic impact (Keller et al. 2011). One of these invasives is the American mink (*Neogale vison*, formerly *Neovison vison* and *Mustela vison*), a mustelid carnivore introduced to Europe from North America during the 1920s for fur farming (Long 2003). Shortly after its introduction, American mink escaped from fur farms, either due to poor housing facilities or through deliberate releases by activists, and established in the wild (Palazón & Ruiz-Olmo 1997, Macdonald & Harrington 2003).

There is substantial resource competition between the American mink and native riparian predators, such as the Eurasian otter (*Lutra lutra*), the polecat (*Mustela putorius*), and the European mink (*Mustela lutreola*), a species that is now considered Critically Endangered by the IUCN (Maran et a. 2016). Although the species have different ecological characteristics, competition for food has led to a decrease in native populations of other mustelids when territories were colonized by the American mink (Macdonald & Harrington 2003, Barrientos 2015). The main reason for this has been identified with competition and intra-guild aggression (Tumanov 1996, Sidorovich 2001, Põdra et al. 2013, Mathews et al. 2018).

American mink also affects aquatic and semi-aquatic vertebrates, through predation on native prey. As stated in the ecological naivety hypothesis, the largest impacts occur in systems where no phylogenetically or functionally similar species exist (Enders et al. 2020). Water and sea birds are among the most seriously impacted, as evidenced by research conducted in Finland (REF?), but also mammals such as the water vole (*Arvicola amphibius*) (Macdonald & Harrington 2003, Barros et al. 2016, Brzeziński et al. 2020), and rare endemic mammals with restricted ranges, such as the Pyrenean desman (*Galemys pyrenaicus*) (Biffi et al. 2016).

Moreover, American mink often invades high-quality sites, such as wetlands that are important breeding grounds for water birds (Brzeziński et al. 2020). The species is currently regarded as an invasive alien species (IAS). Considering its potential impacts on biodiversity (Bouroș et al. 2016), the species was proposed for inclusion on the list of IAS of Union Concern, the IAS Regulation (EU1143/2014) (Bonesi & Palazón 2007, Reynolds 2009, Zuberogoitia et al. 2018), but was ultimately not added (Zuberogoitia et al. 2018, European Commission 2019, Harrington et al. 2021).

American mink is known to play a role in the transmission of several pathogens in Eurasia, such as the Aleutian Mink Disease virus (Jensen et al. 2012, Knuuttila 2015, Leimann et al. 2015, Mañas et al. 2016), distemper, Aujeszky and rabies virus (Yamaguchi & Macdonald, 2001), and parasites including the zoonotic *Trichinella* (Hurníková et al. 2016, Martínez-Rondán et al. 2017, Nugaraitė et al. 2019). Free ranging populations can transmit pathogens to susceptible hosts, especially other mustelids. Recently, captive minks were found capable of hosting and transmitting SARS-Cov-2 virus back to humans, resulting in changes in the viral spike protein that affect the immune response in humans (European Centre for Disease Prevention and Control 2020; Koopmans 2020, Larsen & Paludan 2020, Rambaut et al. 2020, but see van Dorp et al. 2020, Devaux et al. 2021). The novel SARS-CoV-2 virus was transmitted from humans to the American mink in Dutch and Danish mink farms (Koopmans 2020, Munnink et al. 2020, Oreshkova et al. 2020, van Dorp et al. 2020). After that, many other outbreaks appeared in the United Kingdom, Spain, USA, and Sweden, amongst others (European Centre for Disease Prevention and Control 2020, Rambaut et al. 2020). A recent note confirmed the presence of SARS-CoV-2 in a feral American mink in Utah (https://promedmail.org/promed-post/?id=20201213.8015608). Susceptibility of the American mink to the virus could facilitate the transmission of SARS-CoV-2 in feral populations, creating potentially dangerous wildlife reservoirs (Harrington et al. 2021).

Many European countries have control policies and eradication campaigns focused on the American mink. Due to continued escapes and re-invasions, however, complete eradication is difficult to achieve (Fraser et al. 2017). Only local eradication campaigns, mostly on islands, have been successful (Robertson et al. 2017, DIISE 2018, Global Invasive Species Database 2021). Updating the current distribution of feral American mink populations at a European level with the highest possible resolution is a necessary precursor to managing this invasive species and resolving the potential conflicts in which the species is implicated (e.g. Macdonald & Harrington 2003). Additionally, the risk assessment of the introduction, entry into the wild, establishment, spread and impact on other species, including on humans as a disease host, requires high-resolution spatial data (raw or model projections), and, if possible, abundance estimations (baseline data; EFSA and ECDC et al. 2021).

The last assessment of the status of the species in Europe was carried out by Bonesi & Palazón (2007). They reported a wide species distribution at continental scale and highlighted a limited knowledge about its distribution and status. In this context, and bearing in mind the invasiveness of the species, the aims of this study were: (i) to assess the current distribution of the American mink in Europe at the highest possible spatial resolution; (ii) to assess the tren4rds in distribution since the last published account (Bonesi & Palazón 2007) and explore its correlations with the presence of mink farms and/or feral American mink control policies in each country; and, (iii) to make recommendations to close information gaps and homogenize current and future monitoring schemes.

Methods

Data collection

The area considered is the whole European continent, including the mainland and larger islands. Data collection included three sources: (i) a download of observations from the Global Biodiversity Information Facility, (ii) a literature search about American mink presence and distribution in Europe, and (iii) data collected through a survey within the ENETWILD consortium network (www.enetwild.com), national wildlife institutes and respective ministries.

The GBIF observations were downloaded using *Neovison vison* and *Mustela vison* as species filter with the rgbif package (Chamberlain & Boettiger, 2017) from 2000 to 2021 (Appendix S2 for citations).

The literature search was performed using the main scientific online libraries, namely Pubmed, Web of Science, and Scopus, during April and May 2021. Keywords algorithm was: “Neovison vison” OR “Mustela vison” AND “Europe” AND “presence”, filtering the period since 2000. The new nomenclature (*Neogale vison*) was introduced in July 2021, later than this search was performed. A further search was performed adding one by one the European countries in the search algorithm. For each article, the geographic scale, the period considered, the type of presence data (only presence, density, count), and the method of gathering the information (trapping, roadkill, survey, camera trapping, literature search) was noted. Literature outputs were recorded into two groups. The first one included publications that confirmed presence of the American mink, but did not provide a geographical reference with sufficient resolution to be useful to our mapping purposes. The second one included, in addition, publications that provided coordinate points of captures/findings, or confirmed absence in concrete areas of small resolution. Such data were included in our databases for map creation.

The data collection was carried out sending a formal data *request* letter to each data provider, in which they were asked for data on presence (meaning hunting bags, captures, direct or indirect observations), absence and/or data on density or abundance. A template with standardized reporting fields compatible with Darwin Core standards (available on ENETWILD website, https://enetwild.com/2018/07/30/release-model-collect-data-on-wild-boar-distribution-and-abundance-europe/) was provided in the request. Data were requested at the best possible spatiotemporal resolution and starting from 2000. Only data with coordinate uncertainty less or equal to 10,000 meters, which presented at least the recording year and coordinates were considered for mapping. Furthermore, for countries that provided hunting bag or capture data, we asked: (i) if population management had been implemented in the last decade; (ii) the management methods used (trapping or hunting); (iii) if the control effort had been increasing, decreasing, stable, or variable (with peaks); and (iv) in case of a variable trend, a free text answer was available to indicate when and which were the peaks (e.g. LIFE programs). In addition, information was gathered on: (i) the presence and number of mink farms and, if applicable, (ii) ban year and law, (iii) management actions and plans.

All representable data coming from data providers, GBIF download and literature were standardized according to the wildlife monitoring core standard, a version of the Darwin Core standard (Valentin S, Jaroszynska F, Body G : https://github.com/fja062/WLDM.standardisation; ENETWILD consortium et al. 2020; https://enetwild.com/2018/07/30/release-model-collect-data-on-wild-boar-distribution-and-abundance-europe/).

Creation of maps

The compiled data corresponded to regional areas (polygon layer) and coordinates (point layer). A buffer of the size of coordinate uncertainty of the data (point layer) was used, when available, to have a more realistic delimitation of the presence or absence of the species. Layers were transformed into the coordinate reference standard for Europe, ETRS-LAEA (EPGS: 3035). Data standardization, data compilation and data management used WLDM (Body et al. 2020), tidyverse 1.3.0 (Wickham et al. 2019) and sf 0.9-7 (Pebesma & Bivand 2018) packages with R 4.0.4 (R Core Team 2021). Numeric information was grouped and translated into presence/absence/information unavailable in each cell in the European 10x10km grid (https://www.eea.europa.eu/data-and-maps/data/eea-reference-grids-2) using ArcGIS v10.7 (ESRI, 2019). Absence data were accepted only when the recording method actually allowed them to be distinguished from no data.

From the standardized gridded data, we created four maps (i-iv). presence and absence of the American mink, as areas where the species was reported present or absent, was represented for decade (i) 2001-2010 and (ii) 2011-2020. Time aggregation was made to standardize temporal resolution among databases. Where information was missing, graphic reference to the status reported in Bonesi and Palazón (2007) was added to the map of the first decade. Changes in presence of the species were mapped (iii) for countries that provided data at the same spatial resolution for both decades: we included Belarus, Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Latvia, Portugal, Slovakia, Spain, The Netherlands, United Kingdom and Ukraine. Finally, the percentage occupancy was calculated, to create a map (iv) comparable to that of Bonesi and Palazón (2007).

Data analysis

We standardized the area of occupancy using the surface area of the country calculated from the NUT0 layer of the EEA (https://www.eea.europa.eu/data-and-maps/data/eea-reference-grids-2). To compare the data we collected to the distribution obtained by Bonesi and Palazón (2007), a minimum convex hull (MCH) with 95% percentile of all 10x10 grid reported presence data was developed per country (excluding marine areas from the MCH) to determine the extent of the American mink distribution in each country. This calculation was performed with the adehabitat R package (Calenge 2006). Only data with good spatial resolution were considered; therefore, data expressed by administrative polygon unit as NUT0, NUT1, NUT2 were excluded, as well as hunting management unit of Finland. Countries were then classified using the same categories as in Bonesi and Palazón (2007): not reported, not reproductive (either not established or sporadic), occupancy <10% (localized in a few areas), 10-50% (widely distributed, but less than 50%), >50% and data not available. In addition, we identified countries where the data did not allow the percentage of the occupancy to be calculated.

For countries that provided hunting bags or records of captures from consistent trapping programs, a hunting bag/capture index (called Variability Index, VI) was calculated as the mean of the variation from one year to the next:

$$VI = (\frac{Yi+1-Yi}{Yi})/n \qquad \text{(Eq.1)}$$

Where Yi was the total hunting bag or number of captures for the first year, and Yi+1 total hunting bag or number of captures, for the following year. This information allowed us to represent the trend of the hunting bags or captures numerically. In the same way, a Farm Index, representing changes in the abundance of fur farms, was calculated. To test relationships among the extent of the area occupied, the Variability Index and the Farm Index, we used Kendall's Tau-b tests performed in R (R Core Team 2021). We expected i) a positive relationship between Variability Index and extentii) a negative relationship between Farm Index and extent, as a tendency to close farms would lead to fewer escapes and therefore a lower occupancy; iii) a negative relationship between Farm Index and extent, leading the closure of fur farms to less escapes/releases.

Results

We found that since Bonesi and Palazón (2007), the only publication summarising the information on American mink at a continental scale was the risk assessment for the European Union published by Bouroș et al. (2016, then updated in 2018) within the framework of the EU IAS Regulation. Further publications were more geographically constrained, and it was possible to collect further literature information for 16 countries, (Table 1).

Following our systematic data request, all European Member States, except Bulgaria and Croatia, provided data, plus Belarus, Norway, Iceland, Russia, Switzerland, the United Kingdom, and Ukraine provided data, dispersed across 34 databases (metadata reported in Appendix S1). Those also include publications, as previously mentioned. Four countries (Hungary, Serbia, Slovenia, and Switzerland) reported the absence of feral American mink on their territories. In Luxembourg, there was only a record of a dead animal in 2013, which was the only American mink reported in the country since 1993. For most countries, more than one database was provided. Timespan was not equal for every country and information about some years was missing. This was the case for Austria, for which we only had data of 2016, and Italy and Romania, for which we had specific reports of surveillance works. Spatial resolution was also very different (see Figure 1 and 2), although most of the countries provided a fine resolution (hunting grounds, municipalities, county, points, or grids), data from Germany, Austria and Czech Republic was provided at a lower resolution. Hunting bags or capture statistics of national-range systematic trapping were available for 12 countries. Many of the observation data (dead, alive or sign of presence) were centralized from national entities: this was the case for Ireland, the NBN Atlas in the United Kingdom, The Netherlands, Belgium, and France. GBIF data was available for most countries, for a total of 171 databases (Appendix S2). All data was incorporated in the mapping process.

Distribution maps

American mink were widespread in the Baltic States, Germany, Great Britain, and Scandinavia, and is now also widespread in France, Ireland, Iceland, Poland, and Spain (Figure 3 and 4). In the North, its absence is reported in a few areas of Ireland and Norway, while in continental Europe its absence is mainly reported in the southern part. However, data are still lacking for the south-eastern part of the continent.

Changes between the two decades, outlined from our data, were quantifiable only for the ten countries that provided data at the same resolution for both periods (Figure 5). Compared with Bonesi and Palazón's map (Figure 6), only Portugal shows a decrease in the extent of occurrence of American mink on its territory. Despite this, a decrease of reports of the presence of the species is evident in Norway, Southern Germany, and some parts of France (Figure 7). Nine countries showed higher percentage occupancy compared to Bonesi and Palazón's map. Despite this, our collated data show a decrease in the area occupied in France and Sweden, albeit insufficient to change category. Thirteen countries have maintained the same category as in Bonesi and Palazón's map. Our collated data highlighted an increase in the United Kingdom and a decrease in Belgium, which is believed not to have a self-sustaining population. Finally, information on four new countries was added: Luxembourg (not reported), Romania (not reproducing), European parts of Russia (spreading, 10-50%), Serbia (absent), and Ukraine (not reproducing).

Temporal trends in hunting bag

Out of the twelve countries that reported hunting bag data, Czech Republic, Denmark, Estonia, Finland, Lithuania, Poland and Sweden showed on average a negative annual trend in American mink hunting bags/captures. Finland, Latvia, and Spain showed yearly fluctuations in hunting bag despite the decreasing Variability Index. Iceland is the only country that consistently increased its hunting bags over time (Appendix S3). The hunting Variability Index is also negative for most countries (Table 2). Some countries (Denmark, Germany, Norway, Spain, and Sweden) have or have had a targeted control plan, while some others (Czech Republic, Iceland) only rely on specific hunting policies on the species. Farm year index showed that despite a negative trend in fur farming (except for Norway), the species is still widespread in all countries with many of them being invaded entirely (Table 2).

We found that control programs were being implemented in all countries except the Czech Republic, where hunting is opportunistic. All control programs involved both hunting and trapping and the effort trend of control programs was either constant (Poland, Latvia, Iceland) or variable (Sweden). Kendall Tau-b test did not give a significant correlation among the three parameters: tau for correlation variability index ~ area extent is -0.016 ($p = 0.9448$, $N = 12$), tau for correlation variability index ~farm index is 0.254 ($p = 0.2651$, $N = 12$), tau for correlation farm index ~area extent is 0.094 ($p = 0.677$, $N = 12$).

Based on data providers' comments, literature search and internet search, we estimate that mink fur farming is banned in thirteen out of 40 countries. It is still legal and active in twenty-four countries, and eleven countries are either discussing a ban or have planned a ban in the coming years (Figure 8, Appendix S4). Six countries clearly stated that they have no control, fourteen have some forms of control (mostly local-scale), and five rely only on the hunting plan.

Discussion

Since the review of Bonesi and Palazón (2007), little new information on the presence and distribution of the American mink in Europe became available. Bouroș et al. (2016) added some information in a risk assessment for the European Union, yet only at country level and based on older literature rather than updated data. Further publications give an even more fragmented picture (e.g., Poledník et al. 2016, Kopij 2017, Koshev 2019): robust data are available for few European countries (e.g., Léger 2018, Harrington et al. 2020, Baudach et al. 2021), but an updated overview for the continent has been lacking. We synthesized available information for all of Europe, showing an increase in the extent of distribution of this invasive species, with important ecological, economic, and social impacts.

Need for harmonized data

A general issue emerging from our coordinated data collection effort was the lack of quality and comparability of available data across countries. This required a considerable effort in standardization, evident for basic occurrence data but even more for data on management. This case of bringing together and having to standardize the different data types, illustrates the need for harmonized collection of baseline data in Europe for integrated wildlife monitoring, risk assessment and management evaluation (e.g., ENETWILD consortium et al. 2020). Although all data types were valuable to map the distribution of the American mink, they would not all be useful to estimate abundance or perform spatial modelling.

Hunting bag statistics have potential as reliable quantitative data, if they are systematically collected following standardized protocols (Teysseyre 2005, ENETWILD consortium et al. 2020). For the American mink, specifically, two issues arise from hunting bag data. First, not all countries can provide hunting bags for this species and, where they are available (such as in Germany), they are not always a reliable proxy of population size, due to trapping restrictions that decrease the probability of capture. Second, the absence of data on hunting/trapping effort undermines comparability in trend analyses (Mcdonald & Harris 1999, ENETWILD consortium et al. 2018): changes in the number of hunted American mink might only reflect changes in hunting effort or mink activity, rather than changes in population size.

Organized monitoring programmes can provide validated observations that are systematically gathered across a given area. Several monitoring programs have been performed for invasive alien species (Roy et al. 2009, Fraser et al. 2017, Maillard et al. 2020) and observation data is usually centralized in national institutes. However, schemes do not usually cover the entire country and data are seldom representative. Most available data consist of opportunistic observations that are often gathered by citizen science initiatives. Several of these systems (e.g., iRecord, iNaturalist, iMammalia, waarnemingen.be) also have good data validation procedures in place (Adriaens et al. 2021, Prys-Jones et al. in press). Such data are useful to determine presence and distribution extent of the American mink, as well as other ecological parameters, and to develop response actions, yet they are subject to temporal, spatial and reporting biases (Boakes et al. 2010, Beck et al. 2014). Although such data mostly do not allow differentiation between casual occurrences and established populations of American mink, nor are they useful for quantitative population analysis, they can be used to perform occupancy modelling and to draft presence-only species distribution modelling.

A more coordinated approach towards data collection on occurrence and management of American mink would increase quality, availability, and usefulness of the data for defining strategies to control or eradicate this invasive species. As American mink naturally disperse across the borders of many countries (Bonesi and Palazón 2007, A. Kranz, personal communication), these data need to be as accessible and open as possible. Data aggregators like GBIF have an important role to play in this but there are data publication gaps, as our collation of data illustrated. Such gaps are also evident in other invasive alien species and can only be closed by fostering a culture of open data publication by researchers and control operators (Groom et al. 2015). A particular issue is the quality of reporting on hunting statistics: lacking effort, data lose value for modelling and quantitative risk analysis. To improve the situation, governments and European institutions could provide guidance on minimum reporting standards for data on management (hunting, trapping) and the design of structured monitoring schemes. Likewise, the EU IAS Regulation (1143/2014) obliges Member States to report on the management of Union List IAS every six years. The standard reporting sheet asks for information on the management methods used, their effectiveness and any non-target effects on the environment. This requires standardized reporting on management (effort, results, non-target impact) despite the species-specific nature of control efforts.

Moreover, open data aggregators could tailor their data standards to better capture essential data on management of invasive species. To this end, building on the ENETWILD community and experiences, initiatives could be undertaken in collaboration with data standard organisations (e.g. TDWG for Darwin Core) to explore minimum reporting standards for wildlife management operations and to discuss how these can be transformed to machine readable standards. Also, improving structured monitoring programs, with physical or photographic captures and related capture effort, (e.g. MammalWeb camera trapping data: https://www.mammalweb.org/, Agouti wildlife camera-trapping https://www.agouti.eu/, the ENETWILD European Observatory of Wildlife https://wildlifeobservatory.org/), and increasing Europe-wide ad *hoc* reporting of sightings (e.g. iMammalia: https://mammalnet.com/) would be valuable additions that should be encouraged by relevant organisations, national governments and European Institutions.

European distribution of the American mink: a decade later

Although many countries have issued bans on fur farming and implemented control policies, we show that the American mink is still widespread and expanding its range in Europe. Given gaps in our data collection, the distribution we report here could be underestimated. In countries with a long tradition in gathering good distribution data, such as Spain, Ireland, the United Kingdom, or Finland, the expansion of the American mink in the last decade is obvious, although a slight decline in distribution in the United Kingdom is reported in literature (Crawley et al. 2020). In Spain, in the United Kingdom and in Sardinia, the expansion can still be attributed to different nuclei, likely sites where fur farms were or are active (Spagnesi et al. 2002, Lecis et al. 2008), although recent data demonstrate that there is now connection among Spanish populations (Põdra & Gomez 2018).

In most cases, the differences in distribution between the two decades is probably an artefact caused by increased data availability in recent years: the expansion of the species should therefore be carefully evaluated and considered together with the possibility of new populations due to new introductions or farm escapes. In north-eastern countries, there is uncertainty regarding the distribution. Mink farming is, however, traditionally present in these countries and observations are sporadically recorded (Horecka 2019, Sidorovich et al. 2020). The lack of data for the Balkan area could indicate real absence of American mink considering it does not occur in neighbouring countries and there are several bans on fur farming legislation (Slovenia Animal Protection Act ZZZiv-UPB3 2013, Republic of North Macedonia Animal Protection and Welfare 07-3781 2014, Croatia Animal Protection Act 102 2017). Greece, with its 79 fur farms, is a particular case: since 2010 a consistent number of feral American mink populate a limited area in northern regions. Its status as an established population is not confirmed (Adamopoulou & Legakis 2016), but the LIFE program "ATIAS" aims to contain American mink in the wider regions of western and central Macedonia (http://lifeatias.gr/).

The case of the United Kingdom is of particular interest: it was one of the first countries to ban fur farming (https://www.furfreealliance.com/) and it also implemented one of the most intensive control programs in Europe with mink being successfully removed from several larger land masses (Robertson et al. 2017, Martin & Lea 2020). Despite this, the American mink is still widespread and, in some areas, even spreading within the United Kingdom. Poland is another interesting example, with a relatively large number of absence cells, despite the fact that it is one of the countries with the highest number (256) and density (8.19/10,000 km2) of fur farms, where escapes and deliberate releases probably fostered feral populations (Brzeziński et al. 2019). Moreover, transboundary natural dispersal from eastern countries seems to be the main reason for population establishment in the country (Horecka 2019). This could be due to the high resolution of data, in the form of hunting bags, that allow the identification of areas where the American mink is reported and where it is not. This underlines the potential of data with better resolution, that allows for more precise evaluation of the risk of introduction. Our data also highlight the absence of American mink in the two main Estonian islands, which were two examples of successful eradication of the species at a local scale (DIISE 2018)

Success and defeat

Eradication of the American mink is notoriously difficult in mainland areas (MAGRAMA and Tragsatec 2012, Fraser et al. 2017). Although areas where the species ceased to be reported may be related to data quality, it is noteworthy that those countries did enact control procedures (Roy et al. 2009, Léger et al. 2018, Martin & Lea 2020).

Our map of collated data is superficially comparable to that produced by Bonesi and Palazón (2007). However, the earlier map was created from personal communications with national experts, while ours unified data from more varied sources (hunting bags, observations and captures). What emerges after the comparison is that the spatial trend of American mink distribution is increasing, and the percentage of occupied territory is either increasing or stable in most countries. This is clear, even though data limitations constrain our ability to estimate rates of change. Closely related to this, hunting bag statistics for most countries that provided capture effort showed a decreasing trend. The more relevant reduction of hunting bags for Sweden, following an interregional control program begun in 2017 (FAMNA: Förvaltning av Amerikansk Mink i Botnia-Atlantica Området, Management of American mink in the Botnia-Atlantic area; https://www.botnia-atlantica.eu/about-the-projects/project-database/famna-forvaltning-av-amerikansk-mink-i-botnia-atlantica-omradet) shows the potential effectiveness of control. However, the American mink's population was already declining before, possibly due to competition with the red fox (*Vulpes vulpes*; Carlsson et al. 2010). In Norway, where a control plan is still being operated in coastal areas (www.miljodirektoratet.no), the hunting bags are increasing. However, in situations such as in Spain, American mink control projects are often restricted timely and geographically, and trapping effort vary across years and regions. Drawing strong conclusions on the link about eradication projects and distribution/densities without a proper quantitative effort information, would not be possible.

Laws and management

Even before the SARS-CoV-2 crisis, more and more countries had shut down fur farms, and consequently the number of active farms has strongly decreased. This is due to government responses, potentially due to anti-fur farming public sentiment (e.g., see the Fur Free Alliance; https://www.furfreealliance.com). Nonetheless, in general the American mink population is still expanding in Europe. We see two possible explanations for this apparent contradiction. First, the fur trade sector has hindered the inclusion of this species on the list of invasive alien species of EU concern, which would help governments to improve control and eradication plans (Zuberogoitia et al. 2018). Second and despite recommendations, the closure of a mink farm may coincide with illegal animal releases into the wild, adding specimens to the feral invasive population (Bonesi & Palazón, 2007; Brzeziński et al. 2019). Moreover, it is surprising the negative, although not significant probably due to the small N, relationship between Farm Index and area of expansion, suggesting that shutting down farms does not prevent introduction of American minks in nature. Transboundary animal circulation may be a third hypothesis, as previously mentioned.

With massive closures of fur farms, the debate about the real impact in demographic terms on the feral population is still open. As an example, Hammershøj et al. (2005) stated that Danish feral population was probably not yet self-sustained from fur farm escapes, however Zalewski et al. (2010) remarked that Polish feral population was already independent from captive animals. This, together with the issue of whether the geographic barriers are effective to separate American mink populations (Zalewski et al. 2009), supports the need for collaboration between demographic and genetic analysis to structure more efficient management actions.

Countries differ strongly in their American mink management objectives. Many have projects aimed at eradication or control, either at a national or local level (Roy et al. 2009, The Norwegian Directorate for Nature Mangement 2011, Fraser et al. 2017, b.u.r. Emilia Romagna n. 203 of 26.06.2019), yet coordinated approaches aligning management objectives across countries are currently lacking. This is crucial for combating an invasive species which spreads through natural dispersal across national borders (Horecka 2019; Kranz, personal communication) and, in general, for effectiveness control policies (Santulli et al. 2014).

Conclusions

American mink is a widespread invasive alien species in Europe and its range has continued to increase over the last decade. The species now ranges from one side of the continent to the other, and is reported in almost all countries, with only relatively small mink-free areas confirmed. Its spread is currently unaffected by increasing closures of fur farms. Evaluating the distribution and population trend is constrained by the lack of (reliable) data for many countries as well as the heterogeneity in available data. Large data gaps exist, primarily in eastern (and secondarily in Southern) Europe. Moreover, hunting bag data are incomplete and reporting on national and local control plans (captures, observations) is scant. An open attitude towards data publication and the provision of guidance on minimum standards for reporting on management data are needed. These are necessary steps for risk assessment and risk management which, in turn, will provide a foundation for policies aimed at controlling the ongoing invasion of a non-native species with significant conservation and health impacts.

References

Adamopoulou C, Legakis A (2016) *First account on the occurrence of selected invasive alien vertebrates in Greece*. BioInvasions Records, 5(4), 189–196.

Adriaens T, Huysentruyt F, Stuyck J, Van Den Berge K, Vandegehuchte M, Casaer J (2015) *Surveillance voor invasieve exoten: samen op de uitkijk*. Zoogdier, 26(1), 17–19.

Adriaens T, Tricarico E, Reyserhove L, De Jesus Cardoso A, Gervasini E, Lopez Canizares C, Mitton I, Schade S, Spinelli FA, Tsiamis K (2021) *Data-validation solutions for citizen science data on invasive alien species*, EUR 30857 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-42055-2, doi:10.2760/694386, JRC126140.

Animal Protection Act – Official Consolidated Text – ZZZiv-UPB3 (Official Gazette of the Republic of Slovenia [Uradni list RS], No. 38/13 of 3 May 2013)

Animal Protection Act, 102/2017, art. 5 (Croatia)

Barrientos R (2015) *Adult sex-ratio distortion in the native European polecat is related to the expansion of the invasive American mink.* Biological Conservation, 186, 28–34.

Barros Á, Romero R, Munilla I, Pérez C, Velando A (2016) *Behavioural plasticity in nest-site selection of a colonial seabird in response to an invasive carnivore*. Biological Invasions, 18(11), 3149–3161.

Baudach F, Greiser G, Martin I, Ponick W (2021) *Status und Entwicklung ausgewählter Wildtierarten in Deutschland. Jahresbericht 2019.* Wildtier-Informationssystem der Länder Deutschlands (WILD). Deutscher Jagdverband (Hrsg.), Berlin

Beck J, Böller M, Erhardt A, Schwanghart W (2014) *Spatial bias in the GBIF database and its effect on modeling species' geographic distributions.* Ecological Informatics, 19, 10–15.

Biffi M, Charbonnel A, Buisson L, Blanc F, Némoz M, Laffaille P (2016) *Spatial differences across the French Pyrenees in the use of local habitat by the endangered semi-aquatic Pyrenean desman (Galemys pyrenaicus).* Aquatic Conservation: Marine and Freshwater Ecosystems, 26(4), 761–774.

Boakes EH, McGowan PJK, Fuller RA, Chang-qing D, Clark NE, O'Connor K, Mace GM (2010) *Distorted views of biodiversity: spatial and temporal bias in species occurrence data. PLoS Biology*, 8(6), e1000385.

Body G, de Mousset M, Chevallier E, Scandura M, Pamerlon S, Blanco-Aguiar JA, Vicente J (2020) *Applying the Darwin core standard to the monitoring of wildlife species, their management and estimated records*. EFSA Supporting Publications, 17(4).

Bonesi L, Palazón S (2007) *The American mink in Europe: status, impacts, and control.* Biological Conservation, 134(4), 470–483.

Bouroș G, Dekker J, Gómez A, Harrington L, Hegyeli Z, Hodor C, Kauhala K, Kranz A, Korpimäki E, La Haye M, Lambin X, Macdonald D, Manas S, Maran T, Michaux J, Palazón S, Põdra M, Salo P, Zuberogoitia I (2016) *Non-native species risk analysis – Risk assessment template V1.0 (8-06-16)* - EU Non-native organism risk assessment scheme: Neovison vison.

Bouwens S. (2017) *Gaat de Amerikaanse nerts uit ons land verdwijnen?* Kijk op Exoten.6(2):12-3.

Brzeziński M, Żmihorski M, Nieoczym M, Wilniewczyc P, Zalewski A (2020) *The expansion wave of an invasive predator leaves declining waterbird populations behind.* Diversity and Distributions, 26(1), 138–150.

Brzeziński M, Żmihorski M, Zarzycka A, Zalewski A (2019) *Expansion and population dynamics of a non-native invasive species: the 40-year history of American mink colonisation of Poland.* Biological Invasions, 21(2), 531–545.

B.u.r. n.203 del 26.06.2019 periodico (Parte Seconda), Regione Emilia-Romagna. *Piano di controllo dei Visoni americani (Neovison vison) presenti nel territorio della regione*

Emilia-Romagna, con particolare riferimento al comune di Noceto in provincia di Parma. Deliberazione della giunta regionale 6 maggio 2019, n. 698

Carlsson NOL, Jeschke JM, Holmqvist N, Kindberg J (2010) *Long-term data on invaders: when the fox is away, the mink will play.* Biological Invasions, 12(3), 633–641.

Chamberlain S, Barve V, Mcglinn D, Oldoni D, Desmet P, Geffert L, Ram K (2022) *rgbif: Interface to the Global Biodiversity Information Facility API*.

Crawley D, Coomber F, Kubasiewicz L, Harrower C, Evans P, Waggitt J, Smith B, Matthews F (2020) *Atlas of the mammals of Great Britain and Northern Ireland*. Pelagic Publishing Ltd.

Centre for Environmental Data and Recording (CEDaR), National Museum NI

Commission Implementing Regulation (EU) 2016/1141 of 13 July 2016 adopting a list of invasive alien species of Union concern pursuant to Regulation (EU) No 1143/2014 of the European Parliament and of the Council, C/2016/4295, OJ L 189, 14.7.2016, p. 4–8

Convention on the Conservation of European Wildlife and Natural Habitats (ETS No. 104)

Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora, OJ L 206, 22.7.1992, p. 7–50

Devaux CA, Pinault L, Delerce J, Raoult D, Levasseur A, Frutos R (2021) *Spread of mink SARS-CoV-2 variants in humans: a model of sarbecovirus interspecies evolution.* Frontiers in Microbiology, 2842.

DIISE (2018) The Database of Island Invasive Species Eradications, developed by Island Conservation, Coastal Conservation Action Laboratory UCSC, IUCN SSC Invasive Species Specialist Group, University of Auckland and Landcare Research New Zealand. http://diise.islandconservation.org

Dutch National Database Flora and Fauna, export date 3rd February 2021

European Centr for Disease Prevencion and Control (2020) *Detection of new SARS-CoV-2 variants related to mink.* November. https://www.ecdc.europa.eu/sites/default/files/documents/RRA-SARS-CoV-2-in-mink-12-nov-2020.pdf

Enders M, Havemann F, Ruland F, Bernard-Verdier M, Catford JA, Gómez-Aparicio L, Haider S, Heger T, Kueffer C, Kühn I (2020) *A conceptual map of invasion biology: Integrating hypotheses into a consensus network.* Global Ecology and Biogeography, 29(6), 978–991.

ENETWILD-Consortium, Body G, de Mousset M, Chevallier E, Scandura M, Pamerlon S, Blanco-Aguiar JA, Vicente J (2020) *Applying the Darwin core standard to the monitoring of wildlife species, their management and estimated records.* EFSA Supporting Publications, 17(4), 1841E.

ENETWILD-Consortium, Keuling O, Sange M, Acevedo P, Podgorski T, Smith G, Scandura M, Apollonio M, Ferroglio E, Vicente J (2018) *Guidance on estimation of wild boar population abundance and density: methods, challenges, possibilities*. EFSA Supporting Publications, 15(7), 1449E.

ENETWILD consortium, Podgórski T, Acevedo P, Apollonio M, Berezowska-Cnota T, Bevilacqua C, Blanco JA, Borowik T, Garrote G, Huber D, Keuling O, Kowalczyk R, Mitchler B, Michler FU, Olszańska A, Scandura M, Schmidt K, Selva N, Sergiel A, Stoyanov S, Vada R, Vicente J (2020) *Guidance on estimation of abundance and density of wild carnivore populations: methods, challenges, possibilities*. EFSA supporting publication 2020:EN-1947

ESRI 2019. ArcGIS Desktop: Release 10.7. Redlands, CA: Environmental Systems Research Institute.

European Food Safety Authority and European Centre for Disease Prevention and Control, Boklund A, Gortázar C, Pasquali P, Roberts H, Nielsen SS, Stahl K, Stegeman A, Baldinelli F, Broglia A (2021) *Monitoring of SARS-CoV-2 infection in mustelids.* EFSA Journal, 19(3), e06459.

Everything You Need to Know about Natural Fur and Sustainability [Internet]. Available from: https://www.sustainablefur.com/

Finnish Biodiversity Information Facility [Internet]. Available from: https://laji.fi/en

Fraser EJ, Harrington LA, Macdonald DW, Lambin X (2017) *Control of an invasive species: the American mink in Great Britain.*

GBIF.org (16 February 2022) GBIF Occurrence Download https://doi.org/10.15468/dl.9jztbu

GBIF.org (16 February 2022) GBIF Occurrence Download https://doi.org/10.15468/dl.2n269r

Genovesi P, Bacher S, Kobelt M, Pascal M, Scalera R (2009) *Alien mammals of Europe. In Handbook of alien species in Europe* Springer, pp. 119–128.

Groom QJ, Desmet P, Vanderhoeven S, Adriaens T (2015) *The importance of open data for invasive alien species research, policy and management.* Management of Biological Invasions, 6(2), 119.

Hammershøj M, Pertoldi C, Asferg T, Møller TB, Kristensen NB (2005) *Danish free-ranging mink populations consist mainly of farm animals: Evidence from microsatellite and stable isotope analyses.* Journal for Nature Conservation, 13(4), 267–274.

Harrington LA, Birks J, Chanin P, Tansley D (2020) *Current status of American mink Neovison vison in Great Britain: a review of the evidence for a population decline.* Mammal Review, 50(2), 157–169.

Harrington LA, Díez-León M, Gómez A, Harrington A, Macdonald DW, Maran T, Põdra M, Roy S (2021) *Wild American mink (Neovison vison) may pose a COVID-19 threat.* Frontiers in Ecology and the Environment, 19(5), 266.

Hegyeli Z, Kecskés A (2014) *The occurrence of wild-living American Mink Neovison vison in Transylvania, Romania.* Small Carnivore Conservation, 51, 23–28.

Hiery M, Keuling O, Klein R (2013) *Distribution of alien mammals in Germany – hunting bag of raccoon, mink and raccoon dog.* Wild Musteloid Conference, Oxford, 18th-21st March 2013

Hollander H. (2017) Exotische roofdieren in Nederland. Kijk op Exoten. 5(2):10–1.

Horecka B (2019) *Investigating the origin of the American mink (Neovison vison) in Poland, including a study on mink mitochondrial DNA from farm, feral and wild north American populations.* Acta Zoologica Academiae Scientiarum Hungaricae, 65(2), 181–194.

Hunt and wild life administration [Internet]. Available from: https://fauna.au.dk/en

Hurníková Z, Kołodziej-Sobocińska M, Dvorožňáková E, Niemczynowicz A, Zalewski A (2016) *An invasive species as an additional parasite reservoir: Trichinella in introduced American mink (Neovison vison).* Veterinary Parasitology, 231, 106–109.

INBO carnivore database (partly based on the citizen science project 'waarnemingen.be' by NGO Natuurpunt)

Ionescu DT, Hodor C, Drugă M (2019) *Recent occurrence of the American Mink (Neovison vison) in the central Romania.* Proceedings of the Biennial International Symposium" Forest and Sustainable Development", Brașov, Romania, 25-27 October 2018, 25–32.

Iordan F, Lapini L, Pavanello M, Polednik L, Rieppi C (2017) *Evidence for naturalization of the American mink (Neovison vison) in Friuli Venezia Giulia, NE Italy*. Mammalia, 81(1), 91–94.

Jensen TH, Christensen LS, Chriél M, Harslund J, Salomonsen CM, Hammer AS (2012) *High prevalence of Aleutian mink disease virus in free-ranging mink on a remote Danish island.* Journal of Wildlife Diseases, 48(2), 497–502.

Keller RP, Geist J, Jeschke JM, Kühn I (2011) *Invasive species in Europe: ecology, status, and policy.* Environmental Sciences Europe, 23(1), 1–17.

Knuuttila A (2015) *Diagnostics and epidemiology of Aleutian mink disease virus.* Dissertationes Schola Doctoralis Scientiae Circumiectalis, Alimentariae, Biologicae, Universitatis Helsinkiensis.

Koopmans M (2020) *SARS-CoV-2 and the human-animal interface: outbreaks on mink farms.* The Lancet Infectious Diseases.

Kopij G (2017) *Expansion of alien carnivore and ungulate species in SW Poland.* Russian Journal of Biological Invasions, 8(3), 290–299.

Korablev MP, Korablev NP, Korablev PN (2018) *Genetic Polymorphism and Population Structure of the Introduced American Mink (Neovison vison Schreber, 1777) in the Center of European Russia Based on Microsatellite Loci.* Russian Journal of Genetics, 54(10), 1179–1184.

Koshev YS (2019) *Occurrence of the American Mink Neovison vison (Schreber, 1777)(Carnivora: Mustelidae) in Bulgaria.* Acta zoologica bulgarica, 71(3), 417–425.

Krištofík J, Danko Š (2012) *Mammals of Slovakia: distribution, bionomy and protection*. VEDA, vydavateľstvo Slovenskej akadémie vied, Bratislava.

Landesjagdverband Bayern. Wildtiermonitoring Bayern. (2021) 5:370–370. Available from: www.tausendblauwerk.de

Larsen CS, Paludan S R (2020) *Corona's new coat: SARS-CoV-2 in Danish minks and implications for travel medicine.* Travel Medicine and Infectious Disease.

Law on Animal Protection and Welfare, 07-3781/2014, art. 4 (Rep. of North Macedonia)

Lecis R, Ferrando A, Ruiz-Olmo J, Mañas S, Domingo-Roura X (2008) *Population genetic structure and distribution of introduced American mink (Mustela vison) in Spain, based on microsatellite variation.* Conservation Genetics, 9(5), 1149–1161.

Leimann A, Knuuttila A, Maran T, Vapalahti O, Saarma U (2015) *Molecular epidemiology of Aleutian mink disease virus (AMDV) in Estonia, and a global phylogeny of AMDV.* Virus Research, 199, 56–61.

Léger F, Steinmetz J, Laoué E, Maillard J-F, Ruette S (2018) *L'expansion du vison d'Amérique en France Période 2000-2015.* Faune Sauvage, 318, 31.

Long JL (2003) *Introduced mammals of the world: their history, distribution, and influence.* CSIRO publishing.

Macdonald DW, Harrington LA (2003) *The American mink: the triumph and tragedy of adaptation out of context.* New Zealand Journal of Zoology, 30(4), 421–441.

Maillard J, Ruette S, Leger F (2020) *Present status of Raccoon, Raccoon dog and American mink in France.* November, 30–31.

Mañas S, Gómez A, Asensio V, Palazón S, Põdra M, Alarcia OE, Ruiz-Olmo J, Casal J (2016) *Prevalence of antibody to aleutian mink disease virus in European mink (Mustela lutreola) and American mink (Neovison vison) in Spain.* Journal of Wildlife Diseases, 52(1), 22–32.

Maran T (1991) *Distribution of the European mink in Estonia: a historical review.* Folia Theriologica Estonica 1: 1–17.

Maran T, Skumatov D, Gomez A, Põdra M, Abramov AV, Dinets V (2016) *Mustela lutreola. The IUCN Red List of Threatened Species 2016: e.T14018A45199861.* https://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T14018A45199861.en. Downloaded on 01 October 2021.

Marinov M, Kiss JB, Toman A, Polednik L, Alexe V, Doroftei M, Doroșencu A, Kranz A (2012) *7. Monitoring of European Mink (Mustela lutreola) in the Danube Delta Biosphere Reserve–Romania, 2003-2011*. Current status and setting of goals for the European

Martin AR, Lea VJ (2020) *A mink-free GB: perspectives on eradicating American mink Neovison vison from Great Britain and its islands*. Mammal Review, 50(2), 170–179.

Martínez-Rondán FJ, De Ybáñez MRR, Tizzani P, López-Beceiro AM, Fidalgo LE, Martínez-Carrasco C (2017) *The American mink (Neovison vison) is a competent host for native European parasites.* Veterinary Parasitology, 247, 93–99.

Mathews F, Kubasiewicz LM, Gurnell J, Harrower CA, McDonald RA, Shore RF (2018) *A review of the population and conservation status of British mammals.* Natural England

Mcdonald RA, Harris S. (1999) *The use of trapping records to monitor populations of stoats Mustela erminea and weasels M. nivalis: the importance of trapping effort*. Journal of Applied Ecology, 36(5), 679–688.

Ministerio de Agricultura, Alimentación y Medio Ambiente (MAGRAMA), TRAGSATEC (2014) *Estrategia de gestión, control y erradicación del visón americano (Neovison vison) en España.* Ministerio de Agricultura, Alimentación y Medio Ambiente, Secretaría General Técnica, Centro de Publicaciones

Munnink BBO, Sikkema RS, Nieuwenhuijse DF, Molenaar RJ, Munger E, Molenkamp R, Van Der Spek A, Tolsma P, Rietveld A, Brouwer M (2020) *Transmission of SARS-CoV-2 on mink farms between humans and mink and back to humans.* Science.

National Biodiversity Data Centre (2021) *American mink (Neovison vison) distribution record data published under open CC-BY licence on Biodiversity Maps* https://maps.biodiversityireland.ie.

NBN Atlas occurrence download at https://nbnatlas.org accessed on Thu Sep 09 08:53:32 UTC 2021

NOBANIS - European Network on Invasive Species [Internet] Available from: https://www.nobanis.org/

Nugaraitė D, Mažeika V, Paulauskas A (2019) *Helminths of mustelids with overlapping ecological niches: Eurasian otter Lutra lutra (Linnaeus, 1758), American mink Neovison vison Schreber, 1777, and European polecat Mustela putorius Linnaeus, 1758.* Helminthologia, 56(1), 66–74.

Oreshkova N, Molenaar RJ, Vreman S, Harders F, Munnink BBO, Hakze-van der Honing RW, Gerhards N, Tolsma P, Bouwstra R, Sikkema RS (2020) *SARS-CoV-2 infection in farmed minks, the Netherlands, April and May 2020.* Eurosurveillance, 25(23), 2001005.

Pebesma E, Bivand R (2018) *sf: Simple Features for R. R Package Version 0.6-0,* URL Https://CRAN. R-Project. Org/Package= Sf.

Põdra M, Gómez A (2018) *Rapid expansion of the American mink poses a serious threat to the European mink in Spain.* Mammalia, 82(6), 580–588.

Põdra M, Gómez A, Palazón S (2013) *Do American mink kill European mink? Cautionary message for future recovery efforts.* European Journal of Wildlife Research, 59(3), 431–440.

Poledník L, Poledníková K, Munné S, Flousek J (2016) *Výskyt norka amerického (Neovison vison) v Krkonosském národním parku a jeho ochranném pásmu v letech 2012 a 2013/The occurrence of the American mink (Neovison vison) in the Giant Mts (Czech Republic) in 2012 and 2013.* Opera Corcontica, 53, 233.

Price-Jones V, Brown P, Adriaens T, Tricarico E, Farrow RA, Cardoso A-C, Gervasini E, Groom Q, Reyserhove L, Schade S, Tsinaraki C, Marchante E (in press) *Half a billion eyes on the ground: citizen science contributes to research, policy and management of biological invasions in Europe.* DOI: https://doi.org/10.3897/arphapreprints.e81567

R Core Team (2013). *R: A language and environment for statistical computing.*

R Core Team (2021). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/

Rambaut A, Pybus OG, Robertson DL, O'Toole A, Loman N (2020) *Risk assessment of SARS-CoV-2 variants that have been selected in mink.* In Scientific Advisory Group for Emergencies 67.

Réseau petits et méso-carnivores OFB

Reynolds JC (2009) *American mink: the art of the possible and national aspirations for biodiversity*. International Urban Ecology Review, 4, 74–82.

Robertson PA, Adriaens T, Lambin X, Mill A, Roy S, Shuttleworth CM, Sutton-Croft M (2017) *The large-scale removal of mammalian invasive alien species in Northern Europe.* Pest Manag Sci 73:273–279 https://doi.org/10.1002/ps.4224

Roy D (2020) *Mammal records for Europe* via the iMammalia app. Version 1.3. Biological Records Centre.

Roy S, Reid N, McDonald RA (2009) *A Review of Mink Pre dation and Control for Ireland.* Irish Wildlife Manuals, No. 40. National Parks and Wildlife Service, Department of the Environ Ment, Heritage and Local Government, Dublin, Ireland.

RStudio Team (2019) *RStudio: Integrated Development for R.* RStudio, Inc., Boston, MA URL http://www.rstudio.com/.

Santulli G, Palazón S, Melero Y, Gosálbez J, Lambin X (2014) *Multi-season occupancy analysis reveals large scale competitive exclusion of the critically endangered European mink by the invasive non-native American mink in Spain*. Biological Conservation, 176, 21–29.

Sidorovich VE (2001) *Study on the decline in the European mink Mustela lutreola population in connection with the American mink M. vison expansion in Belarus: story of the study, review of the results and research priorities*. Säugetierkundliche Informationen, 5(25), 133-153.

Sidorovich A, Novitsky R, Solovej I (2020) *Road mortality of Carnivores (Mammalia, Carnivora) in Belarus.* Zoodiversity, 54(3).

Šimková Z, Šimko J, Šimko Š (2019) *American mink (Neovison vison Schreber, 1777) in Slovakia: biological minimum (status, impact and control) and social significance.* Slovenský Veterinársky Časopis, 44(1), 82–87.

Spagnesi M, Toso S, De Marinis A M (2002) *I mammiferi d'Italia*. Ministero dell'Ambiente e della Tutela del Territorio e Istituto Nazionale per la Fauna Selvatica. Italy.

Statistics Norway [Internet]. Available from: https://www.ssb.no/en

Stefansson RA, von Schmalensee M, Skorupski J (2016) *A tale of conquest and crisis: invasion history and status of the American mink (Neovison vison) in Iceland*. Acta Biologica, 23, 87–100.

Stien J, Hausner VH (2018) *Motivating and engaging volunteer hunters to control the invasive alien American mink Neovison vison in Norway.* Oryx, 52(1), 186–194.

Teysseyre A (2005) *Contribution à l'étude du parasitisme intestinal du renard roux (Vulpes vulpes) en Midi-Pyrénées; recherche d'Echinococcus multilocularis. Deuxième partie: les départements du Gers (32), du Lot et Garonne (47) et des Hautes-Pyrénées (65).*

The Convention on Biological Diversity [Internet]. Available from: https://www.cbd.int/convention/

The Norwegian Directorate for Nature Mangement (2011) *Scientific basis for action plan against American Mink in Norway. Invasive American Mink (Neovison vison): Status, ecology and control strategies.* DN-utredning 6-2011

Tumanov IL (1996) *A problem of Mustela Lutreola: Reasons of dissappearance and conservation strategy*. Зоологический Журнал, 75(9), 1401–1403.

Van Den Berge K (2008) *Carnivore exoten in Vlaanderen.* Areaaluitbreiding of telkens nieuwe input? *Zoogdier*, 19(2), 6-9.

Van Dorp L, Tan CCS, Lam SD, Richard D, Owen C, Berchtold D, Orengo C, Balloux F (2020) *Recurrent mutations in SARS-CoV-2 genomes isolated from mink point to rapid host-adaptation.* BioRxiv.

Viltdata [Internet]. Available from: https://rapport.viltdata.se/statistik/

Wickham H, Averick M, Bryan J, Chang W, McGowan LD, François R, Grolemund G, Hayes A, Henry L, Hester J (2019) *Welcome to the Tidyverse*. Journal of Open Source Software, 4(43), 1686.

Yamaguchi N, Macdonald DW (2001) *Detection of Aleutian disease antibodies in feral American mink in southern England.* Veterinary Record, 149(16), 485–488.

Zalewski A, Michalska-Parda A, Bartoszewicz M, Kozakiewicz M, Brzeziński M (2010) *Multiple introductions determine the genetic structure of an invasive species population: American mink Neovison vison in Poland.* Biological Conservation, 143(6), 1355–1363.

Zalewski A, Piertney SB, Zalewska H, Lambin X (2009) *Landscape barriers reduce gene flow in an invasive carnivore: geographical and local genetic structure of American mink in Scotland*. Molecular Ecology, 18(8), 1601–1615.

Zuberogoitia I, Põdra M, Palazón S, Gómez A, Zabala N, Zabala-Albizua J (2018) *Facing Extinction, Last Call for the European Mink.* Ann. Rev. Resear, 2, 555581.

Caption to figures

Figure 1. Spatial resolution and geographical range for information provided as administrative areas and point coordinates, for decade 2001-2010.

Figure 2. Spatial resolution and geographical range for information provided as administrative areas and point coordinates, for decade 2011-2020.

Figure 3. American mink distribution in the decade 2001-2010.

Figure 4. American mink distribution in the decade 2011-2020.

Figure 5. On the x-axis, dark grey bars: change in the extent of occurrence (calculated from the Minimum Convex Hull from our collated data) of American mink from one decade (2001-2010) to the other (2011-2020) and grey bars: the current (2011-2020) relative occupancy per country with data.

Figure 6. Updated estimation of extent of occurrence (percentage) in each country expressed as the categories defined by Bonesi and Palazón (2007). The reference map from Bonesi and Palazón (2007) is shown in the top right corner.

Figure 7. Changes in the distribution of the American mink between the decades 2000-2010 and 2010-2020, based on collated data of reporting of this species.

Figure 8. Fur farming legislation in Europe. Countries are coloured by the state of fur farming (if it is permitted, currently banned, or soon to be banned), with ban year in the squares and farm numbers in the bubbles.

Tables

Table 1: Literature available per country

Country ID	Literature with general information in specific areas					Literature used for mapping		
	Citation	Geographic scale	Year	Presence	Method	Citation	Year	Method
BE	(Van den Berge, 2008)	Flanders, northern part	2008	Present	Observations, captures, roadkills			
	(Adriaens et al. 2015)	Country						
BY	(Sidorovich et al. 2020)	Central-Western Belarus	2018	41.1-14.9 ind/100km^2	Census and roadkill			
BG	(Koshev, 2019)	Stara Zagora District	2019	103	Biosecurity check, observations, captures, tracks			
CZ	(Poledník et al. 2016)	Krkonoše/Giant Mountains	2013	Present	Census with floating rafts			
DE	(Hiery et al. 2013)	Country	2013	Present	Observations	(Baudach et al. 2021)	2006-2019	Hunting bags
	(Baudach et al. 2021)	Country	2021	Present	Hunting bags			

ES	(Põdra & Gomez, 2018)	Country	2012	Present	Trapping			
FR	(Léger et al. 2018)	Country	2015	Present	Surveys			
	(Mathews et al. 2018)	Scotland (except northern Sc.), Wales, England	2017	Present	Literature			
GB	(Harrington et al. 2020; Martin & Lea 2020)	Country	2019	Widespread	National surveys			
	(Crawley et al. 2020)	Country	2019	Declining	Observations			
GR						(Adamopoulou and Legakis, 2016)	2000-2016	Questionnaire
IS	(Stefansson et al. 2016)	Country	2015	Increasing	Hunting bags			
IT						(Iordan et al. 2017)	2013	Live trapping
LT	(Nugaraitė et al. 2019)	Country	2017	Present	Roadkill			
NL	(Hollander, 2017)	Country	2016	Present	Observations			
	(Bouwens, 2017)	Country	2017	Present	Observations			
PL	(Brzeziński et al. 2020)	Country	2019	7 mink / 100 trap nights	Live trapping			

	(Kopij, 2017)	Southwest	2017	98	Questionnaire			
RO						(Ionescu et al. 2019)	2015-2018	Camera and live trapping
						(Marinov et al. 2012)	2003-2011	Scat survey, camera trapping
						(Hegyeli and Kecskés, 2014)	2007-2012	Opportunistic records
RU	(Korablev et al. 2018)	Caspic, Balkan	2018	Present	Dead animals			
SE	(Carlsson et al. 2010)	Country	2006	Present	Hunting bags			
SK	(Šimková et al. 2019)	Country	2019	Present		(Krištofík and Danko, 2012)	2000-2012	Oportunistic records

Table 2. Hunting bags of American mink for twelve European countries. Hunting bags Variability Index (see text for details), extent (% surface area invaded in the decade 2011-2020), Farm Index (see text for details) and results of the questionnaire submitted about control plans.

Country	Variability Index	Extent (in %)	Farm Index	Control Plan
Czech R.	-0.03	NA	-0.33	No proper control plan, as the American mink are culled by hunting managers or guards when required (e.g., damages)
Denmark	-0.09	98.27	-0.08	American mink management from Danish environmental protection agency
Estonia	-0.13	91.90	-0.36	Hunting allowed all year round. No special control program. Effort unknown. Successful eradication programs were carried out on main islands (Saaremaa and Hiiumaa).
Germany	-0.03	79.69	-0.66	Hunting bags are not a reliable source to evaluate fluctuations in American mink populations, as i) this species is not regulated by the same laws in all German states, ii) hunting is not extensively practiced, iii) other control programs apart from hunting are usually performed.
Finland	-0.08	98.24	-0.05	Successful eradication programs on Islands
Iceland	0.07	99.7	-0.17	Both hunting and trapping, by bounty system. Effort has been constant despite population decline since 2000. Eradication was attempted in two areas of Iceland in 2007-2009.
Latvia	0.02	99.49	-0.02	Hunting allowed all year round. No special control program. Effort unknown
Lithuania	-0.05	99.03	-0.05	American mink is hunted the whole year long, although no trapping or specific control plans are reported
Norway	0.02	73.78	0.10	Control plan in 2011 (Norwegian directorate) and engaging hunters (Stien & Hausner 2018).
Poland	-0.12	99.41	-0.10	Hunting allowed all year round. There are some regional programs, implemented in small, limited areas.

Sweden	-0.09	98.27	-0.19	Control plans that involve both trapping and hunting, with a variable effort that was implemented with an interregional control program of 3 years, ended January 2020.
Spain	0.65	62.72	-0.05	Control programs are coordinated by single regions (e.g. Com. Valenciana), by national plans (MITECO in 2003) and several LIFE projects (LIFE Lutreola Spain, IREKIBAI, INSAVEP, DESMANIA)