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Research Project

A feasibility study on the reintroduction of the European Mink (*Mustela lutreola*) in the Netherlands

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by

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Abstract

In the past three decennia, a dozen mammal species were saved from the brink of extinction through conservation efforts such as reintroductions. The European mink (*Mustela lutreola*), as the most critically endangered mammal of Europe, requires increased conservation efforts to survive. Since the abolishment of American mink (*Neovison vison*) farms in the Netherlands, only a very small number of these animals has been observed in the wild, and therefore the question arose whether it would be feasible to reintroduce the European mink in the Netherlands with one of their major threats gone. This project aims to study the possibility of the reintroduction of the European mink in the Netherlands based on the IUCN guidelines for reintroduction, to provide an outline and identify the knowledge gaps that need to be filled for a successful reintroduction in the future.

In general, most threats to the European mink have been mitigated. The presence of the American mink needs to be monitored closely, and its inability to settle in the Netherlands compared to other countries should be researched. The European mink is unlikely to pose a large risk to native Dutch biodiversity such as meadow birds, but is instead likely to consume invasive American crayfish species and aid in its control. There are several societal issues to overcome: the image of the general public of the European mink might be tainted due to COVID-19, and fishermen and trappers are likely to feel inconvenienced. Proper communication and support is necessary to ensure a long-lasting successful project.

The most suitable locations appear to be the Weerribben-Wieden and the Biesbosch, although their prey availability in winter months needs to be studied. A habitat suitability analysis needs to be conducted. The release of animals would have to occur over a span of multiple years, and to reduce the stress of travel in the animals, the best course of action would be to set up a breeding centre in the Netherlands. Each year pregnant females can then be placed in a soft-release enclosure, which can be opened up in August to allow the mothers and their young out in the wild. More research is needed on proper monitoring methods, such as the suitability of radio-harnesses compared to intraperitoneal transmitters and the usage of scats for DNA analysis.

1. Introduction

1.1 Introduction

The loss of biodiversity under human induced climate change and environmental destruction is one of the most urgent and critical issues humanity currently faces. Even in the most conservative calculations, the sixth mass extinction is progressing, and the window to avert the loss of ecosystem services and biodiversity is closing rapidly (Ceballos *et al.*, 2015). Around a dozen mammal species were saved from the brink of extinction through conservation efforts such as reintroductions since 1993 (Bolam *et al.*, 2020), yet 229 are still critically endangered (IUCN, 2021).

The European mink (*Mustela lutreola*) is a semi-aquatic mustelid native to Europe, extant sparingly in fragmented populations in northern Spain and southern France, in the Volga and Dvina basin, and in the Danube delta (Maran, 2007). With only a few thousand individuals remaining, it is listed in the IUCN Red List as a Critically Endangered Species (IUCN, 2021), and is considered both an Annex II and Annex IV species of the EU Habitats Directive (European Commission, 1992); Annex II species' core areas must be managed in accordance with the ecological needs of the species, and Annex IV species are under a strict protection regime across their entire natural range.

Despite its current rarity, the European mink used to be a common and widespread species, ranging from Finland to Greece, and from Spain to the Ural Mountains in Russia (Heptner *et al.*, 1967; Youngman, 1982). The grave decline of the European mink commenced in the 19th century in central Europe, progressing to eastern Europe in the 20th century. The decline has been attributed to several varying antecedents, although none can individually provide a full explanation. The American mink (*Neovison vison*, formerly known as *Mustela vison* and *Neogale vison*) is commonly regarded as the main cause. The alien species was introduced to Europe for its fur in the late 1920's in eastern Europe and later in the 20th century in numerous other European countries, consequently facilitating the establishment of wild populations through accidental escapes (e.g. Brzeziński *et al.*, 2018; Kauhala, 1996; Ruiz-Olma *et al.*, 1997; Smal, 1988). They are thought to have affected European mink populations through competition (Sidorovich & MacDonald, 2001), reproduction impediment (Ternovskij, 1977), and inter-specific aggression (Sidorovich *et al.*, 1999; Sidorovich, 2001).

Before 2021, the bulk of (American) mink fur production originated in Europe (60% of world total), with a production of around 40 million mink skins per year, and the Netherlands was the third largest European producer (Hansen, 2017). In 2020, the coronavirus disease (COVID-19) transferred from humans to several American mink pelt farms in the Netherlands (Enserink, 2020). Although at the time no proof was found of mink infecting humans in return, the government mandated culling all animals in the infected farms, after which new legislation was adopted abolishing mink farms per 25 December 2020 (article 2 Wet verbod pelsdierhouderij, 2020). This sudden disappearance of a source for the wild American mink populations in the Netherlands preceded a dramatic decline in observations of wild American mink throughout the Netherlands (observed by the Dutch Mammal Society), suggesting that perhaps the species will disappear from the Netherlands entirely. This raised the question whether a reintroduction of the European in the Netherlands becomes feasible, as one of the larger threats to the European mink has almost vanished.

This project aims to study the possibility of the reintroduction of the European mink in the Netherlands. This study will be based on the IUCN guidelines for reintroductions (IUCN/SSC, 2013) in order to provide an outline and identify the knowledge gaps that need to be filled for a successful reintroduction in the future.

1.2 Species Profile

The European mink is a small carnivore of the family Mustelidae, which encompasses carnivorous mammals such as mink, ferrets, martens, otters, and badgers. Its closest relatives are the Black-footed ferret *Mustela nigripes*, the European polecat *M. putorius* (hereafter referred to simply as 'polecat'), and steppe polecat *M. eversmanii* (Law *et al.*, 2018). The European mink is one of the smaller mustelids, weighing only between 500 and 1000 g. It is 30 to 40 cm in head and body length, and its tail an additional 12 to 18 cm. Female size is approximately 85% of the male's. It has a thick, brown fur that is generally slightly lighter on the ventral side, although both the legs and the tail are darker in colour and the tail thinner in fur. Its muzzle has a white spot – both around the lower and upper lip –, the prominence of which varies between individuals (*Figure 1*). Some individuals will equally have a white patch on the breast (e.g. Saint-Girons, 1991).

European mink are semi-aquatic, feeding on amphibians, small mammals, fish, and crustaceans (e.g. Palazón *et al.*, 2004; Sidorovich, 2000). They are mainly active from dusk to dawn, and their home ranges stretch along lagoon shores, tributaries, and rivers, where males have significantly larger linear home ranges than females (10 versus 2 km) (Palomares *et al.*, 2017). This discrepancy is indicative of a polygynous breeding system, as a male includes several females' home range within his own. European mink reproduce from mid-March to mid-May, and their litter size ranges between 3 till 7 kits per year (up to 12 kits exceptionally) with a gestation length of around 43 days (Kiik *et al.*, 2017; Nagl *et al.*, 2015).

Historically, the European mink's range extends over nearly the full continent of Europe (*Figure 2*). Although there is some debate on the southern edge, it is considered to have roamed from west France to the Ural Mountains in Russia, and as far north as Finland to possibly all the way south to Greece (Heptner *et al.*, 1967; Novikov, 1939; Youngman, 1982). The presence of the European mink in northwest Europe (Belgium, Denmark, Germany, and the Netherlands) and the origin of the French population remains unclear, but Maran (2007) deems the bottleneck hypothesis as the most likely: through some unknown cause, the European mink went through a grave decline in western Europe, and partially recovered from a limited number of founders. This recovering population would then continue to spread to northern Spain.

Around the beginning of the twentieth century, European mink populations everywhere started to decline rapidly, eventually deteriorating to remain extant only in three independent areas: western France and northern Spain; the Danube delta; and the Volga and Dvina basin (Michaux *et al.*, 2005; Skorupski, 2020). Possible explanations of this extinction process are reviewed in the next chapter. Since 1984, European mink have been a part of a breeding programme of the EEP (European Endangered species Programme) of EAZA (European Association of Zoos and Aquaria). Presently, three reintroductions of European mink in the wild have been initiated: I) on the island Hiiumaa, Estonia, animals were released between 2000 and 2016, after which they were observed to have a stable population size and additional releases were stopped (Maran *et al.*, 2009); II) in Saarland, Germany, the first animals were released in 2006 and – although little is known about the state of the population – release continues to this day (Peters *et al.*, 2009); III) and near the Steinhuder Lake, of which I was unfortunately unable to retrieve any information (pers. comm. Dick Klees).

*Figure 1: European mink (*Mustela lutreola*) ©Dick Klees.*

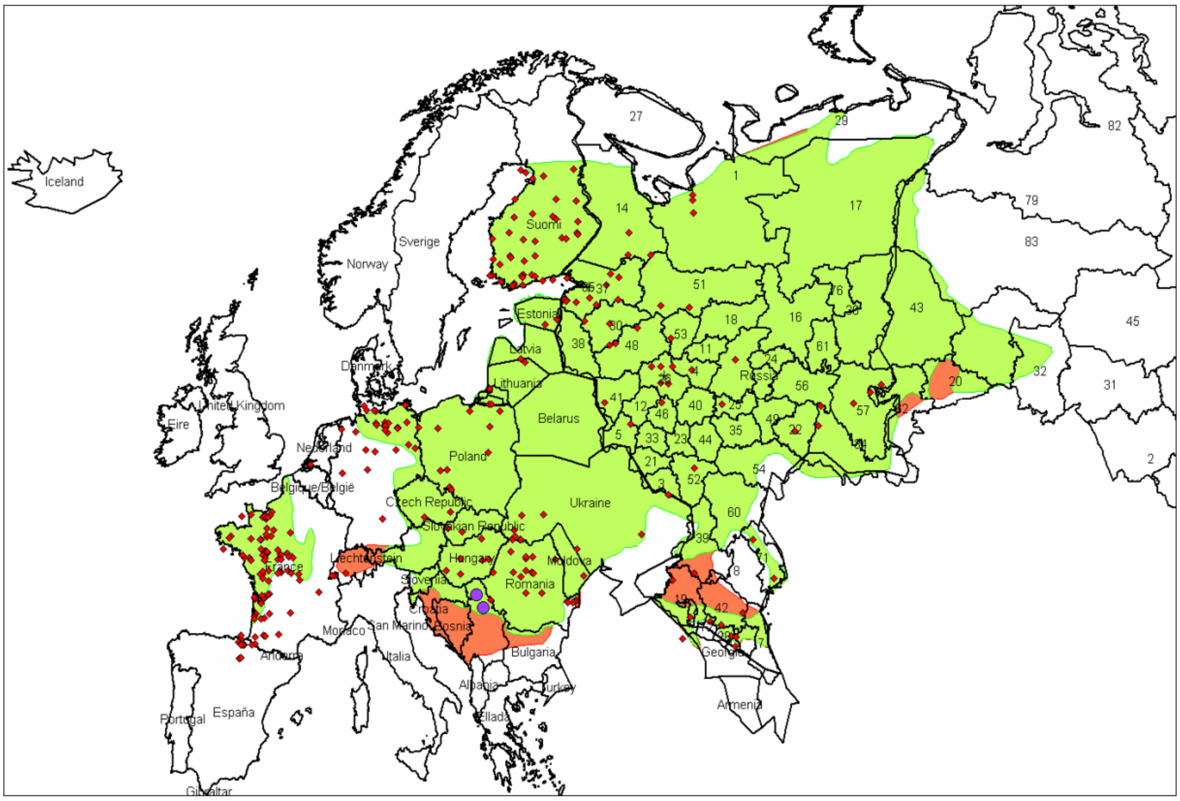

Figure 2: Map on the historical range of the European mink, as presented in Maran, 2007. Green areas: range determined by Novikov, 1939. Red areas: Modifications by Heptner et al.*, 1956. Red squares: Records added by Youngman, based on museum specimens and literary records. Lilac dots: Records added by Krustufek* et al.*, 1994.*

2. Methods

2.1 Literary aspect

Most data was acquired via a literature review. To create a complete overview of prior research on the European mink, I used the broad search query '*"European mink" OR "Mustela lutreola"*' in the Scopus search engine, and judged the titles of all papers for relevance, both to this part and other parts of this feasibility project. Relevant papers were scanned for their conclusions and archived to be studied later on. The search query returned 190 documents on 2021-11-09 to 18-03-2022.

2.2 Interviews

Interviews were conducted with a broad scale of experts on subjects such as reintroductions, wildlife management, IUCN guidelines, stakeholders, and public education. The aim of these discussions were to bring my attention to matters I may not have previously considered and to determine what they believe is of high importance in the reintroduction of the European mink.

The experts were the following:

I) Dr. Loek Kuiters, coordinator of the reintroduction of the European otter (*Lutra lutra*) in the Netherlands;

II) Dr. Coenraad Krijger, from the IUCN National Committee of the Netherlands;

III) Mark Zekhuis, ecologist at Landschap Overijssel, prior local coordinator of otter monitoring, and co-author of the book *Gewilde Dieren* on reintroductions in the Netherlands;

IV) Paul Voskamp, ecologist and policy officer at Province Limburg;

V) Hanneke de Boer, manager education and nature conservation at GaiaZOO, Bas Martens, head of animal care at GaiaZOO, & Emile Filipe Prins, curator at GaiaZOO;

VI) Johan van der Haven, field coordinator of nature at Avifauna, & Joost Lammers, curator at Avifauna;

VII) Menno de Ridder, policy officer of Species at the Ministry of Agriculture, Nature, and Food Quality.

Brief summaries of each interview are in *Supplementary Material 1*.

2.3 Visit to Estonia

07-03-2022 to 12-03-2022, I travelled to Tallinn, Estonia, to learn about European mink keeping, breeding, and release from Dr. Tiit Maran. With me were Glenn Lelieveld, my supervisor from the Dutch Mammal Society, and Dick Klees, expert on predators. Due to COVID-19, the breeding facility was closed to visitors, but we discussed methods with the head of the caretakers and saw the enclosures from the outside. We visited the pre-release enclosures located on Hiiumaa island, as well as several inhabited streams. A brief report of the trip along with relevant conversation points and photos are in *Supplementary Material 2*.

3. Feasibility

The primary question to answer before planning a reintroduction, is whether or not it is feasible for the species to establish itself in their new environment. There are many aspects to species' wellbeing, ranging from biotic needs to disease and parasite considerations. Furthermore, there are legislative matters to consider, on regional, national, and international levels. Additionally, communication with and consideration for the inhabitants of the Netherlands is important. Is there reason for them to oppose the reintroduction of this particular species? How could their concerns be addressed and, where possible, mitigated? This part aims to address all issues that fall under initial feasibility of the reintroduction of the European mink in the Netherlands, and make recommendations for future steps or research.

3.1 Threats

Numerous reasons of the European mink decline have been brought forward, although none by themselves can be considered the sole cause for decline of the species across all of Europe. For example, the disappearance of the European mink in Spain coincided perfectly with the arrival of the American mink (Santulli *et al.*, 2014), but in France, the former abandoned habitat the latter had not yet invaded (Lodé *et al.*, 2001). It is rather a lethal combination of a variety of forces across the entirety of the European mink's range that have affected it so much. This part briefly outlines the main driving forces postulated by research, and elaborates on their applicability to the Netherlands.

Habitat loss

The European mink, as a semi-aquatic species, utilises small rivers and streams surrounded by lush vegetation. Although previously abundant, the 19th century saw an overwhelming amount of transformation of these biotopes, decreasing suitable habitat significantly (Lodé *et al.*, 2001; Maran & Henttonen, 1994). Reports as early as 1866 mentioned the threat of increased land drainage for mustelid species, both in Germany and Lithuania (Claudius, 1866; Löwis, 1899; reviewed in Maran & Henttonen, 1994). More recently, the pollution of numerous waterways has reduced suitable habitat even further, as European mink avoid polluted water (Lodé *et al.*, 2001; Lodé, 2002). Lodé (2002) postulated that the fragmentation of European mink population is mainly driven by these polluted waterways, creating artificial barriers that limit the gene flow between populations.

Road kills, trapping, and hunting

Human intervention has also added to the decline of the European mink in a more direct way. In the early 20th century, hunting of the European mink for its fur largely exceeded the annual productivity of the species (Shashkov, 1977), and unselective trapping of pests in Romania and France in the last decades has put pressure on the remaining populations (Fournier & Maizaret, 2003; Gotea & Kranz, 1999). This encroachment on the European mink was pronounced across its entire range (reviewed in Maran & Henttonen, 1994). Even currently, destructive human influence affects European mink: in Spain and France, the main causes of mortality in the second half of the 20th century were traps and shooting, and road kills after the turn of the century (Lodé *et al.*, 2001; Palazón *et al.*, 2012).

American mink

The American mink is commonly regarded as the main cause of the European mink's extinction. The alien species was introduced for its fur in eastern Europe in the late 1920's, and in numerous other European countries later in the 20th century, consequently facilitating the establishment of wild populations through accidental escapes (e.g. Brzeziński *et al.*, 2018; Kauhala, 1996; Ruiz-Olma *et al.*, 1997; Smal, 1988). Their ability to settle and expand is significant: their distribution area increased 17-fold over a period of 27 years only (Põdra & Gómez, 2018). American mink have been excluding European mink from their native areas, increasingly reducing the latter's available habitat (Santulli *et al.*, 2014; Sidorovich & MacDonald, 2001).

The pressure of American mink on their native European counterparts may have several cumulative causes. Competition between both species is likely high, not only because they occupy similar habitats, but also because their diet preferences overlap considerably (Maran *et al.*, 1998; Sidorovich *et al.*, 2010). European mink diet alters under the presence of American mink, diverging from their preferred aquatic prey to amphibians or birds (García *et al.*, 2020; Sidorovich *et al.*, 2010). This change in diet could result from direct aggression between the mink species, often leading to the European – the smaller – counterpart to flee the fight and hide in unfavourable terrain (Sidorovich & MacDonald, 2001). Furthermore, American mink may impede European mink reproduction: American mink become reproductively active earlier in the year than European mink, and hybrid embryos are resorbed by female European mink (Ternovskij, 1977), making them reproductively ineffective for that year.

Hybridisation

Maran and Raudsepp (1994) discovered hybrids between the European mink and the polecat (*Mustela putorius*), which they speculated could have aggravated the decline of the former through competition and hybridisation. This is contested however, as research has also found that hybridisation events between the two were only detected in areas where European mink were already extremely rare. It could be that European mink only breed with polecats if there is a lack of mating partners for the former, a situation in which they already risk extinction (Cabria *et al.*, 2011; Lodé *et al.*, 2005).

Crayfish specialist

Henttonen (1922) linked the decline of the European mink to the simultaneous decline of the European crayfish (*Astacus astacus*) after invasion of the crayfish plague in Finland. Although some studies indeed found crayfish to be an important part in European mink diet (García *et al.*, 2020; Maran *et al.*, 1998; Sidorovich *et al.*, 2010), in others crayfish were not at all a significant addition (Palazón *et al.*, 2004; Palazón *et al.*, 2008; Sidorovich, 2000). European mink are likely to adapt the crayfish proportion in their diet to availability in their environment.

Rodenticides

European mink have been found to suffer from secondary poisoning by rodenticides in France. 13% of the animals in the sample had been exposed, and a fifth had died directly from bromadiolone poisoning, although it is likely that more if not all would have been increasingly vulnerable under the effects of the rodenticide (Fournier-Chambrillon *et al.*, 2004). Bromadiolone is used extensively to reduce coypu (*Myocastor coypus*) and muskrat (*Ondatra zibethicus*) densities, and the poisoned bait is placed in the same aquatic habitats that European mink use to hunt.

Relevance to the Netherlands

The next question to answer is whether these threats apply to the Netherlands, and could possibly complicate reintroduction efforts.

Habitat loss: Habitat suitability is discussed in *3.2 Habitat and climate*.

Road kills: The Netherlands is already taking precautionary measures to avoid road accidents with larger mammals, such as deer, by placing fences around nature reserves, and 'ecoducts' (wildlife crossings) arching over highways for connectivity. Unfortunately, these fences don't protect the smaller mustelids, and could therefore endanger settling European mink populations. This concern was already present during the reintroduction of the otter in the Netherlands, and precautionary measures were taken to protect the otter from the dangers of the road, such as otter-proof fences and fauna tunnels below highways (pers. comm. Loek Kuiters). Despite these precautionary measures, road accidents were – and still remain – the number one cause of death of wild otters. It is important to revisit and strengthen the safety measures before European mink are released into the wild.

Trapping: The Netherlands is actively trapping coypu, muskrat, and American mink, and these traps could pose a threat to novel European mink. However, in their report, the Dutch *Unie van Waterschappen* (translates to Union of Water Boards) showed that through intensive trapping muskrat and coypu can be fully eradicated from the Netherlands (Bos & Gronouwe, 2018). They estimated this project to take an approximate 12 years, and would push muskrat back to the borders of the Netherlands with Germany. At that moment, only the wetlands on the borders would need to be monitored and provided with traps.

American mink: American mink in the Netherlands have been frequently caught as by-catch. After mink farms were closed due to the COVID-19 pandemic in 2021, the number of caught and detected American mink dropped drastically, from ca. 100 to a mere dozen a year (Dutch Mammal Society, unpublished). Most sightings and trappings have unequivocally been concentrated around areas with high mink farm densities, and as such the Dutch Mammal Society believes that no wild American mink populations have established. This is paramount in the introduction of European mink, and the American mink presence in the Netherlands needs to be monitored with utmost scrutiny. If necessary, live trapping of this invasive species could be implemented. Although most traps are a threat to both species of mink, traps on top of small flotillas on bodies of water are highly attractive to American mink, while their European counterpart generally avoid it (pers. comm. Dick Klees). This theory needs to be researched however, as some European mink do appear to climb onto these flotillas (pers. comm. Tiit Maran).
The trend of the American mink in the Netherlands poses an interesting thought. In many other countries, escaped American mink established wild populations, yet in the Netherlands they have failed to do so. This raises the question whether that might be because there is an unknown factor that impedes their ability to settle, and if that could apply to the (quite similar) European mink as well. It could be that the high intensity of muskrat and coypu trapping removes the American mink from the wild as fast as the farms lost them, or that the farms were located in highly unsuitable areas. Research needs to be done to determine whether the absence of American mink predicts the failure of European mink settlement.

Hybrids: The polecat is widespread in the Netherlands, and hence the risk of hybrids exists. However, as discussed before, it is likely that European mink only mate with polecats when they lack male partners of their own species. Introducing plenty of males along with the females should avoid this situation. As far as is currently known, European mink cannot procreate with any other species.

Crayfish: The European crayfish, although priorly abundant in the Netherlands, was brought near extinction due to the crayfish plague, and replaced by several invasive American crayfish species. These invasive species (e.g. *Orconectes limosus*, *Pacifastacus leniusculus,* and *Procambarus clarkii*) have spread widely across the Netherlands and have severe negative ecological impact (Soes & Kroese, 2010). As was mentioned above, European mink adapt their diet to prey availability. However, Haage *et al*. (2017) demonstrated they become crayfish specialists if given the choice, and in Spain they are consuming the invasive crayfish *Procambarus clarkii* in great numbers (García *et al.*, 2020). It is therefore plausible that European mink would prey on American crayfish in the Netherlands as well, and may add to the control of an undesirable exotic species. Small mustelids were shown to slow population growth of their prey species, which is a first step in eradication (Klemola *et al.*, 1997). Coincidentally, reintroduced otters were also observed consuming these exotic species (Prescher, 2020; see also *Supplementary Material 3.* Otter consuming crayfish), *Rodenticides:* Like France, the Netherlands utilises poison traps to eradicate crop pest species. Although its usage is undergoing rapid reduction (pers. comm. Dutch Mammal Society), it is important to keep habitat suitable for the European mink free of such traps to avoid secondary poisoning.

3.2 Habitat and climate

As can be deduced from the historical and current range, European mink have a high tolerance for a large range of climatic conditions. They thrive both in the snowy brooks of Estonia, and the warm summer streams of Spain (see *1.2 Species Profile*). Therefore, it is to be expected that the climate of the Netherlands will pose no problem for their survival.
Contradictory, European mink as semi-aquatic predators have distinct habitat preferences. They settle along rivers, tributaries, and lagoons that have ample bramble bushes and reeds for cover and protection while resting. They prefer permanent water bodies and open marshland, but avoid dense forests and cultivated fields (Fournier, 2007; Zabala & Zuberogoitia, 2003b). There appears to be a dichotomy between sexes: females prefer lagoons and tributaries or small streams, where they mainly den under the cover of bramble bushes, whereas males prefer river sections and have a much larger linear home range than females – 12 km for the former versus 2.5 km for the latter (Fournier *et* al., 2007; Palomares *et al.*, 2017a, 2017b). Male European mink rest at the very edges of their territory, possibly as a cost-effective way to patrol and defend their home range (Zabala & Zuberogoitia, 2003a). Both sexes and all age classes rest primarily within bramble bushes and reed patches, although they occasionally settle in burrows, breakwaters, or between roots (Fournier, 2007; Palomares *et al.*, 2017b). On Hiiumaa island, where the bramble and reed are lacking especially in winter months, they hide between the roots that hold the stream bank (see *Supplementary Material 2.3*).
European mink are highly sensitive to fragmentation of river stretches, as well as pollution and canalisation of streams, and avoid inadequate wildlife crossings that would expose them to predation (Lodé *et al.*, 2001; Lodé, 2002; Zabala *et al.*, 2006; Zuberogoitia *et al.*, 2013). Hence, the area of reintroduction will need to be scanned for anthropological modifications, and judged for their impact on the European mink. Not all anthropological modifications will have a negative effect, and many can be negated with careful consideration.

European mink live in close sympatry with both polecat, and otter. Wherever the European mink may be found, one or both of the other riparian mustelids are present as well (Cabria *et al.*, 2011; Fournier, 2007; Fournier-Chambrillon *et al.*, 2004; Lodé *et al.*, 2001; Maran *et al*., 2009; Palazón *et al.*, 2004; Palazón *et al.*, 2008; Sidorovich, 2000). Although there are numerous differences between the three species, and a habitat suitable for one might not be favourable for the other two, the polecat is common throughout the Netherlands in both aquatic and terrestrial ecosystems, and the otter has been thriving in locally suitable habitat (NDFF & Zoogdiervereniging, 2022). It is expected that the European mink, as a species intermediate between the otter and polecat, may thrive in the same areas in the Netherlands, provided those areas have ample bramble and reed cover. The Netherlands is saturated with wetlands, marshland, and reed-lined streams and rivers. This is further explored in *5.1 Release Sites*.

3.3 Genetics

Despite the European mink's critical status, its genetic diversity is relatively high compared to other Mustelidae taxa (Skorupski, 2020), although this genetic diversity isn't equally distributed geographically: the western European populations have a significantly poorer genetic diversity than both eastern European ones (Michaux *et al*., 2005). The high homozygosity in the Spanish population does not seem to impede its growth however, suggesting they are not hindered by inbreeding yet (Skorupski, 2020). The primary discussion around the genetic management of the European mink, is whether all three populations can be considered independent, or if they fall within a single European-wide, though fragmented, metapopulation. In a genetic study of Michaux *et al.* (2005), populations of European mink did not have any geographical genetic structure, and had not evolved into separate populations. They concluded that not only do the three populations fall within the definition of a single Distinct Population Segment, but also that the best chance to save the species is to maximise genetic variability of all populations – particularly in reintroduction programmes. Intermixing several unconnected populations poses an outbreeding depression risk, which is a reduction in reproductive fitness due to the loss of genotypes adapted to a specific location. According to the decision tree in Frankham *et al.* (2010, Figure 1), it would be appropriate to evaluate the probability of outbreeding depression in more detail, as there are substantial environmental differences between the three European mink populations and then have been separated for over 20 generations. However, Frankham *et al*. (2010) advocate for a proactive approach, encouraging to augment gene flow wherever possible and monitoring the possible effects closely.

3.4 Diseases

In any reintroduction programme, disease considerations are of utmost importance (IUCN/SSC, 2013). Pathogens, both from the population of origin and the target area, can have a most severe negative impact on a newly establishing and vulnerable population. Viggers *et al.* (1993) argued that a few simple steps may avoid numerous disease related complications in reintroductions, the very first of which is to investigate pathogens to which the target species is especially vulnerable. Below is an elaboration on the most notorious mink diseases, but it is by no means a complete overview.

In today's society, COVID-19 plays a prominent role. Following the initial report of Sars-CoV-2 infections resulting in COVID-19 on mink farms in the Netherlands, many countries mandated culling of American mink, fearing mink-to-human infection and new variants (reviewed in Sharun *et al.*, 2021). No reports have been made of European mink infected by Sars-CoV-2 so far, but it is likely that this species too is vulnerable. In the breeding centre in Estonia, only caretakers are allowed in and they are required to change clothes and wear a mask before interacting with the European mink, to reduce the risk of infection (pers. comm. Tiit Maran). So far, this has been effective in their facility. However, COVID-19 still poses a threat and can be fatal for at least the American mink (Sharun *et al.*, 2021).

Possibly the second most obvious disease risk to discuss, is the Aleutian mink disease (AMD), caused by the Aleutian mink disease virus (AMDV). AMD leads to spontaneous abortion and death, and can be identified by the antibodies that are produced by the host – but are ineffective against the virus (Leimann *et al*., 2015). As the name suggests, it is a virus primarily affecting mink species. It has been found regularly in captured American mink, but the prevalence of infections is lower in wild European mink and free-ranging American mink (reviewed in Zaleska-Wawro *et al.*, 2021). AMDV antibody positive European mink are not restricted to American mink farm areas, but are spread throughout their entire range (Mañas *et al*., 2016). A third of wild European mink were found to be AMDV antibody positive, and it is likely that AMD affects the reproductive capacity of the females, exercising an indirect effect on the survival of the species. No information could be acquired on the prevalence of AMDV antibodies in captive European mink.

Another disease of interest is leptospirosis, caused by the bacteria *Leptospira interrogans*. It is the most widespread zoonosis, having been found on all continents (except Antarctica) and is present in nearly all mammalian species examined – including humans and European mink (Adler & Peña Moctezuma, 2010; Moinet *et al.*, 2010). Infection usually occurs through direct contact with another infected animal or its urine, and animals in aquatic or humid environments have an increased risk of exposure (André-Fontaine *et al.*, 1992). European mink, along with several other mustelid species, were found to have a very high prevalence of leptospirosis in southwestern France, possibly through exposed waterbodies (Moinet *et al.*, 2010). They are especially vulnerable because they reside in (semi) aquatic habitats, which they share with known leptospirosis reservoirs such as rats, muskrat, and coypu. Moinet *et al.* (2010) stress the vulnerability of European mink to leptospirosis and the importance of properly disinfecting traps to avoid infection.

Canine Distemper (CD), caused by the Canine Distemper Virus (CDV), is one of the most prevalent diseases in captive and wild ferrets. It has broad host range and has been found in several mammalian families such as Canidae and Mustelidae, transmitting through direct animal-to-animal contact (Martella *et al.*, 2008). Despite the high occurrence of the virus in ferret species, only 9% of European mink were found to have CDV antibodies, as opposed to 20% and even 33% of polecats and stone marten respectively (Philippa *et al.*, 2008). This is most likely because polecats and stone marten live in closer contact with domestic dogs – a species known for its transmission of CDV to other species (Müller *et al.*, 2011; Philippa *et al.*, 2008). Several CD outbreaks have been reported on American mink farms in the Netherlands, after vaccination was deemed optional instead of mandatory (Molenaar & Buter, 2018). Fortunately, due to the closure of all mink farms, this specific risk can be dismissed.

3.5 Legislation

The acquisition, transportation, and release of wild animals is accompanied by extensive legislation. This part is not an extensive overview of these laws and how to apply them, but provides a first impression on what needs to be considered.

First and foremost, the acquisition of the European mink for release. Animals can be either caught from the wild, or bred for release. Each country has their own legislation in relation to capturing wild animals – especially if they are critically endangered. Precisely what this legislation entails should be discussed when it has become clear if and from where wild animals could be translocated. If only captive animals are used, this part can be omitted.

Secondly, ownership and transportation. The CITES regulation (*The Council Regulation (EC) No 338/97 of 9 December 1996 on the protection of species of wild fauna and flora by regulating trade therein*) covers most of the legislation related to the ownership and transportation of endangered animals, and the parties involved in the reintroduction of the European mink will have to apply for numerous certificates.
Transportation will have to agree with the *CITES guidelines for non-air transport of live wild animals and plants*, and must be in agreement with the laws and regulations from the countries of origin, transit, and destination. Prior to transportation, all animals must be examined thoroughly by a veterinarian.

Thirdly, the release of the animals. According to article 3.34 of the Dutch *Wet Natuurbescherming*, reintroduction of wild animals must be approved by the states or the ministry prior to implementation. Following article 3.5 and 3.6 of the *Wet Natuurbescherming*, protected wild animals may not be owned, harmed, or even disturbed in their natural habitat. During any reintroduction project, disturbance of the environment and loss of reintroduced animals is near inevitable. However, under article 3.8, states and the ministry can provide exemption for these laws if i) there is no other suitable solution, and ii) it is necessary for the protection of the species.

3.6 Public concerns

All reintroductions face the challenge of public opinion, although some more than others. The reintroduction of a butterfly might go completely unnoticed, while the reintroduction of wolves in North America caused more resistance (Williams *et al.*, 2002). The more damage the animal is expected to do, or interference it is expected to have, the more likely people are to take an interest in the reintroduction.

Because the European mink is so rare, it has so far caused very little damage. Hence, it is advisable to look at related and similar species. British research concluded that polecats caused damage to farmers and gamekeepers, for example by predation of penned game and livestock, although this damage was minimal (Packer & Birks, 1999). Another mustelid species, the beech or stone marten (*Martes foina*), has been known to cause biting and scratching damage to cars, notably wiring and coolant hoses (Müskens & Broekhuizen, 2005).

Unfortunately, as could be deduced from some of the interviews, the European mink could suffer from an initial negative image that might be hard to overcome: in 2020 in the Netherlands, American mink – a species that is very alike to the European mink in looks – were culled *en masse* to protect us against spill-back of typical mink Sars-CoV-2 viruses. The general public might not even be aware that there is any difference at all between the critically endangered European mink and captive American mink, and former fur farmers could feel slighted that the government would support a reintroduction but not their livelihood. Of note in this discussion is that the government of the Netherlands already had mandated the closing of American mink farms by 2024, and the emergence of COVID-19 merely brought the deadline forwards (Staatsblad, 2020). Therefore, the decision to close the mink farms didn't solely rely on the danger from COVID-19.

Another discussion point regularly arises when one discusses the European mink: can it be considered a native species[1], entitled to our protection? Due to its recent emergence in Spain and its prolonged absence in numerous countries, there is an ongoing debate on whether the European mink deserves the protective status in western Europe that it now receives. Carbonell (2015) argues the Spanish population is not endemic, but rather a growing unit beyond the European mink's native range, and urges to proceed carefully to ascertain native Spanish mammals are not disadvantaged under the growth of the European mink population. Michaux *et al.* (2005) concluded that the European mink was introduced in Spain and France through anthropological aid, and based on these findings Clavero (2014) regards the European mink as an introduced and invasive species. Zuberogoitia *et al.* (2016) counters that there is no evidence for an anthropological introduction, but rather that the European mink established in western Europe through *natural* expansion. Indeed, this theory appears to be more likely. The fossils found in the Netherlands suggest the species used to be widespread in Europe, and genetic studies revealed that the western and eastern populations separated shortly after the last glaciation, after which the western population expanded and restored from a severe and unknown bottleneck effect, crossing the southern French border into Spain (Cabria, 2015).

When the otter reintroduction was initiated in the Netherlands, people local to the reintroduction site were informed through news articles, radio, and television, but also educated through more personal lectures and excursions into the release areas (Hof & Langevelde, 2004). However, despite the educational aspect, no assessment was done of the public's opinion and feelings regarding the otter's reintroduction. In fact, very little research at all has been done around the public opinion of mustelids and their reintroductions (Jacobs, 2021). To ensure a long-lasting and prosperous project, involving the community and having their approval is paramount and must be ensured. The only record of a European mink in the Netherlands is over 4000 years olds (Bree, 1961a,b), and people are likely to confound it with its unwanted invasive American counterpart. Much like was done at the time of the otter reintroduction, it is advisable to educate the public on the differences between the species, and the benefits of reintroducing the endangered European mink to aid the species' survival. In contrast to the otter reintroduction however, it is also important to – before and/or after

[1] What precisely the definition of a native species is, remains a subject of debate and complicates the matter even further. For the sake of simplicity, I will adhere to the definition used by the IUCN: "A species, subspecies, or lower taxon, occurring within its natural range (past or present) and dispersal potential (i.e. within the range it occupies naturally or could occupy without direct or indirect introduction or care by humans)."

the educational campaign – assess the public's attitudes towards the project. To ensure approval and support from the people, they should be encouraged to participate where possible. For example, during the reintroduction on Hiiumaa island, the local inhabitants were hired (paid and voluntary) to build the soft-release enclosures for the European mink, place food in them, and even the monitor the released animals (pers. comm. Tiit Maran). This simple act of involvement created a feeling of responsibility in the people.

3.7 Resource availability

Chapters *5. Release & Implementation* and *6. Monitoring & Continuing Management* outlines several steps that need to be taken to reintroduce the European mink in the Netherlands. This project would be a long, and expensive undertaking, and financing needs to be acquired with this in mind.
The European Union provides grants under the *Programme for Environment and Climate Action*, more commonly known as LIFE. The sub-programme *Nature and Biodiversity* focusses on the implementation of EU nature and biodiversity legislation, of which protecting a critically endangered European species is a major part. The reintroduction of the European mink in the Netherlands would fall under the LIFE Nature and Biodiversity Intervention area "Safeguarding our species", and could therefore be eligible for funding (European Commission, 2021).
If a LIFE grant is approved, there still remains a significant financial burden. The reintroduction of the otter in Sweden was financed by the World Wide Fund for Nature (WWF) Sweden, the Swedish Environmental Protection Agency, and the Swedish Hunters Association (Sjoasen, 1997). The reintroduction of the European mink in Saarland, Germany, was financed by the Ministry of Environment of Saarland (Germany) and Saar Toto (Peters *et al*., 2009).
Aside from governmental and non-governmental organisations, national zoos and parks can sometimes be interested in participating with a reintroduction as well. Avifauna, a zoo that focusses on birds but is presently expanding its number of mammals, and GaiaZOO, which has been part of the European mink the EEP since 2005, have both expressed their wish to be a part of the reintroduction (pers. comm. Johan van der Haven resp. Hanneke de Boer).

3.8 Conclusions

Most of the threats to the European mink have been addressed in the Netherlands. The dangers of roads are in need of further investigation, and wild American mink sightings need to be monitored closely, as well as the cause of their inability to form a wild population. There should be ample habitat for the European mink to settle, which will be further discussed in *5.1 Release Sites*. It is advisable to run a habitat suitability analysis before deciding on the final release location. Genetically, the European mink appears to be healthy for now, but considerations regarding the intermixing of the three separate wild populations need to be made. More research needs to be done regarding disease risks in the Netherlands, and how to best protect the animals before reintroduction. Lastly, much like was done during the otter reintroduction, the public should be involved in the European mink reintroduction to ensure a long-lasting prosperous project, as well as educated on the urgency of the reintroduction and the differences between the American and European mink.

4. Risk Assessment

Any reintroduction comes with risks, both to the reintroduced species and the reintroduction sites. After assessing the feasibility of the reintroduced species to survive and thrive in their new environment, it is important to determine what the risks of failure and unfavourable effects are before deciding to move forward with the reintroduction programme. This part aims to assess these risks, as well as point out areas for further investigation.

4.1 Source Populations

Reintroductions using wild-trapped carnivores are significantly more likely to be successful than reintroductions using captive-born animals, as the latter are more susceptible to starvation, predation, and disease (Jule *et al.*, 2008). However, this leaves the source population weakened, as population size is one of the highest predictors of extinction risk (O'Grady *et al.*, 2004). When the European mink was introduced on the island of Hiiumaa and in Saarland, only captive-bred individuals were released from a breeding programme initiated in 1984 (Maran *et al.*, 2017; Peters *et al.*, 2009). If the risk to the wild source populations is found to be too significant, releasing captive bred individuals would be a feasible alternative. Currently, a European mink breeding programme is established under the EEP (European Endangered species Programme) of EAZA (European Association of Zoos and Aquaria), but efforts need to be upscaled if successful restoration of the wild populations is to be achieved (Maran *et al.*, 2017). Ideally, the wild and captive populations of European mink would fall under a joint management programme, which would allow for maximum genetic variety of both the wild and the breeding animals.

4.2 Ecological Risks

Bringing a novel species into an established environment also poses risks for the native biota, such as competition or hybridisation with indigenous species. These risks need to be considered before a decision for reintroduction can be made.

Competition between similar species can be strong when the diets overlap, forcing them to reduce their breeding attempts or alter their diet composition (e.g. Charter *et al.*, 2018). There are numerous other mustelids residing in the Netherlands, such as the otter, polecat, or the common weasel (*Mustela nivalis*). Berge *et al.* (2021) studied the food niche of six Belgian mustelids, compared their overlap, and concluded that all food niches differed from one another quite clearly. Although the European mink's diet is similar to the polecat's, there is still a significant divergence in the former's preference for amphibians and crustaceans. Furthermore, the European mink readily coexists with these close relatives in most of its existing range. Therefore, although competition is always a risk, it appears to be minor in the case of the European mink.

There is a hybridisation risk between the European mink and its close relative, the polecat (Maran & Raudsepp, 1994). These hybrids occur in areas where the European mink is extremely rare, and it is possible that European mink mainly hybridise with polecats if there is a lack of mating partners for the former (Cabria *et al.*, 2011; Lodé *et al.*, 2005). This is, of course, a concern. During its reintroduction, the European mink will be sparse and it is not unlikely that it might hybridise with the polecat. This risk can be reduced by introduction plenty of male individuals, to allow for sufficient intraspecies breeding opportunities. No hybridisation events between the European mink and other species than the polecat are currently known.

As an opportunist, the European mink predates on a variety of organisms based on what is available. It shares its prey with a range of other predators, such as the otter and polecat, to a point where they even consume the same species. The European mink consumes the same fish as the otter (Palazón *et al.*, 2008), and the same small mammals as the polecat (Palazón *et al.*, 2004; Weber, 1989). Because both of these predators are already present in the Netherlands and their prey

species are thriving regardless, it is unlikely that the European mink will overhunt them. Rather, it is likely to aid in containing pest species such as the rat (*Rattus norvegicus*), voles, and mice.
Another prey item the European mink might focus on is crayfish. The European crayfish is nearly extinct in the Netherlands, yet several invasive American crayfish species have spread widely across the Netherlands and have a severe negative ecological impact (Soes & Kroese, 2010). Although several studies have shown that the European mink is not bound to a crayfish rich diet (e.g. Palazón *et al.*, 2008), another study found that captive European mink – when presented with a choice – lean towards a crayfish specialization (Haage *et al.*, 2017). Indeed, Palazón *et al.* (2004) has already made mention of American crayfish (*Procambarus clarckii*) consumption by the European mink, rendering it possible – if not likely – that the mustelid will aid in the control of the invasive crayfish.
Lastly, the Netherlands is home to many protected medium-sized meadow bird species, which are threatened by predation on their chicks and eggs. Despite predatory birds being the main culprits, the stoat (*Mustela erminea*), another small mustelid species, contributes significantly to the loss of meadow bird eggs and chicks as well (Teunissen *et al.*, 2006). However, stoat and European mink differ significantly in their diet, as the main contributors to the stoat's diet are rodents (Berge *et al.*, 2021). Although small passerine birds have been observed in the European mink's diet, predation on medium-sized birds is limited, and only one study mentioned the consumption of eggs, which were duck eggs from a nearby farm (Palazón *et al.*, 2004; Palazón *et al.*, 2008; Sidorovich, 2000; Sidorovich *et al.*, 2010). The possibility of predation on the meadow birds is present but appears to be quite small.

4.3 Disease Risks

The European mink does not appear to have any diseases which are not already present in Dutch mammals. AMDV, leptospirosis, and CDV have all been observed in the Netherlands in the past (resp. Kowalczyk *et al*., 2019; Goris *et al.*, 2013; Molenaar & Buter, 2018). Hence, the risk of introducing novel and dangerous pathogens is small. Regardless, quarantine of the animals to be released and careful monitoring is of utmost importance, both for the safety of the European mink and native Dutch fauna.
Careful considerations need to be made around precautions against COVID-19. A breeding centre is at risk of forming a source of this disease when it has otherwise been removed from the human population (Sharun *et al.*, 2021).

4.4 Associated Invasion Risk

Associated invasion occurs when an organism is present on the reintroduction species (such as a pathogen, fleas, ticks) and become invasive in the reintroduction site. Unfortunately, this aspect is beyond the scope of my knowledge and expertise, and should be analysed by a professional in the field of associated invasions.

4.5 Gene Escape

Gene escape consists of two separate risks: intraspecific hybridisation in the case of reinforcement of an already establishes species, and interspecific hybridisation with closely related local species. The former is not relevant to this case, as there are no European mink currently residing in the Netherlands. The latter has already been discussed under *4.2 Ecological Risk*.

4.6 Socio-Economic Risks

Animals living in close proximity to anthropological settlements affect human society, for better or worse. Mice infect food storages, and bees keep the garden flowers alive. Only very minor damage reports have been made on the European mink, but this could primarily be because of the scarcity of the species. Therefore, it is important to consider related species.

British research concluded that polecats caused damage to farmers and gamekeepers, for example by predation of penned game and livestock, although this damage was minimal (Packer & Birks, 1999). Another mustelid species, the stone marten (*Martes foina*), has been known to cause biting and scratching damage to car parts, notably wiring and coolant hoses (Müskens & Broekhuizen, 2005). However, no major damage reports have turned up during my search on any small mustelid species. The European mink's habitat is isolated enough from cities and the animal is shy enough that it is unlikely to be noticed often. During the first 25 days of the release of European mink on Hiiumaa, several attacks on free-ranging chickens were recorded, but these attacks stopped after the first month (Põdra *et al.*, 2013).

Despite this low chance at economic damage for the average citizen, there is a high possibility that people from specific professions will have concerns regarding the European mink. Although I will address a few of those concerns, it is advisable to involve other stakeholders to hear their view on the matter and possibly come to a resolution that suits all.

As a semi-aquatic mammal, the European mink is vulnerable to fishermen and their traps, much like the otter. A report in 2018 by the Dutch Mammal Society and Stichting Otterstation Nederland (Bekker & Jongh, 2018) emphasised the lack of consistent regulations concerning fish traps, which has caused several otters to drown, both due illegal and legal trapping. In many regions that have established otter presence, fish traps are mandated to have a 'stop grid', a metal grid that prohibits otters from swimming into the trap but is big enough to let fish pass through. This seems like an ideal solution for the European mink as well, but currently used grids are too big (9x9 cm) and won't keep the otter's smaller cousin out. Fishermen are already losing desired large bycatch to the stop grids (Bekker & Jongh, 2018), and mandating even tighter grids risks affronting the fishermen. An alternative to the stop grids could be an escape slit in the traps, which allows otters to leave the trap – even though the animals are subjected to significant stress in the process (Bekker & Jongh, 2018). It is possible that, similar to the otter, European mink would be able to escape the traps through these escape slits. A third solution could possibly include a type of fish trap that is partly above water, thus allowing trapped mammals the opportunity to breathe until they are released. More research needs to be done on this front, and responsibility cannot solely be placed at the feet of the fishing organisations.

As was already discussed in *3.1 Threats*, professional coypu and muskrat trappers would need to adapt their trapping methods if the European mink is to be reintroduced. Live trapping is a feasible alternative, and more research could be done around selective trapping – such as small flotillas – that European mink seem to avoid.

4.7 Conclusions

Due to the critical status of wild European mink, replacing animals from a wild population to the Netherlands may be too large a risk for the source population. Ideally, the wild and captive populations would fall under a joint management programme, which would allow for the highest genetic diversity in all populations.

European mink may pose a threat to meadow birds, although present knowledge deems that threat to be low. It is likely that they will become a natural predator of the invasive American crayfish, and as such aid in its control. More research needs to be done concerning disease and associated invasion risk by experts in pathology. The socio-economic damage could be relevant, especially for certain professions like fishermen, and open communication is important for damage mitigation.

5. Release & Implementation

If a reintroduction is deemed favourable and within reasonable risk margins, several logistic details need to be considered. There are both economic and ecological constrains to the number of animals, the age structure, and the location(s) for the release. Adaptations can be made during the reintroduction process, and certain decisions cannot be made before more information is known – such as where the animals can come from and how many can be acquired -, but determining a baseline to expand on can be done early on.

5.1 Release Sites

There are several sites in the Netherlands that meet the requirements of water bodies and ample hiding spots from bramble bushes and reeds, which are the main requirements for suitable European mink habitat. The water needs to be clean enough to sustain a (cray)fish population and plenty of amphibians. The site also needs to have enough water shore length for a European mink population to settle, and preferably to allow for connectivity with other suitable sites for a stable meta population.

The National Park Weerribben-Wieden is a peat swamp area of roughly 100 km^2, characterised by freshwater lakes and canals, reed beds, fens, wet meadows, and forested peatland. Since their reintroduction in 2002, an otter population thrives in the park (Ramsar Sites Information Service, 2017). Polecats are a common sight as well (NDFF & Zoogdiervereniging, 2022). The park is closely connected to the Zwarte Meer, a lake with reed banks and patches of forest. Upstream is the IJssel, a fairly calm river that runs south through agricultural lands and other national parks. A possible downside of the Weerribben-Wieden is that the soil is of relatively low quality, and the habitat has a possible deficit of prey in the winter months (pers. comm. Paul Voskamp).

In the province South-Holland, there are numerous interconnected lakes and rivers between The Hague, Uithoorn, and Nieuwkoop. It consists of a varied landscape, with intermittent forests, meadows, and reed covered riverbanks. Otters have been sighted there, along with polecats (NDFF & Zoogdiervereniging, 2022). However, not all these lakes are properly connected, some can only be reached by following rivers through densely populated areas, and disturbance by recreation is high.

Another more isolated National Park is the Biesbosch, a tidal wetland of 90 km^2 filled with reedbeds, swamp forests, and creeks (Ramsar Sites Information Service, 2014). Although otter observations in the area are scarce, polecats occur commonly (NDFF & Zoogdiervereniging, 2022). The river Waal runs through the middle of the park, but following the water downstream brings few interesting patches, and the river debouches into the ocean not much further. Upstream of the river Waal is nothing more than agricultural fields and hamlets for over 50 km until the German border.

Considering that there is no intrasexual home range overlap even between captive born individuals (Peters *et al.*, 2009), the animals should be released solitarily or in mating pairs. Females can be released around 2-3 km apart, and males around 12 km (see *3.2 Habitat and climate*).

During the releases in Hiiumaa, European mink were found to spread up to 32 km from their initial release site over a period of three months, although most stay within a 5 km radius (Harrington *et al.*, 2014). Assuming this to be universal, the animals should not find any problems to expand from the Weerribben-Wieden park to the Zwarte Meer, or colonise new lakes and rivers in South-Holland. If reintroduction is to commence in the Biesbosch, it may be necessary to aid the European mink in colonising new areas.

5.2 Age Structure & Sex Composition

When releasing individuals, it is important to consider both the age and sex composition of the animals. In the Hiiumaa reintroduction of the European mink, survival of the released individuals did not vary with age but rather with sex. Males were three times more likely to survive the first months than females (Maran *et al.*, 2009). In Saarland, some of the adult females delivered their kits in naturalistic enclosures before release, but most were released with their mating partners while pregnant and this appears to have been successful (Peters *et al*., 2009). In the first years of the reintroduction on Hiiumaa, adults were released both with and without kits, but in later years only pregnant females were introduced through soft release (pers. comm. Tiit Maran). This method ensures that the juvenile mink have only had limited contact with humans and are as independent as can be achieved on their release.

Preliminary research conducted for the reintroduction of the European mink in Estonia suggested 30 to 40 founder animals to guarantee sufficient genetic diversity (Macdonald *et al.*, 2002), and subsequently 112 individuals were released in the first three years of the project (Maran *et al.*, 2017). The German reintroduction in Saarland featured the release of 75 animals in a three-year period (Peters *et al.*, 2009). Both reintroductions were successful, although Maran *et al.* (2017) released many more individuals in the years to follow. This was likely necessary, because the survival rate of released European mink in the first three years was low (40% confirmed dead, 48% unknown, and only 12% confirmed alive), severely decreasing the effective population size after release.
Although it is naturally advisable to release as many animals as possible within economic and ecological constraints, it seems no less than prudent to pick a bare minimum of 75 animals – like the Saarland reintroduction -, and have a female-male composition of around 3:1 to balance out the lower survivability of females and the polygynous mating system. A more skewed composition could possibly lead to hybridisation with the polecat, as was suggested in *3.1 Threats*.

5.3 Season for Release

On Hiiumaa, adult European mink were released in May and June whereas juveniles were released in September (Maran *et al.*, 2017). In Saarland, adults were released in April and May, and mother-offspring pairs were released in July and August (Peters *et al.*, 2009). Releasing animals in the summer months ensures that plenty of prey is available, facilitating survival and adaptation to the wild and allowing the animals to prepare for the scarcer winter months.

5.4 Pre-Release Conditions

If animals are to be bred for release, the best course of action would be to set up a breeding centre in the Netherlands, to avoid excessive stress for the animals through travelling. Ideally, this centre would be able to hold over 100 animals, which can produce 10 pregnant females a year for release (pers. comm. Tiit Maran). The European mink enclosures in Tallinn Zoo are 8 m^2, but this is the bare minimum; 16 m^2 would be more suitable. The animals should have access to flowing water to properly develop swimming skills and ample enrichments to occupy them.
Captive European mink selected for release on Hiiumaa received live prey once to twice a week to train them in hunting, which may have helped the animals to catch their natural prey in the wild (Põdra *et al.*, 2013). However, during the first ten days after release the diet was atypical, and the researchers speculate that this was still caused by the captive born animals' inability to find and catch prey. Although there may be moral objections, allowing the captive European mink more opportunity to catch live prey could ameliorate their adaptation. For example, live American crayfish could be fed to them, as there is plenty available and invertebrates can be freely fed while alive without the need for a special license or exemption (pers. comm. Johan van der Haven & Joost Lammers).

During the reintroduction of the European mink on Hiiumaa, Maran *et al.* (2008) studied whether large, naturalistic enclosures before release aided the animals to adapt to a life in the wild. Although at the time of the paper's publication the data wasn't sufficient to confirm, in later years they observed much better results with soft-released than hard-release (pers. comm. Tiit Maran). Pregnant females were placed in a pre-release enclosure (see *Supplementary Material 2.2*), which was opened in early August to allow mother and young to come and go at their leisure. Feeding inside the enclosure continued until the mink stopped returning, which was usually after seven to ten days. The enclosure was designed to represent the European mink's natural home range, and as such encompassed a water body and ample hiding spots. Preferably, the enclosure would be as large as a female's habitat, although this is often not realistic (pers. comm. Tiit Maran).

An in-depth review on the selection of habitat by introduced animals stressed how the captive environment might shape the habitat preference in the wild, suggesting that we need to carefully consider what visual, olfactory, and auditory cues we provide the captive animals (Stamps & Swaisgood, 2007). Because of the high importance of waterbodies to the European mink, along with reed beds and bramble bushes serving as hiding places, it could aid reintroduced individuals in selecting proper habitat in the wild if these cues are present in their enclosures, especially in the pre-release enclosures which are young mink's very first impression of their environment.

5.5 Conclusions

National Park Weerribben-Wieden is possibly the best candidate for release location, although research on its prey availability in winter months is advised. The area is large enough to house a European mink population, and has proper connectivity with other suitable sites both up- and downstream. The exact length of stream banks in the park is unknown, but is important to determine if a proper estimate of viable European mink population size in the park is to be made. Ideally, it would be able to hold at least 40 animals. At least double that amount should be initially released to mitigate for early losses. Similar to the Hiiumaa and the Saarland reintroduction, this can be done over a period of 1 to 3 years. Adults should be released in spring, whereas mother-offspring pairs should be released in late summer, to ensure the young to be mobile. The most successful method of release is considered to be placing pregnant females in pre-release enclosures during spring, and allowing them to leave the enclosure in early August. Pre-release conditions need to be optimised for semi-aquatic mustelids, to prepare them for a life in the wild, preferably with hunting opportunities and proper water bodies.

6. Monitoring & Continuing Management

Once animals have been released for reintroduction, all developments need to be monitored. The establishing population's demography, behaviour, reproduction, and health can give insight into the success – or failure – of the reintroduction, and possibly indicate whether more measures need to be taken to ensure success. Furthermore, the development of the public's feeling and the economic aspects must be assessed as well to ensure that no conflict arises between the people of the Netherlands and the wild European mink.

Surprisingly, very few reintroductions set up a rigorous monitoring plan, although improvements have been made in the past two decade. During the reintroduction of brown bears (*Ursus arctos*) in northern Italy, genetic monitoring revealed a strong decline in genetic diversity and a need for intervention if the reintroduction was to be successful (Derba *et al.*, 2010). Genetic monitoring of the common hamster (*Cricetus cricetus*) after reintroduction in the Netherlands and Belgium highlighted the differences in success of population supplementation, and allowed the researchers to optimise conservation actions (Haye *et al.*, 2017).

This part aims to suggest different methods that can be employed to monitor the reintroduced European mink, to ensure continued adaptive management and an improved chance at success of the reintroduction.

6.1 Founder Monitoring

The initially released European mink need to be tracked meticulously. Their habitat use and movement through the area, as well as their mortality, will provide insight on the success of the adaptation to the area and consequently the reintroduction. Animals released on Hiiumaa were equipped with a radio-collar, while animals in Saarland had a microchip implanted under their skin (Maran *et al.*, 2009; Peters *et al.*, 2009). Although radio-collars are less invasive than the implantation of a tracker, collars are more likely to be lost due to the similar head and neck circumference of mustelids, or cause skin irritation and injuries (Eagle *et al.*, 1984). Fournier *et al.* (2007) tested several different radio-collar types but found that every one of them caused minor injuries to the European mink and as such adopted implantable transmitters instead. Palomares *et al.* (2017) successfully used intraperitoneal radio-transmitters with movement and mortality sensors to radio-locate the researched animals once to twice daily. Signal was generally lost between 2 and 6 months after release, but in very exceptional cases the signal was kept for over a year. However, the invasiveness of the transmitter remains, along with the risks of operating on such small mammals. It might be possible to equip the mink with a harness – providing it is not too heavy – which can be made looser than a collar while remaining in place. Research should be done on the applicability of radio-harnesses on European mink, and the advantages and disadvantages of both the radio-harness and the intraperitoneal chip should be considered carefully. This research can initially be done on similar species like ferrets, polecats, and American mink.

6.2 Continued Monitoring

A detection method often employed for (semi-)aquatic species is environmental DNA (eDNA). This method extracts species DNA from water samples, and is thus a non-invasive way to determine presence/absence. It has proven to be as reliable as traditional survey methods, but also has its limitations: i) it is impossible to determine the life stage of the detected animal, or even whether it is alive or dead; ii) little is known about the degradation rates of eDNA, with current estimates ranging between one day and one month; iii) due to rapid diffusion of DNA in water, an animal can be detected throughout the waterbody regardless of its exact location, which can be considered both an advantage and a disadvantage (reviewed in Rees *et al.*, 2014). Although eDNA could be useful to determine on a large scale whether European mink have migrated to new territories, it will provide very little information on the growth or the health of the population.

Another method would be to place camera traps around the release sites. González-Esteban *et al.* (2004) found that camera trapping is a reliable, and non-invasive or -intrusive way to monitor

European mink, as they were caught on camera as regularly as many other, less elusive and more common species. The researchers speculated that the European mink's photographability might be because they are bound to the stream- and riverbeds and thus have predictable routes. However, camera trapping will only provide very limited information. It will be difficult to recognise individuals – although it allows for observing life stage –, and impossible to track lineage and inbreeding.
During the reintroduction of the otter in the Netherlands, reproduction and demography was tracked through DNA analysis of otter spraints (Koelewijn *et al.*, 2010). The researchers were thus able to determine the reproductive success of the released otters, and confirm that the population was growing. They were able to confidently track the lineage of all new-born otters, as the population could be considered closed (it was considered unlikely for individuals from Germany to reach the Dutch population). As it is likely a European mink population in the Netherlands would also remain closed for quite some time, this method could be employed for their reintroduction as well. European mink place their scats in self-made latrines that are mostly hidden from human viewpoint, but trained wildlife detection dogs can easily track them (pers. comm. Tiit Maran). DNA analysis is time- and cost-intensive, but does provide lineage and inbreeding information which can be crucial to determining the health and growth of the population.

6.3 Societal Monitoring

In an interview, Coenraad Krijger (IUCN National Committee of the Netherlands) stressed the importance of communication with and consideration for the varying professions that might be affected by the reintroduction of the European mink. This has mostly been discussed in *4.6 Socio-Economic Risks*, but – much like assuring the welfare of the animals doesn't end at release – communication needs to remain open throughout multiple years. An example of the importance of continued communication is the raven (*Corvus corax*) reintroduction in the Netherlands: before the start of the reintroduction, information was spread to educate the public on the importance and positive impact of the raven; however, in the beginning phase ravens and their nests were still being destroyed, and the project managers realised the need for continued education (Vogel, 2021).
If the precautions taken to avoid European mink drowning in fish traps turn out to be insufficient, fishermen need to be supported in the implementation of alternative precautions. Damage reports from European mink on farms and towns should be gathered and assessed.

6.4 Continuing Management

The results that the continued monitoring provide will aid in deciding on steps necessarily to reinforce the reintroduction, or – if even reinforcing fails to improve the reintroduction results – disband the project altogether. If the population is growing slowly, or mortality rate is high, more individuals need to be released. If there are signs of inbreeding, new founders should be added. If man-induced mortality is significant, more precautions need to be taken.
However, it is also important that one dares to acknowledge when a reintroduction has failed. Despite the success of the reintroduction of the otter in the Netherlands, we cannot be certain that the critically endangered European mink will fare just as well. Due to the very limited amount of resources in terms of individuals, my advice would be to set a timeframe of a predetermined number of years after which an evaluation is done on if the European mink established a naturally growing wild population in the Netherlands.

6.5 Conclusions

Initial monitoring of the founders can be done through intraperitoneal radio-transmitters, which allows tracking for 2-6 months after release. If a less invasive method is preferred, more research needs to be done on the applicability of radio-harnesses. Further non-invasive monitoring can be done through I) eDNA, which is as reliable as traditional survey methods but gives little information other than presence/absence; II) camera traps, which allows for observation of life stage and precise

location, but doesn’t track lineage or inbreeding; III) and scat DNA analysis, which enables the monitoring of lineage and inbreeding, but is the most cost- and time-intensive method of all.
The impact of European mink on society should be carefully registered, and these data combined with the monitoring data of the released animals can set the groundwork for continued management of the reintroduction.

7. Conclusion & Closing Remarks

Most threats to the European mink have been successfully addressed in the Netherlands. To avoid the native mustelid to be once again outcompeted by the invasive American mink, sightings of the latter need to be monitored scrupulously. A study should be conducted to research why the American mink has never succeeded in settling a wild population in the Netherlands, to ensure this cause will not hamper a European mink reintroduction. Although suitable wildlife crossings have been implemented for the otter, it is advisable to ensure they are abundant enough and no potentially dangerous road bottlenecks are left in European mink suitable areas.

While European mink are predators, there is no reason to suspect they will form a major risk to protected Dutch fauna such as meadow birds: predation of European mink on medium-sized birds is limited. Much more importantly however, is the likely predation on invasive American crayfish species. Although not bound to a crayfish diet, European mink show a preference for crustaceans and they can be expected to aid in the control of American crayfish in Dutch rivers and streams.

A paramount consideration in the reintroduction of the European mink, is the source population. With the scarcity of wild individuals, the risk may be too great to extract European mink from wild populations, but animals that have been in captivity for several generations risk difficulty adapting to a new lifestyle. Breeding programmes should be upscaled if reintroductions are to be successful, and exchange between populations is necessary to ensure genetic diversity and health, for example through a joint management programme of wild and captive populations.

Soft-release of pregnant females in large pre-release enclosures has been found to be the most effective method of release. However, the most efficient monitoring scheme of the wild animals has yet to be determined and needs to be researched thoroughly.

There are several areas in the Netherlands which are suitable for the European mink. Two National Parks that stand out are the Weerribben-Wieden and the Biesbosch. While the former has superior connectivity, its soil is also of poor quality. Research is needed to determine whether prey species abundance is sufficient in the winter months, and a habitat suitability analysis should be conducted to determine total suitable areas and connectivity.

The societal image of the European mink has two negative sides: firstly, the species hasn't been observed in the Netherlands for over 4 millennia; secondly, American mink farms have just been closed and all animals culled due to COVID-19, and people are unlikely to be aware of the difference between the native and exotic species. To ensure a prosperous and long-lasting project, the reintroduction needs the support of the public and many professional sectors such as fishermen. As of now, no satisfactory solution is implemented to avoid mink from drowning in fish traps and research will need to be done to determine the most effective solution. However, if communication remains open and support is provided to the fishermen, they too are likely to welcome a crayfish predator, as the benefits might outweigh the costs in the long run.

All reintroductions face numerous hurdles on their way to success. One but has to read the book '*Gewilde Dieren*' to know the Netherlands has had its fair share of complications with reintroductions as well. But also its fair share of successes. We have to account for as many factors as possible, while staying open for sudden and unexpected turns and results, and it is perhaps this flexibility that distinguishes success from failure. Still, opposition can be found in every corner, and unfortunately it is unrealistic to expect unanimous support.

The world is changing rapidly, biodiversity is dwindling, and many species are running out of time. The European mink, once such a widespread animal, needs help if it is to survive and grow. I can already hear many people thinking, "But why the Netherlands?". The answer is simple: the Netherlands is one of the most – if not the most – water saturated country in Europe. If not here, then where?

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Supplementary Material

1. Interview Abstracts

1.1 Abstract of the interview with Dr. Loek Kuiters, coordinator of the reintroduction of the European otter in the Netherlands, conducted on 31-01-2022

The conversation with Dr. Loek Kuiters mostly covered the reintroduction of the otter in the Netherlands. We discussed the obstacles they had to overcome, such as road safety, water quality, and genetic similarity between the indigenous (extinct) otter population and the reintroduced animals. The measures taken to protect reintroduced otters against the dangers of roads had been adequate in the direct area of the release sites, but the otters migrated faster than the measures were extended. On top of that, Dr. Kuiters elaborated on the difficulties they initially encountered with catching wild otters from a source population, and their need for a backup captive breeding programme. He furthermore stressed the need to communicate with trappers on trap safety for the European mink, and to consider possible predation of European mink on protected meadow birds.

1.2 Abstract of the interview with Dr. Coenraad Krijger, IUCN National Committee of the Netherlands, conducted on 10-02-2022

The conversation with Dr. Coenraad Krijger focussed on the societal, cultural, and economic aspects of a reintroduction, as laid out in the IUCN guidelines. He stressed the importance of highlighting the added value of reintroducing the European mink, as well as considering the concerns that certain stakeholders (e.g. fishermen, farmers, and the Dutch government) might have. Political context should equally be taken into account. For example, the recent extermination of the American mink farms followed closely by a reintroduction of a very similar species could be a source of confusion. We discussed several ways to clarify potential broader benefits of the European mink reintroduction, such as the mink's predation on the invasive American crayfish. Furthermore, he pointed at that within the IUCN community perspectives and opinions may well differ on the need for reintroducing species, notably after long periods of absence.

1.3 Abstract of the interview with Mark Zekhuis, ecologist at Landschap Overijssel, prior local coordinator of otter monitoring, and co-author of the book 'Gewilde Dieren' on reintroductions in the Netherlands, conducted on 14-02-2022

The conversation with Mark Zekhuis encompassed a variety of topics, but focussed on the responsibilities *after* animals have been released into the wild. Responsibility for the protection of reintroduced species goes beyond the very first years, and continues into monitoring and proper care for the wildlife facilities. Mr. Zekhuis stressed that it must be clear who carries these responsibilities. He further stated that communication with the public is important. Although ecologists might like the idea of reintroducing the European mink, many people will believe it a first-time introduction instead, and he advised us to discover and address the concerns of the agricultural and fishing sector, as well as bird protectors and pest trappers.

1.4 Abstract of the interview with Paul Voskamp, ecologist and policy officer at Province Limburg, conducted on 21-02-2022

In our conversation, Paul Voskamp primarily aimed to speculate and think 'out of the box'. He directed attention towards a few points of interest, such as the American mink's inability to have established a population in the Netherlands, possible predation pressure on the European mink, and the decline of other mustelids in the Netherlands. Although the otter reintroduction was initiated in the Weerribben-Wieden, Mr. Voskamp pointed out that – especially compared to the Biesbosch – the former is relatively nutrient poor and could lack prey in the winter months. Hence, there exists a trade-off between best connectivity and most suitable starting area. Furthermore, we discussed how reintroductions will always involve risks and opposition (often even from within nature protection organisations), and reintroducing a new species doesn't need to be at the cost of protection of existing species.

1.5 Abstract of the interview with Hanneke de Boer, manager education and nature conservation at GaiaZOO, Bas Martens, head of animal care at GaiaZOO, & Emile Prins, curator at GaiaZOO, conducted on 03-03-2022

In the conversation with Dr. Hanneke de Boer, Bas Martens, and Emile Prins we discussed GaiaZOO's past, current, and future involvement in the European mink breeding. They have been involved in the EAZA EEP for European mink since 2005, as only Zoo in the Netherlands, and currently house one male and one female European mink. The Zoo currently has three enclosures. Because the European mink needs quite large enclosures considering its small size, they would encourage other Zoos and parks to support a reintroduction. GaiaZOO has experience with the public education aspect of reintroductions, and already have a European mink exposition in their park. Hanneke de Boer stressed the importance of reaching a broad public, and GaiaZOO can fulfil an educational role in cooperation with the Dutch Mammals Society and other nature organisations.

1.6 Abstract of the interview with Johan van der Haven, field coordinator of nature at Avifauna, & Joost Lammers, curator at Avifauna, conducted on 04-03-2022

The conversation with Johan van der Haven and Joost Lammers took place inside Avifauna park. We mostly discussed the many questions they had concerning the European mink and their housing, some of which could be answered and others were noted down to discuss with Tiit Maran in Estonia. Avifauna is able to build a facility to house and breed European mink, and believe their experience with EAZA's EEP will enable them to do so successfully. If the necessary size of the breeding facility exceeds the free space they currently have, they suggested involving other parties (such as other nature parks or zoos) and they would be willing to fulfil a coordinating role.

1.7 Abstract of the interview with Menno de Ridder, policy officer of Species at the Ministry of Agriculture, Nature, and Food Quality, conducted on 23-03-2022

The conversation with Menno de Ridder concerned the involvement that the Ministry of Agriculture, Nature, and Food Quality has in reintroductions in the Netherlands. In general, the Ministry practices reluctance in reintroductions: it is better to support natural expansion of a species than to relocate it through human intervention. If natural expansion is impossible, a reintroduction can be considered. However, that needs a strong argumentation, for example through an ecological study followed by a stakeholder analysis. Mr. De Ridder concurred that the European mink's predation on the invasive crayfish is an interesting angle, and the European mink can also serve as an ambassador for the increasing water quality in the Netherlands.

The ministry avoids directly supporting reintroductions, but rather finances the research conducted beforehand. In the case of the European sturgeon, they could fall back onto the European action plan, facilitating the justification of supporting its reintroduction. Drawing up a European action plan for the European mink could aid in acquiring support as well.

2. Visit to Estonia – conversation report & photos

2.1 Conversation report

Day 1 – 07/03/2022

Upon arrival we were brought to the guest house in the zoo by Tiit Maran, where we could drop off our luggage. After this we went for a quick lunch at a nearby restaurant. During this luncheon, we discussed numerous subjects, and Tiit told us many things about the European mink reintroduction. Of note are his monitoring methods on Hiiumaa:

They search on predetermined plots along rivers for tracks, along 500m after it had been dry for 5 days to ensure no fluctuating water levels that can inundate the tracks. However, they discovered that there were major discrepancies in tracking results retrieved from different people, making it a highly subjective method. They have been considering eDNA, especially to implement on the reintroduction in the other island, as it is much larger. The use of radio-collars is intensive in terms of manpower, and was often a cause of frustration if the animals could not be found due to malfunction of the collar.

Currently, they're using 8 m^2 per enclosure for European mink, but this is the bare minimum and 16 square meters would be better. The interior of the enclosures is extremely important, as it needs to reflect their natural environment. So far, they haven't found a method to add a proper water system to their enclosures.

Day 2 – 08/03/2022

At noon, Tiit brought us to the research centre of European mink reintroduction, to talk with him and the caretakers of the mink. Below is a short summary of what we discussed:

- Currently, the European mink reside in 8 m^2 enclosures. These enclosures are enriched with natural materials such as plants and branches, but also with tubes hanging high, plastic bottles, bags, or even old shoes. These enrichments allow the mink to interact with objects and avoid boredom. The caretakers watch for signs such as pacing to identify stress or boredom in the animals (although currently the enclosures are quite 'cluttered', rendering it difficult to properly observe the animals).
- Tiit stressed that 8 m^2 enclosures are the bare minimum. He would heavily advice to lean towards 16m^2 enclosures instead, to provide the mink with more space to perform natural behaviour. This equally allows for more space to hunt live prey, if that would be implemented. Currently, they're providing their captive mink with live quail once a week. Tiit believes that if a suitable water system can be added to the enclosures, providing live crayfish could be of great value.
- In the past, they have attempted to provide the European mink with anti-predatory training before release. Unfortunately, this has never worked out and was quickly abandoned. The same happened with swim training: European mink need to be confronted with water and swimming from a young age to ensure appropriation to water.
- The animals selected for release are usually pregnant females. They are moved to pre-release enclosures on site, of which there are currently three. Ideally, these enclosures are as large as European mink home range size, but economic constraints have to determine the maximum realistic size. In early August, the enclosures are opened up, allowing for the females and the new-born young to leave whenever they wish, but return for food if necessary. Usually, they permanently leave the enclosure after seven to ten days. The next year, the very same enclosures can be used to release new pregnant females. This method ensures that young mink are immediately immersed in natural conditions, which aids in their adaptation to the wild. Tiit advised to keep the pre-release enclosures relatively close to one another (a few hundred meters apart). The European mink will spread out sufficiently after release, and this ensures convenience for the humans in maintaining the enclosures.
- In the middle of March, the caretakers commence testing females for oestrus. They do this through vaginal smears. Once the females are in oestrus, one male is placed in their enclosure for breeding. They are observed for at least half an hour, to wait for acceptance cues such as clucking, flehming, or preferably breeding. If the interaction is not positive, the male is removed and another male is tried instead. If the interaction is accepting, they are left together for up to five days. Males and females are paired based on genetics, and oftentimes several suitable males are selected for a single female. Aside from the breeding season, animals are kept in their own separate enclosures. Even breeding pairs are kept apart, to minimise stress in the animals. After all, in the wild, European mink are solitary and territorial animals, only coming together for breeding.
- The health of the animals is tracked based on sight. They look for signs such as malfunctioning hindlegs or low fur quality and take appropriate measures when observed. The animals do not receive an annual check-up.
- Tiit advised us, based on quick back-of-the-envelope calculations of suitable habitat in the Netherlands, to ideally release ten pregnant females a year (which would mean ten pre-release enclosures). This would require the Netherlands to have around 100 captive European mink for breeding, and thus a significant breeding facility. However, such a facility in the Netherlands would come with great advantages, as it would avoid need for yearly transportation of animals from Estonia to the Netherlands for release. On top of that, it would spread stochastic risks that are often associated with endeavours on a single location (a disease rampaging through a breeding facility, environmental stochasticity, etc.), and Tiit is unsure whether they would even be able to expand the Tallinn breeding facility to provide both Estonia and the Netherlands with animals for release.

- Nowadays, breeding programmes are based on genetics, but genetics isn't everything. It's important to take a broader look at the programme, as well as make a concept for a joint management of the captive and wild populations.
- Although not recurrent, European mink have occasionally attacked livestock such as chickens. A compensation scheme is in place, yet many people do not report the loss as they think it such a small issue. Whether the attack was done by a mink is often determined through location, camera images, and tracks. You cannot distinguish mink specific bite marks. Protection from martens is often not sufficient again European mink, as the latter tend to dig their way under fences. Communication with the people is important to avoid complaints of the reintroduction programme.
- The predation from foxes in the Netherlands might pose a problem for European mink, although low predation pressure should be fine. The American mink however needs to be monitored very closely; they are devastating for European mink presence. Wild cameras or footprints in muddy banks in May are a good indicator. It's interesting that no wild American mink populations appear to have established in the Netherlands, while they did seem to in other countries. One hypothesis is that the intensity of the muskrat and coypu trapping has avoided long-term establishment.
- In Spain, European mink were observed going onto the rafts.
- On Hiiumaa, the population has been stable since 2016 and hence hasn't needed any more releases. The population size is 60-100 in spring, and up to 250 in autumn. It's necessary to establish a second population in Saarumaa, and there should be a joint management of the two wild and the captive populations.
- For this project, securing long term funding is paramount. It will take years of releasing animals to establish a stable wild population. Tiit advises at least 20 released animals per year (minimum of 4 pregnant females).
- One major mistake in Estonia was that all founder animals for the captive population came from a single location. It would be more favourable to combine the genes of several wild (and captive) populations to ensure maximum genetic diversity.
- The local people can be involved in more ways than just educational. On Hiiumaa, locals were asked to bring food to the pre-release enclosures, and were asked to exterminate the American mink (which they found to be too challenging, and thus they asked an expert). This ensures that the people see the European mink as 'theirs' and want to protect them.
- Some European mink have drowned in fishing traps on Hiiumaa, but it's a very limited problem.

Day 3 – 09/03/2022
Around noon, Tiit came to pick us up to travel to Hiiumaa. During the trip, we discussed many things, notably the breeding programme. Tallinn has around 100 animals, and around New Year's, all the EEP zoos send their data to Tallinn. They then determine which animals should breed, and if animals should be moved from one zoo to another. On average, around 6 animals are moved between zoos each year. This is quite the pricey enterprise, as translocation costs around 500 euros per animal. Occasionally, zoos do not understand certain decisions, but communication rectifies that quite easily.

Day 4 – 10/03/2022
We left the hotel early morning to make our way past several streams and a pre-release enclosure. In general, the streams are around 1-1.5 meters broad and lined with trees. Often, the banks are high to allow for fluctuating water levels, and the roots of the trees form hiding spots on the banks for the mink. Although vegetation was scarce at our time of visit, Tiit ensured us that there is a dense cover in the spring and summer months. The mink hide their scats in latrines, which can be detected by wildlife detection dogs to allow for DNA analysis.
The pre-release enclosures are larger than the breeding enclosures: this one was around 15 m^2 with access to a water body. The fence was a little over 2 meters high, with a cap on top to avoid animals being able to climb out or in. It also went 50 cm deep into the ground, and another 50 cm inwards to avoid digging out of the enclosure. A small square on the bottom of the enclosure that can be closed off allows the mink to go in and out when they're ready for release. There were branches and hiding spots scattered throughout the enclosure. Although this enclosure was rather small, Tiit stressed the importance of a large pre-release enclosure, as large as can be arranged.

Day 5 – 11/03/2022
Kristel came to visit us late morning, to discuss a few more details on the caretaking of the European mink. There are numerous tasks, some of which are daily while others are yearly.
Daily tasks: Every morning, the first task is to feed the mink. The food is hidden somewhere in the enclosure. After feeding, the mink usually return to the nest box, which allows for cleaning the enclosure. Enrichments are moved (even from cage to cage), to change the environment, and the sawdust from the nest box is cleaned daily. It takes around 10 minutes per mink if you're practiced and efficient. Caretakers note if the mink has left any food from the day before and ensure they've seen the mink in the enclosure.
Other tasks: The sleeping section of the next box, with straw, is cleaned once a week, as well as the pools. If a mink is moved into a new enclosure, the whole enclosure is cleaned thoroughly. Disinfectant is only used if the late inhabitant was sick. Every month the mink are weighed, which is written down. The sand in the enclosure is replaced two times a year, once during spring and once during autumn.
It's impossible to identify pregnancy on sight. Usually, the keepers count the days from the possible insemination on, and then listen for kit sounds coming from the nest box. The breeding success rate varies per year; sometimes it's 100%, and

occasionally only 50%. Generally, all kits survive, although occasionally one or two kits die if the litter is large. The last couple of years, female oestrus hasn't been as good as before. Although causes are unknown, a theory is that there is too much sound coming from the water system. European mink are highly sensitive to noise and need silence.
All the care is provided during the day, but there are still clear indications that the mink are crepuscular/nocturnal in captivity as well. They often sleep after the cages have been cleaned, and there are signs of nightly activity in the morning.
Tallinn zoo tried to breed with 25 females this year, and across all other zoos the number is around the same (although many more were available). Most of the other zoos don't test for female oestrus but rather place the male and female together halfway April. This means that more often than not breeding doesn't happen.
Occasionally, an individual isn't afraid of people but rather curious. Sometimes they leave their enclosure while it is being cleaned, then go back inside at the end. These bold mink are however also often non-breeders.
The ideal building for the mink, according to the managing caretaker, would be as follows: big enclosures (6x4 m), a proper water system, open enough to allow observation, live vegetation, fenced off from one another (e.g. with boards up until 1.5 m high), no physical contact possible between the mink (e.g. double wire mesh or space between the cages), and quiet. Perhaps one-way glass would be useful for observing the mink while granting them privacy.
If the litter is 6+ kits, a hole is made in the wire mesh between the female's enclosure and an empty neighbouring enclosure, to give them more space.

2.2 Photos of the pre-release enclosure

Photo 1: Inside of the pre-release enclosure, with a nest box and branches that form hiding places.

Photo 2: The water body on the inside of the pre-release enclosure, currently frozen over.


Photo 3: The top of the pre-release enclosure, which has a cap to avoid escape of the European mink and entrance of other animals.


Photo 4: The opening in the pre-release enclosure that allows the coming and going of the European mink.

2.3 Photos of European mink suitable streams


Photo 5: A stream on Hiiumaa that is inhabited by European mink.

Photo 6: Roots hugging the river bank, they are used by European mink as hiding places.

Photo 7: A stream on Hiiumaa that is inhabited by European mink.

3. Otter consuming crayfish

Screenshot taken from Prescher (2020), which shows a mother otter and her two young hunting and feeding. The otter on the right is feeding on an invasive American crayfish in the Wieden-Weerribben.