Zoonosis Risk of the Coronavirus – SARS-CoV-2 on Mink Farms

Based on information available on 27 November 2020

Finnish Food Authority

Risk Assessment Unit

CONTENTS

1. BACKGROUND

SARS-CoV-2 is increasingly spreading in humans in Finland. In Europe, SARS-CoV-2 infections have been found in animals on mink farms, which is why the Animal Health and Welfare Department of the Finnish Food Authority asked the Risk Assessment Unit on 12 October 2020 to provide a report on the possible coronavirus risk caused by farmed mink to humans.

The scenario on which the Risk Assessment Unit's statement was requested was the following:

A coronavirus infection has been found in the mink on a mink farm. There is no information about the coronavirus situation on other fur farms. After the infection was discovered, the farm adopts more effective hygiene and infection prevention practices.

- What can be assessed in terms of the infection risk caused by the mink infections to humans, considering the farm employees, their communities, other visitors to the farm, and other people (e.g., via secondary transmissions or from the surroundings of the farm)?
- What is your assessment of the risk that the infection will spread to other mink farms (exposing more people as a consequence)?
- How would it affect the risk to humans if the mink on the farm were euthanised compared to the alternative that the farm only adopts more effective hygiene practices?
- Is it possible to assess the effects of decisions related to individual farms? For example, could the size, structures and location of the farm reduce the risk to human health?

Very little research information about SARS-CoV-2 on fur farms currently exists. Information for the statement of the Risk Assessment Unit was collected from reports made to the World Organization for Animal Health (OIE), scientific studies (incl. non-peer-reviewed studies), statements of the authorities and ProMedMail reports, and through expert interviews. Most of the published studies are based on information from a limited number of Dutch mink farms available at the start of the epidemic.

The following countries have reported SARS-CoV-2 infections on mink farms: the Netherlands, Denmark, the United States, Spain, Sweden, France, and Lithuania.

The Netherlands

The first outbreak of SARS-CoV-2 on Dutch mink farms was discovered at the end of April 2020. At the start of June, the decision was made to euthanise all the mink on infected farms. By the end of November 2020, 70 infected farms had been discovered in the Netherlands, which is more than half the farms in the country.

Denmark

In Denmark, the first SARS-CoV-2 outbreak was discovered in mid-June 2020, and the following two in early July. The mink on the first three farms were euthanised, and the authorities collected and tested samples from 125 other farms, but none tested positive. The fourth infected farm was discovered in late August via the samples sent in for analysis in the context of a monitoring programme.

After the fourth outbreak was detected, the authorities decided that animals on infected farms would no longer be euthanised, and at the end of September, Denmark stated in its OIE report that the farm in question had joined a testing programme to verify that the infection on the farm was no longer active. In its OIE report of 1 October, Denmark reported that there were 27 SARS-CoV-2-positive farms in the country, and that samples were taken of all dead mink twice each week. On 2 October, the Danish authorities decided that all mink on infected farms would be euthanised. According to the information reported in week 42, in addition to the mink on the infected farms, all animals on mink farms within 7.8 kilometres of the infected farms would also be euthanised. By 27 November, of the 1,147 farms in the country, 289 mink farms had reported a SARS-CoV-2 infection (Fødevarestyrelsen 2020).

On 4 November 2020, Denmark decided that all farmed mink in the country would be euthanised, because it was feared that the mutated strains (variants) found in the infected mink would start spreading. The same variant of the virus had also been found in samples from 12 humans. It was feared that the mutations in these variants would hinder the development of vaccines and reduce the immunity already achieved.

Spain

Spain reported a SARS-CoV-2 infection on one mink farm to the OIE in mid-July. No other farms were near the farm in question. Of the samples collected from the animals on the farm (30 adults, 60 juveniles), 87 per cent tested PRC-positive. The animals on the farm were euthanised.

The United States

The United States Department of Agriculture (USDA) has reported that infections have been found on 15 mink farms since mid-August, mostly in Utah (USDA 2020). Infections have later been discovered in Wisconsin and Michigan as well. According to the USDA, the farms were investigated due to increased mortality rates, which led to the discovery of the first infected farms. No animals have been euthanised because of SARS-CoV-2 infections, and the pelts from mink that died of the infection will be treated to eliminate the virus, after which they will be sold as usual. A total of 12,231 mink have died because of the infection on the farms.

Sweden

Sweden reported its first SARS-CoV-2 infection on a mink farm (SVA 2020) in week 43 in October 2020. The infection was discovered when the farm sent dead mink for examination in the context of a control programme. The farm's mortality rate had increased, but the animals showed no other symptoms. A mink farm employee had also tested positive for SARS-CoV-2, but there is still no information about the connection between the employee's infection and the mink infections. There are currently 10 infected mink farms in Sweden. All infected farms are within the same area.

Greece

In its mid-November OIE report, Greece reported that a SARS-CoV-2 infection had been discovered on a mink farm. The farm is in northern Greece. The animals on the farm were tested after they had had respiratory symptoms, their feed consumption had reduced, and their mortality rate had increased. The farm owners, who also worked on the farm, also tested positive for SARS-CoV-2. Greece reported that it also suspected a SARS-CoV-2 infection on another mink farm, but the laboratory test results for that farm had not come out yet. The farm was within the 10-kilometre restriction zone of the other infected farm. The symptoms of the animals on the farm were similar to those observed on the infected farm.

Italy

Italy reported in its OIE report that a test result from one mink on a mink farm in Lombardy had come back as a weak positive for SARS-CoV-2. Samples had been collected for testing after an employee tested positive for SARS-CoV-2. A total of 1,124 additional samples were collected from the farm, and 340 mink carcasses were examined. Of these, one faecal sample came back as a weak positive. In its November OIE report, Italy reported that another faecal sample from the same farm had come back as a weak positive. Based on the results, the Italian authorities considered that SARS-CoV-2 had not spread in the farm, and that the positive samples could have been due to contamination or non-specific reactivity.

France

France reported in November 2020 that it had discovered a SARS-CoV-2 infection on one of the four mink farms in the country (the French Ministry of Agriculture and Food).

Lithuania

In November 2020, Lithuania reported that a SARS-CoV-2 infection had been discovered on one mink farm in the country. The mortality rate of mink had increased on the farm, and the infection was verified after collected samples were tested (Lithuania: State Food And Veterinary Service).

2. HAZARD IDENTIFICATION AND CHARACTERIZATION

2.1. Characteristics of the virus

Coronaviruses are a large group of enveloped RNA viruses that have been found in both humans and animals. The novel coronavirus is called the SARS-coronavirus-2 (SARS-CoV-2) after its relative, the SARS coronavirus. The disease caused by the novel coronavirus is called COVID-19.

The European Commission has proposed that SARS-CoV-2 be classified in risk category 3, the second most dangerous category of biological agents. The US Centers for Disease Control and Prevention (CDC) have instructed laboratories to handle samples in biosafety level 3 facilities (CDC, 2020).

2.2. COVID-19 in humans

The disease causes an acute respiratory infection whose symptoms include a cough, sore throat, fever, difficulty in breathing, muscle pain and headaches. The disease is also sometimes associated with diarrhoea. Infectious persons can also be asymptomatic.

The novel coronavirus is primarily transmitted via droplets when an infected person coughs or sneezes. The virus can also be transmitted via contact with surfaces on which droplets from the respiratory tract of an infected person have recently landed. Aerosol transmission is also possible.

The minimal infectious dose is unknown for humans or animals, but in human ACE2-transgenic mice, repeated exposure to even small doses of the virus resulted in an infection (statement of the Belgian scientific committee of FASFC, Avis rapide 19-2020, SciCom 2020/11).

2.3. COVID-19 in animals

2.3.1. Mink and other mustelids

Symptoms of mink infected with SARS-CoV-2 vary both within farms and between them, and infections can also be asymptomatic (Munnink et al., 2020). Reported symptoms include respiratory symptoms and an increased mortality rate (Molenaar et al., 2020). The respiratory symptoms include difficulty in breathing and a watery or thick nasal discharge, and their severity has varied from mild to extremely severe (Molenaar et al., 2020). In necropsy, acute pneumonia was the primary finding (Molenaar et al., 2020). Based on the information from four Dutch mink farms, the mink were symptomatic for one to two days, after which they often stopped eating and died the following day, which means that the clinical symptoms of individual animals lasted for two to three days (Molenaar et al, 2020).

In the Netherlands, the mortality rate on farms has varied from negligible to as high as 10 per cent (Enserink et al., 2020). The reported mortality rate of individual farms was 3.8 per cent for females and 3.7 per cent for males on one farm (Molenaar et al., 2020) and 2.4 per cent and 1.2 per cent respectively on two other farms, while the regular mortality rate is 0.6 per cent (Oreshkova et al., 2020). In the US, the mortality rate of older animals has been as high as 40 to 50 per cent. Developing a serious form of the coronavirus disease causes suffering to the animals, which means that a coronavirus infection spreading on a mink farm is also an animal welfare question.

On farms with verified SARS-CoV-2 infections, the infection has also spread extensively to other animals on the farm. By comparing sequenced viruses from two different Dutch farms, Oreshkova et al. (2020) proved that mink also transmitted the virus between them. In the study, infected animals were found throughout the different farm buildings and their parts, and no single cluster of infections on a certain part of the farm could be detected. Of the samples randomly collected from the farms, 100 per cent had antibodies. At this stage, the mink on the farm no longer had symptoms, and the mortality rate was normal.

As infected animals can be asymptomatic, SARS-CoV-2 can also spread on a farm undetected. Of the rectal swabs from asymptomatic animals from two infected farms studied by Molenaar et al. (2020), 22 per cent and 30 per cent tested PRC-positive, after two weeks 0 per cent and 52 per cent were positive, and after four weeks, 0 per cent of samples from both farms were positive. An OIE report from the Netherlands (6 October 2020) states that of the 62 SARS-CoV-2-positive farms, 25 (40%) were discovered based on the mink showing symptoms. In the remaining 37 (60%) infected farms, the infection was detected in connection with a control system that obliged the farms to send samples from dead animals for testing every week. The first infected farm in Sweden was also discovered based on samples required by a control system. The mink on the farm had no symptoms, but the farm's mortality rate had increased (SVA).

Ferrets are also susceptible to SARS-CoV-2 infections, but in ferrets, the virus has been found to only replicate in the upper respiratory tract and possibly in their digestive system. The virus was not found in lung samples tested in a Chinese study (Shi et al., 2020). Ferrets and mink are both members of the Mustelidae family, so observations about ferrets can be generalised to apply to mink as well. Sables are also a member of the same family.

The Belgian scientific committee of FASFC summarised a non-peer-reviewed publication (Ryan et al., 2020) in which one in six ferrets exposed via their respiratory tract became infected with a 100 pfu dose, and all 12 ferrets in the study became infected when the dose was 10,000 pfu or more. Based on these results, the scientific committee concluded that an infectious dose between 100 and 10,000 pfu in one or more instances was sufficient to infect animals like ferrets or mink (statement of the Belgian scientific committee of FASFC, 2020).

A study that has still not been peer reviewed (Kutter et al., 2020) focused on examining whether ferrets infected with SARS-CoV-2 and SaRS-CoV could transmit the virus via the air to healthy ferrets one metre away. The study design did not allow the distinct effects of small aerosols, large droplets and fomites to be studied, but each virus was found capable of infecting other ferrets over a one-metre distance. In the study, the cages of the animals were connected with tubes with several straight angles that allowed airflow (100 l/min). None of the SARS-CoV-2-infected ferrets had symptoms, but they still infected half the healthy animals (2/4), and swabs from their throats and nostrils still came back positive after 15 days when the test ended. With a shorter distance of 10 cm, three of the four healthy animals were infected.

2.3.2. Raccoon dog

According to a study conducted by Freuling et al. (2020), raccoon dogs are susceptible to the SARS-CoV-2 virus and can transmit it to their surroundings. The study assessed that raccoon dogs were only slightly less susceptible to the virus than ferrets and mink.

2.3.3. Cat

Cats are susceptible to infections and can transmit infections between each other (Shi et al., 2020). According to the Belgian scientific committee, cats cannot become infected with the coronavirus after surviving it once (Bosco-Lauth et al., 2020). In a Dutch study, samples were collected from stray cats in the vicinity of two infected mink farms (Oreshkova et al., 2020). One (n=24) of the cats tested positive in a PCR test, and three had antibodies. The viral load of the PRC-positive cat was low.

2.3.4. Pets

The statement of the Belgian scientific committee refers to laboratory tests carried out on different rodent lineages, and it concludes that rats, mice and squirrels should be considered. The golden hamster has been found susceptible to SARS-CoV-2 infection in experimental exposure tests, which is why rodents cannot be excluded as possible carriers of the virus. Rodents are also often found on animal farms.

According to unpublished information, New Zealand rabbits can also be infected, but based on the information collected for the statement of the Belgian scientific committee, rabbits do not show clinical symptoms, and secondary infections from rabbits are therefore deemed uncommon. However, there is still very little information about the susceptibility to coronavirus infection of different pests and their ability to spread the virus.

2.3.5. Other possible carrier animals

Very little research information exists about the role of animals other than those discussed above in spreading SARS-CoV-2 infections. SARS-CoV-1 infections have been found in foxes, but no research exists on SARS-CoV-2, and the significance of foxes therefore cannot be assessed. According to studies, SARS-CoV-2 replicates less in dogs, pigs, rabbits and ducks. SARS-CoV-2 RNA has not been isolated from dogs, but experiments with them have not indicated that the virus spreads between dogs. There is also no scientific evidence that dogs have transmitted SARS-CoV-2 to other species (Shi et al., 2020; ANSES, 2020a). On one infected farm in Denmark, a sample from an asymptomatic dog tested positive for SARS-CoV-2 (OIE report). The new sample taken from the dog five days later was negative.

2.4. Environmental factors

Based on experiences from Denmark and the Netherlands, farms near other farms are more susceptible to infection. Based on experiences from Denmark, infections easily spread to farms within one to two kilometres of an infected farm. The risk to farms farther away seems significantly smaller. Based on experiences from the Netherlands, all farms within a 10-kilometre radius are susceptible to infection. Denmark introduced a restriction zone with a 7.8-kilometre radius within which the animals at un-infected farms were also euthanised. There is no clear evidence on the size of the zone and its effect on the virus's spread between farms.

Later, the decision to euthanise the animals on all mink farms was made. The breeding, vaccination, pelting and whelping seasons cause stress and increase human contact, which can result in an increased susceptibility to developing a symptomatic disease, in which case the animals also transmit the virus more.

3. FACTORS AFFECTING SPREAD

According to the assessment of the Belgian scientific committee (statement of the Belgian scientific committee of FASFC, 2020), it is highly likely that an individual mink will contract the infection when it is in (close) contact with an infected human. The severity of the symptoms of mink and the prevalence of asymptomatic infections were considered when the risk of infection was assessed. Based on this, the risk of mink being infected by a human was assessed to be moderate.

The likelihood of a mink-to-human infection varies between different groups of people. Infection is unlikely in the case of most people, but for those who are regularly and closely in contact with infected fur animals, the risk is high. According to the view of the Belgian scientific committee, the risk of infection is highest for owners of mink farms and their families, farm employees and veterinarians. For these people, the risk of infection was assessed to be moderate, and for those at risk because of their health, it was assessed to be high (statement of the Belgian scientific committee of FASFC, 2020).

According to the ECDC's (2020) assessment, the likelihood of being infected with a mink variant (strains mutated in mink) is low for the human population as a whole, moderate for communities near mink farms, and high for those whose work involves handling mink. According to the current information, mink variants do not cause a more severe variant of the disease in humans than the other SARS-CoV-2 strains circulating in the human population.

3.1. Mutations

The SARS-CoV-2 mink variants in Denmark have been found to spread quickly between mink and to the communities near mink farms. In the Netherlands, mink variants have mostly been transmitted to people near mink farms. Mink variants seem to spread as readily as all other SARS-CoV-2 strains.

In Denmark, new variants of SARS-CoV-2 have been found and isolated from both human and mink samples. In some of these variants (cluster 5), the mutations have occurred in the genes encoding the spike protein (Boklund et al., 2020). This has caused concern about the effect of the new variants on vaccine development and the effectiveness of the already achieved immunity, but more research is required on this topic. In Denmark, the cluster 5 strains have been proved to have infected 12 humans, but no new cases have been found since September.

The ECDC states that additional research is required to assess whether the cluster 5 strains i) affect the risk of reinfection, ii) reduce vaccine efficacy or iii) reduce the effectiveness of treatment with plasma. The ECDC states that if any of the above are confirmed, the risk to human health caused by the cluster 5 strains is expected to be even greater than currently assessed. In initial studies, the cluster 5 strains have been found less susceptible to neutralising antibodies than other SARS-CoV-2 strains. Cell-mediated immune response to cluster 5 strains has not yet been studied. The cluster 5 strains and other Danish mink variants have not been found to affect the efficacy of the RT-PRC method used to detect COVID-19. They may affect the sensitivity of antigen and antibody tests, but the effect is expected to be slight, and more research is required. Of the mink variants that have spread more extensively than the cluster 5 strains, the ECDC states that based on current information, they do not pose a greater than normal risk to immunity.

Close and continued monitoring of the situation is still required, as the long-lasting epidemics on mink farms enable the virus to mutate into new variants (ECDC, 2020). These possible new variants could have

new characteristics related to the immune response, or they could cause a more severe disease than other variants. The severity of the risk and its possible consequences are still unknown according to the ECDC, but such a scenario should still be considered.

3.2. Humans on farms

In April 2020 in the Netherlands, it was found that respiratory infections of mink and their mortality rate had increased. In the case study of the two first infected mink farms (Oreshkova et al., 2020), virus sequence analysis showed that the mink contracted COVID-19 from an infected employee. The virus was deemed to spread among the mink via droplets, their feed or litter, or dust contaminated with animal faeces. Based on the preliminary sequencing results, on one of the farms, the virus had also been transmitted from the mink to a human, who then experienced mild respiratory symptoms.

SARS-CoV-2 has been proved to be transmitted from mink to humans on Dutch and Danish fur farms. Munnink et al. (2020) studied 16 infected farms in the Netherlands. An infection in the mink was discovered on one farm, after which seven farm employees were tested for SARS-CoV-2, but all their results came back negative. Later, five of the seven employees developed symptoms indicating COVID-19 and tested positive for SARS-CoV-2. Previously found mink variants were also found in the humans (Munnink et al., 2020). There had also been previous suspicions of mink-to-human infections on the mink farm. One farm employee had been found infected with a variant of the virus that had previously been found in the mink. However, the direction of the transmission could not be confirmed at that time (Oreshkova et al., 2020). In the Netherlands, it was found that 68 per cent of the people who had come into contact with infected mink were seropositive (Munnink et al., 2020). However, the transmission direction was not investigated in some of these cases.

In Denmark, by the start of November, 214 human SARS-CoV-2 infections have been found where the pathogen is a mink variant (ECDC, 2020). These mink variants make up 4.2 per cent of all SARS-CoV-2 strains that have been isolated from humans and sequenced in Denmark (n=5,102). However, most virus strains found in humans have not been sequenced. In the North Jutland Region, which has seen a large number of SARS-CoV-2 epidemics on mink farms, mink variants have caused around 40 per cent of human SARS-CoV-2 infections. The spillover of mink variants to humans was proved in Denmark when the first infections on farms were discovered (Boklund et al. 2020). The mink were infected by the farm employees, and it is considered likely that a mutated variant spread from the mink back to the humans on the farms and through them to the nearby care home. The mink variant in question also spread to two other mink farms in the same region.

The routes of transmission of SARS-CoV-2 between farms are not known. No other routes of transmission between the farms have been verified in addition to infection via humans. It is deemed likely that other still unknown routes also exist. Studies focusing on wild animals such as bats, other mustelids and birds have been started. Connections between the infected farms were investigated in two Dutch studies (Munnink et al., 2020; Oreshkova et al., 2020), but in addition to some of the farms having the same owner, no common factors were found. The significance of cats as spreaders of SARS-CoV-2 between farms has also been discussed, and seropositive or PCR-positive cats have been caught near mink farms (Oreshkova et al., 2020).

3.3. Live animals

SARS-CoV-2 is easily transmitted between mink, and an asymptomatic animal can also infect others. Live animals should not be moved between farms as long as there is a risk of a SARS-CoV-2 infection. The ECDC recommends that the movement of live animals within the EU and worldwide is banned.

Mink must be prevented from escaping the farms and other animals must be prevented from entering the farm with secure fencing. The risk of infection among wild raccoon dogs is suspected to be at its highest during the autumn, when young raccoon dogs seek new territories. For mink, the risk is at its highest during the mating season in the late winter and in the autumn when young mink start dispersing.

3.4. Pelts

Animal faeces, respiratory symptoms or saliva may be contaminated with the coronavirus. According to the initial results from a Finnish study and based on the ECDC's assessment, the virus can remain infectious in pelts for up 10 to 14 days, which means the pelts can spread the infection.

Based on the study of Riddel et al. (2020), the virus can remain infectious on different surfaces for up to four weeks, depending on environmental factors such as temperature, humidity and the surface material. Hot and dry conditions decrease the virus's survivability. The viral load reduced only slightly in 21 days at 4 °C. According to an OIE report (2020), freezing the virus at -80 °C is insufficient to destroy it.

If a SARS-CoV-2 infection is found on a farm, pelts must be destroyed. According to the ECDC and the OIE, raw pelts carrying SARS-CoV-2 can remain infectious until the virus is chemically inactivated. The OIE and the ECDC also recommend that raw pelts from infected farms be destroyed. The ECDC also recommends that the raw pelts produced in 2020 are not moved within the EU or worldwide.

3.5. Carcasses, manure and other waste

If handled inappropriately, the infected animals and bodily fluids on an infected farm may spread the infection. If a SARS-CoV-2 infection is found on a farm, the dead animals, manure and other potentially infectious material must be stored, treated and disposed of appropriately on the farm.

The OIE recommends several procedures for handling waste on fur farms. The carcasses of animals with verified or suspected infections, or those that have been exposed to pathogens, must be disposed of in accordance with local legislation and instructions from the authorities. Composting, burial, incineration, rendering or a combination of these carried out on the farm are suitable options.

4. RISK MITIGATION FACTORS

4.1. Measures taken in regions with mink SARS-CoV-2 infections

Denmark

According to its OIE report, the animals on the first three infected farms in Denmark were euthanised in accordance with the precautionary principle. After 20 July, animals were no longer euthanised, as it was assessed that the established control and sampling programmes had reduced the risk of transmission to humans to a very low level. Restrictions, including movement restrictions, were established for the farms. In early July, the Danish veterinary authorities classified SARS-CoV-2 infections in mink as infections to be reported based on a suspicion. According to the OIE reports, after 20 July, participating in control studies by sending samples from dead mink every three weeks became mandatory for all farms. According to an OIE report dated 24 August, restrictions were placed on farms whose samples tested positive.* On 1 October, Denmark decided to introduce additional measures for mink farms. These included the requirement for all farms in the areas with the highest risk to send all dead mink to be analysed twice each week. In other areas, samples are taken every three weeks or in pre-determined weeks. At the start of October, Denmark decided to euthanise all animals on infected farms and all animals on farms within 7.8 kilometres of an infected farm, even if no SARS-CoV-2 infection had been found on these farms.

In a decision dated 4 November, Denmark notified its decision to euthanise all farmed mink, but the situation is still unclear in terms of legislation. In Denmark, new variants of SARS-CoV-2 have been found and isolated from both human and mink samples. In some of these variants, the mutations have occurred in the genes related to the virus's spike structure (Boklund et al., 2020). This has caused concern about the effect of the new variants on vaccine development and the effectiveness of the already achieved immunity, but more research is required on this topic.

The Netherlands

Based on OIE reports, after the first SARS-CoV-2 infections on mink farms were discovered in the Netherlands, the farms were quarantined, and restrictions were placed on animal and manure transport and on visiting the farm. Farms, veterinarians and research institutions were also required to report all symptoms indicating a SARS-CoV-2 infection on the farms to the authorities. In the OIE report in early June, the Netherlands reported a total of 13 infected farms. Mink farmers were required to report respiratory symptoms of their mink and increases in the mortality rate to the authorities immediately. Of all dead mink, three to five carcasses were required to be sent for analysis each week. The Netherlands carried out serological studies on all mink farms in June and September to study the spread of the infection.

*) Further studies are carried out on the farm; animals cannot be transported away or to the farm; everyone visiting the farm must be informed of the SARS-CoV-2 situation; dead animals, farm machines, cages, and other materials, feed, and manure must be handled and treated in accordance with the instructions of the authorities; feed delivered to a farm must be left outside the farm, and the vehicle used may not be used to make feed deliveries to other farms during the same day; employees must use appropriate protective equipment such as FFP3 respirators and airtight safety goggles; anyone leaving the farm must take a shower with soap; pets must not be allowed on the farms; farm fencing must be checked with the authorities; any escaped animals must be immediately caught; and the farms must prepare a self-monitoring system that includes practices for feed consumption and the detection of escaped animals.

In mid-July, the Netherlands tightened the biosecurity requirements of farms by requiring that employees use a face mask and protective gloves to prevent asymptomatic employees from transmitting their infection to the mink. In early September, the requirements were made stricter, and employees were prohibited from changing employers without a 10-day quarantine. The spread of SARS-CoV-2 is controlled by collecting five dead mink from all farms every week for analysis. If the samples of a farm test positive, the results are verified with a throat swab.

At the end of May, the Netherlands decided to euthanise all animals on infected farms. The decision was justified by the fact that after the whelping season, the number of animals on the farms increased five- or sixfold compared to the start of the epidemic. At first, the kits were assumed to be immune to the virus because of the antibodies they inherited from their mothers, but as their antibodies decreased, the kits also became susceptible to the virus, and the second wave of the disease was feared to last longer than the first because of the larger number of animals and the gradual decrease in the immunity of the kits. At the same, the number of people visiting the farms was expected to increase because of the vaccination and weaning seasons. The possibility of new virus mutations also affected the decision to euthanise. At the start of September, the Government of the Netherlands ordered all mink farms to be closed by March 2021 to prevent mink farms becoming long-term reservoirs of SARS-CoV-2. One factor causing concern was that measures already implemented had not proved successful in breaking the chains of infection. The Netherlands had already previously decided to ban mink farming by 2024.

Spain

The animals on the only SARS-CoV-2-positive mink farm in Spain were euthanised. No other mink farms were near the infected farm.

The United States

According to the United States Department of Agriculture (USDA/APHIS, 2020a), infected farms have been placed in quarantine, and disinfecting measures have been carried out on them. The farms have been provided with instructions for how to protect employees and how to monitor health (USDA/APHIS, 2020b). Animals are not euthanised, and infected animals are not treated. Farms have been instructed to send samples for analysis if their mortality rate is five animals or more per day. No restrictions have been placed on selling pelts.

Sweden

In Sweden, restrictions were placed with the aim of preventing the infection spreading to other farms. The animals on infected farms have not been euthanised.

Greece

The adult mink on a SARS-CoV-2-positive farm were euthanised, and a 10-kilometre restriction zone was established around the farm. The Greek authorities have reported that they will test eight other mink farms whose employees have a verified SARS-CoV-2 infection, as well as all the employees of the 92 farms in the country. Employees will be tested every week until the pelting season is over.

Ireland

The Irish Government has recommended that all farmed mink in the country be euthanised to prevent the mutation of SARS-CoV-2 into new variants. No SARS-CoV-2-positive mink have been found in Ireland (Government of Ireland).

France

In France, the animals on a SARS-CoV-2-positive mink farm were euthanised.

4.2. Risk mitigation options for farms with a verified SARS-CoV-2 infection

The following are risk mitigation options for managing the SARS-CoV-2 risk of fur farms. The options are introduced from the least to the most severe. Because very little research information and experience-based information exist, the effectiveness of the options cannot be assessed.

A. Improved hygiene measures on mink and raccoon dog farms

- No animal traffic.
- Carcasses, feed, manure, and other waste may not be transported outside the farm.
- Raw pelts may not be transported outside the farm.
- Increased monitoring of animal feed consumption, mortality, and other symptoms.
- All humans entering the farm must use farm-specific and personal respirators and eye protection equipment, protective clothing and gloves, and footwear.
- Farm employees may not visit other farms.
- Work machines and equipment must be used on one farm only.
- Increased testing of animals on nearby farms.
- Preventing other animals such as cats and pests entering the farm and catching small predators more effectively.
- Preventing animals escaping and possibly making recapture of escaped animals more effective.
- Record keeping (human visitors to the farm, animal mortality rate and symptoms, feed consumption, escaped animals).

→ Based on experiences from Denmark, the Netherlands and Sweden, improved hygiene measures are insufficient to prevent the spread of a SARS-CoV-2 infection.

B. The mink and raccoon dogs on the farm are euthanised, and the farm is sanitised

- In addition to the above measures, all mink, other mustelids and raccoon dogs on the farm are euthanised.
- The farm is cleaned, disinfected, and kept empty for a sufficient time.
- All other fur animals on the farm are tested.
- Increased testing of animals on nearby farms.
- Pelts are destroyed.

C. The mink and raccoon dogs on the nearby farms are also euthanised, and the farms are sanitised

- In addition to the above measures, the mink and raccoon dogs on nearby farms are also euthanised.
- All nearby farms are also cleaned, disinfected, and kept empty for a sufficient time.

D. The mink and raccoon dogs on all farms in the area are euthanised, and the farms are sanitised

- In addition to the above measures and the animals on the infected farm, the animals on farms within a 2-kilometre radius of the infected farm are also euthanised.
- The farms are cleaned, disinfected, and kept empty for a sufficient time.
- Increased sampling is carried out on all mink and raccoon dog farms within a 2- to 10-kilometre radius.

E. The mink on all farms in the region are euthanised, and the farms are sanitised

- In addition to the above measures and the animals on the infected farm, the animals on farms within a 10-kilometre radius of the infected farm are also euthanised.
- The farms are cleaned, disinfected, and kept empty for a sufficient time.

4.3. Sampling

All mustelids or raccoon dogs on fur farms should be tested for SARS-CoV-2 to form an understanding of the overall situation. In regions with farms with a verified SARS-CoV-2 infection, samples have usually been required from five dead animals from each farm every week. Regular and frequent sampling must be continued for as long as the risk of SARS-CoV-2 infection on fur farms exists. The French ANSES proposes requiring five dead animals and faecal samples for PRC testing from all mink farms to ensure situational awareness (ANSES 2020b). If the disease is investigated with serological studies, 59 samples from 10,000 animals will be taken. If the number of animals is larger than this, the number of samples is increased in accordance with the instructions provided. To diagnose the disease, the number of samples is increased, PCR samples are also taken from the farm buildings, and blood and throat samples are collected from the animals if possible. The sampling procedure is initiated if the mortality rate exceeds one per cent, or if more than five per cent of the animals have symptoms. Random sampling of five animals is sufficient to detect an infection with a 95 per cent probability if the share of infected animals on the farm is 45 per cent, and the special characteristics of the coronavirus are not considered (Table 1). The results in Table 1 and the curves in Figure 1 were produced with a tool designed for assessing the probability of infection (Mikkelä, 2020). The tool calculates the probability of having at least one positive sample in a sample batch after the user selects the total number of samples, the population size, and the prevalence of the disease in the population under study. If sampling is targeted only at animals with symptoms, it is easier to detect infections. However, the aim is to detect SARS-CoV-2 infections in farm animals as early as possible, which would require a larger number of samples.

Table 1. Effect of the number of samples on detecting infection. The results show how many samples are required for the probability of detecting infection to be 95 per cent. The required number of samples depends on the size of the farm and on the share of infected animals.

Samples from farms with 100 animals	Samples from farms with 1,000 animals	Samples from farms with 10,000 animals	Probability of detection	Prevalence
5	5	5	95%	40%
10	10	10	95%	24%
25	30	30	95%	10%
63	100	100	95%	3%
95	260	300	95%	1%

Samples from a farm testing negative only means that there is a certain probability that the farm is not SARS-CoV-2-infected. Figure 1 illustrates the relationship between prevalence and detection probability if 3, 5, 10 or 30 samples are tested from a farm with 1,000 animals.

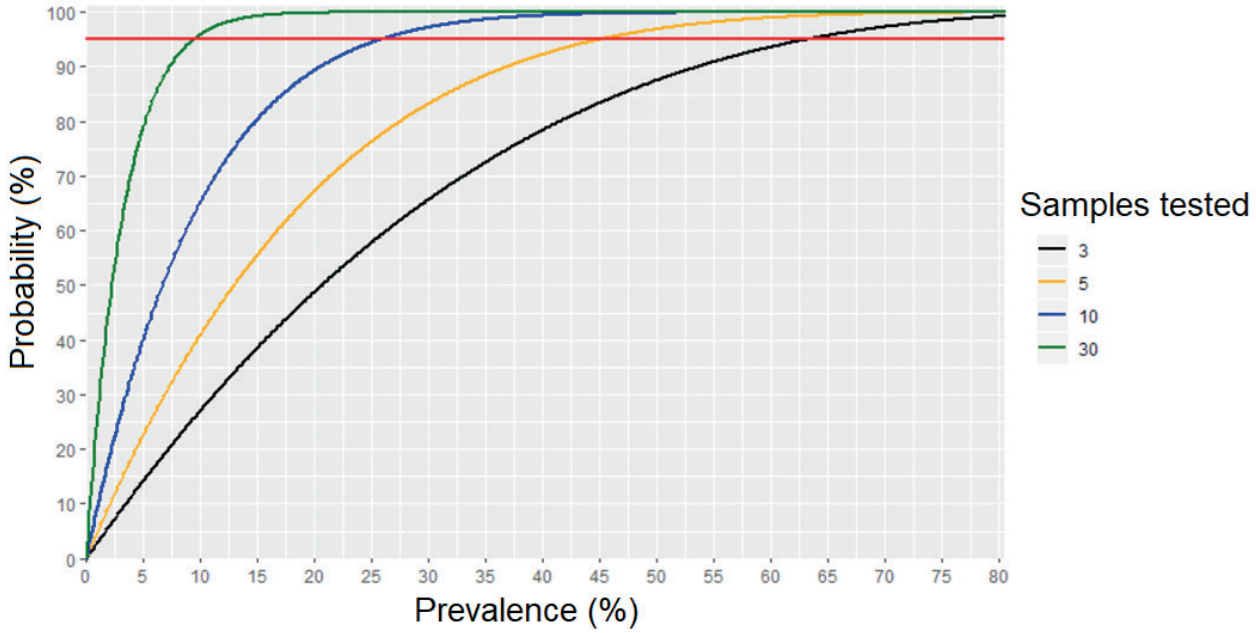

Figure 1. Probability of detection (y-axis) in relation to prevalence (x-axis). In the assessed scenario, 3, 5, 10 or 30 samples are tested from a farm with 1,000 animals. The red line is a probability of 95 per cent.

As humans are considered a significant source of coronavirus infection for mink, regular SARS-CoV-2 testing of humans entering the farm could improve the detection sensitivity and even protect the animals from infection. New employees entering the farm should be tested before they start their work.

It is important to study the connection of mink infections on mink farms to human infections by sequencing the strains found in mink and comparing them to the strains isolated from humans. This will allow the significance of mink as a source of infection to be assessed. This will also provide information about the sufficiency of the prevention methods introduced on mink farms. SARS-CoV-2 has been proved to mutate on mink farms, so further sequencing would also allow mutation to be monitored in case of any new variants.

5. EXPERT INTERVIEWS

Seven coronavirus or mink farming experts were interviewed in drafting this report, and the following summarises the interviews. The experts were interviewed in mid-October, and their responses reflect the information about the connection of SARS-CoV-2 infections and mink then available.

What is currently known about mink and SARS-CoV-2?

The virus spreads between mink very effectively. It spreads quickly, and almost all the animals in the same shed are infected. Symptoms appear quickly. The clinical spectrum is wide and ranges from mild to fatal. Like humans, mink develop an acute respiratory infection with symptoms such as coughing, difficulty in breathing, a nasal discharge and loss of appetite. Some individuals develop pneumonia. On farms with Aleutian disease, mortality increases (this applies to diseases in general). Infected mink seem to recover in a couple of weeks after symptom onset. The virus spreads quickly from humans to mink and mink to humans.

Infectious viruses are found in mink nasal discharge, saliva, urine, and faeces. The surest way to detect the virus is with samples from the respiratory system, and a RT-PCR test on a throat swab is the most effective method. Mink faeces samples may come up positive in a RT-PCR test (but more rarely than throat swabs). An antibody test has also been developed, which is cheaper but less reliable than the PRC test because SARS-CoV-2 cross-reacts with the mink-specific coronavirus.

What biosecurity measures have Finnish farms introduced?

Because of the coronavirus risk, farmers were recently instructed to ensure good hand hygiene and to use face masks. In addition, they have been instructed to use farm-specific protective clothing and work shoes, and it has been stressed that employees should not enter the animal facilities if they are sick or under quarantine. According to the law, fur farms must be escape-proof, and most farms have fences to ensure this. However, not all farms are fenced, and mink may escape from them into nature.

According to several interviewees, farms usually do not have actual biosecurity plans, and the farms are often very close to each other in areas assigned to the industry in municipal land use plans. However, the animals are not usually touched except during the mating, vaccination and pelting seasons. The faeces and urine of fur animals fall to the ground through the grated or mesh wire floors, and large quantities of flies lay eggs in them. The animals in adjacent cages are in direct contact with each other. Birds perch on the roofs of the animal sheds and can also eat the feed hanging outside the feed silos.

In March–December during the pelting season, many non-Finnish seasonal workers who stay in shared accommodation arrive on the farms. The workers may not have a common language, and some do not understand English or Finnish. Many of the experts were concerned about how these workers would be able to protect themselves if they did not understand the instructions given. In addition to the risk that the employees infect the mink, the experts considered it likely that the workers would infect each other in the small break and accommodation spaces. Not all farms provide sufficient facilities for washing hands. Drying pelts in sawdust seems to create extensive amounts of dust, which can facilitate the spread of air-borne pathogens.

In your assessment, how high is the risk of infection from mink to humans?

Cases where the mink have transmitted the infection to an employee have been found outside Finland. This has been proved by sequence analysis. Contact between the fur animals and the employees is not very close, so some of the experts did not consider the risk to be high. Droplet transmission is the primary route of transmission of SARS-CoV-2, but in work tasks creating dust, aerosol transmission is also possible. However, in theory, employees can be sufficiently protected. Transmission was considered more likely to happen between the employees than from mink to humans. The instructions for protecting employees are sufficient, but may not be implemented in practice.

Can wild animals (mink and raccoon dogs in particular) come into contact with fur animals?
Can wild animals become a SARS-CoV-2 reservoir in Finland?

Several of the experts stated that it was difficult to prevent wild animals entering the farms. The experts said that on many farms, wild animals could come very close to the fur animals (the sheds are open on the sides). Raccoon dogs in particular may be attracted to the farms during oestrus. In Denmark, a wild mink (that had previously escaped from a fur farm) was caught that was SARS-CoV-2-positive. Wild mink and raccoon dogs can become a SARS-CoV-2 reservoir. Animals that escape from the farms can also spread the virus to wild animals. Some of the experts still did not consider the risk to be that significant for mink because only a small number of escaped mink can survive in the wild. In addition, mink are naturally solitary animals that avoid contact with members of their species except during oestrus. They may occasionally encounter other wild predators, for example, when scavenging.

Wild raccoon dogs are more common, and they often roam near human settlements. In the warming climate, they are also active during the winter. A raccoon dog that escapes from a farm is better equipped to survive in the wild than mink. Raccoon dogs can also encounter cats because they share territories, sometimes even backyards. The European badger has a large territory, and it encounters many other animals.

What kind of human and animal traffic occurs on farms?

The daily animal care is usually taken care of by a single person, although larger farms may have several employees. Feed is delivered from a 'feed kitchen' shared by several farms. Veterinarians visit the farms when required, as do auditors, although during the pandemic, the aim has been to avoid all additional visits. During the pelting and mating seasons, rotating seasonal workers come to work on the farms. Artificial insemination is carried out in March, and pelting in November and December. There is very little animal traffic. Breeding animals are sometimes purchased, and some farms only farm mink from kits, which means the kits arrive from several farms. In areas with several farms, animals are often artificially inseminated in the same facilities.

In your assessment, how severe is the risk that SARS-CoV-2 will spread from one infected mink farm to other mink farms in Finland? How likely is the virus to spread from one farm to another?

In the view of most experts, transmission between farms is a significant risk. SARS-CoV-2 is likely to spread through a 'vehicle' (expert statement, no data), as the virus has spread inexplicably in Denmark. In certain regions of Finland, farms are very close to each other, and they may share seasonal workers. The virus has been proved to spread between cats via airborne transmission and to replicate in them well. Cats on farms can therefore contribute to the persistence of the virus and its spread.

If an infection is detected on a farm, how do you view euthanising the mink will affect the risk of infection to humans compared to adopting more effective hygiene practices? In your assessment, is adopting more efficient hygiene practices sufficient, or should all animals on the farm be euthanised? What do we know about immunity?

The views of the experts on this question differed most. Some considered that the disease could no longer be controlled once it entered a farm, but some believed that employees could be protected from infection.

Denmark attempted to control the disease with stricter hygiene practices and by letting the virus run its course in the animal population, but the desired results could not ultimately be achieved. According to a currently unpublished Finnish study, the virus can remain infectious for several days in mink pelts, for example. After some time, the infected farm animals will no longer be PCR-positive and will become antibody-positive instead (the antibody test is not reliable because of cross-reactions with a mink-specific coronavirus). No information is currently available about how long immunity lasts. During whelping season, the animals are under stress and more susceptible to infection.

Basic care tasks can be taken care of without contact with the animals, in which case the risk of infection to employees with proper protective equipment is small. Protection is possible if properly carried out. Situations in which humans must handle the mink cause a more significant risk. Mink bite easily. It remains unknown whether the virus is still infectious in faeces and for how long. The risks of spreading manure are being studied. The infectiousness of faeces should be investigated, as should the capabilities of farms to quarantine infected animals.

In your view, what are the most significant biosecurity risk factors on farms? What should be done to solve these problems?

Several significant risk factors were mentioned. Humans were considered to be the most significant risk; rotating seasonal workers with insufficient language skills who arrive from several different countries and live in small shared spaces, and people who visit other farms. Farms often lack showers, protective clothing or other protective equipment, which increases risks. The risk of infection is at its highest when humans come into contact with the mink. Workers should be tested with a low threshold in Finland, and training on personal protection should be provided. Non-Finnish workers should be tested and placed under quarantine before they enter the farms. Awareness of the SARS-CoV-2 risk caused by mink should be increased in healthcare, and mink farm employees should be directed to testing if they show even the slightest respiratory symptoms. In addition to humans, contact with wild animals was mentioned as a risk.

6. SUMMARY

Transmission from mink to humans

- Humans, particularly those who work on a farm, can be infected with SARS-CoV-2 by mink.
- The viral load is significant everywhere on SARS-CoV-2 infected mink farms. The high animal density increases the risk of infection.

Mink and raccoon dogs

- Preventing the virus entering mink and raccoon dog farms is the primary objective.
- Biosecurity on fur farms must be good, and it must be reviewed and increased to a high level if necessary.
- The farm area must be completely fenced.
- SARS-CoV-2 is most likely to be spread from an infected human to a mink farm. Other vectors are possible, but no evidence of them exists.
- If SARS-CoV-2 enters a mink farm, it quickly spreads to all the animals on the farm. Monitoring and prevention methods should therefore be introduced immediately.
- SARS-CoV-2 also easily spreads to other nearby farms.
- The risk of infection will be a reality for mink farms for the entire duration of the pandemic.
- SARS-CoV-2 is suspected to persist on an infected mink farm for a long time and the farms may become reservoirs of the virus.

Testing

- Regular SARS-CoV-2 testing and health monitoring of humans who visit mink farms (checking body temperature and other COVID-19 symptoms daily).
- A quarantine of 10 days or more for new employees before they start their work.
- Monitoring the SARS-CoV-2 situation of the animals on mink farms with regular sampling.
- The animals on farms that send animals for pelting must be tested for SARS-CoV-2, and the results must be negative.
- Increased catching and testing of small predators and animals that escape the farms is recommended in areas near farms.
- The virus can mutate into new more dangerous variants on mink farms. Mutation of the virus must be monitored continuously. SARS-CoV-2 strains isolated from mink must be sequenced systematically, and they must be compared to strains isolated from humans.

Other measures

- The mortality and symptoms of animals on fur farms must be monitored more closely than previously, and the condition of the animals must be monitored daily.
- Collaboration between humans and sectors responsible for animal health must be increased (One Health compatibility).
- Careful outbreak investigations must be carried out on fur farms that are SaRS-CoV-2-positive, and preparations for carrying out such investigations must be made in advance.
- Investments must be made in the development of antibody-based testing to enable neutralising antibodies to be examined.

The likelihood of different routes of transmission was assessed based on current information, OIE reports, research results, websites of the authorities and the information provided by the experts (Table 2).

Table 2. Rough assessment of the likelihood of different routes of transmission (+ low, ++ moderate, +++ high).

Route of transmission	**Host**	**Likelihood**	**Comment**
Infection from a human	Mink farm employees and other farm visitors	+++	Can also happen in shared break facilities or accommodation.
	Mink	+++	Probably also applies to raccoon dog farms.
Infection from mink	Employees	+++	
	People close to employees	++	
	Other visitors	++	
	Other mink on the same farm	+++	One mink infects the entire farm.
	Other mink farms	++(+)	Depends on the distance and connections between farms.
	Raccoon dog farms	++(+)	Only a few studies, but they indicate that raccoon dogs are suspectible to the virus and can transmit it to humans. Depends on the distance and contact between farms.
	Other mustelids	+++	
	Wild mink and raccoon dogs	+	Positive individuals found. Oestrus?
	Felines	+	Detected in stray cats near farms.
	Other animals	No data	Possible mechanical transmissions.

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