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Summary

Given the current knowledge available, the overall estimated risk for the spread of nodavirus from the infected cod farm Nærøysund A/S to the other commercial cod farms in the fjord system of Hellefjorden/Norddalsfjorden is regarded conservatively as high.

Horizontal mode is the likely mode of transmission when escaped subclinical infected cods or wild fishes infected by the farm, come into contact with susceptible cods from other cod farms. Disease infection will take place under stressful conditions e.g. high temperature and poor husbandry.

Sammendrag

Ut fra den kunnskapen vi har i dag, må risikoen betraktes som høy for at det kan skje overføring av nodavirus fra den infiserte torskelokaliteten Nærøysund A/S til andre kommersielle torskeoppdrett i fjordsystemet. Denne vurderingen er konservativ i den forstand at mange ukjente forhold automatisk bidrar til høy risiko.

Mest sannsynlig vil smitteoverføring skje horisontalt ved at subklinisk infiserte rømt torsk eller vill fisk som er infiserte fra Nærøysund A/S, kommer i kontakt med mottaklig fisk på de øvrige lokalitetene. Infeksjon skjer helst under betingelser hvor mottakelig fisk er stresset, for eksempel ved høy vanntemperatur og dårlige miljøforhold.

Introduction

The locations in question are Parisvatn hatchery that supplied the infected fingerlings to the commercial farm Nærøysund A/S in the fjord area of Hellefjorden/Norddalsfjorden 100 km to the north (see map on front page).

Parisvatn (60° 37' N, 4° 48' E) at Fjell County is a hatchery that produces Atlantic cod fingerlings for research purposes. The fingerlings and larvae that are not used for research have in the last years been transported about 100 km north to a commercial fish farm (Nærøysund A/S) (61° 37' N, 4° 57' E) for further growth to market size before commercial sale. Nærøysund A/S is in the fjord area of Hellefjorden/Norddalsfjorden. This fjord has also other intensive cod production operations and hatcheries.

Parisvatn in 2006 had an outbreak of Viral encephalopathy and retinopathy (VER) in Atlantic cod caused by nodavirus. However, 450,000 subclinically infected cod fingerlings were moved from Parisvatn to this same grower farm Nærøysund A/S for research purposes according to the Institute of Marine Research (IMR).

The nodavirus situation (cod and other fish farms, wild fishes) in the fjord system of Hellefjorden/Norddalsfjorden is unknown at the time that this risk assessment is conducted (June 2007). This is because routine surveillance for nodavirus on Norwegian hatcheries stopped since 2004. There have been no reported outbreaks of nodavirus in fjord system in question.

There are at least 30 marine fish farms within a 10 km radius from Nærøysund A/S (See Figure 3). This includes a cod hatchery that is 7 km away from Nærøysund A/S. So far all of these farms have not reported nodavirus infection on their farms.

The local fish health services (Vestvet AS) for some of these fish farms in the fjord system of Hellefjorden/Norddalsfjorden requested the Veterinary Institute of Norway to help them assess the risk of nodavirus spreading from Nærøysund A/S to other farms in the same fjord system.

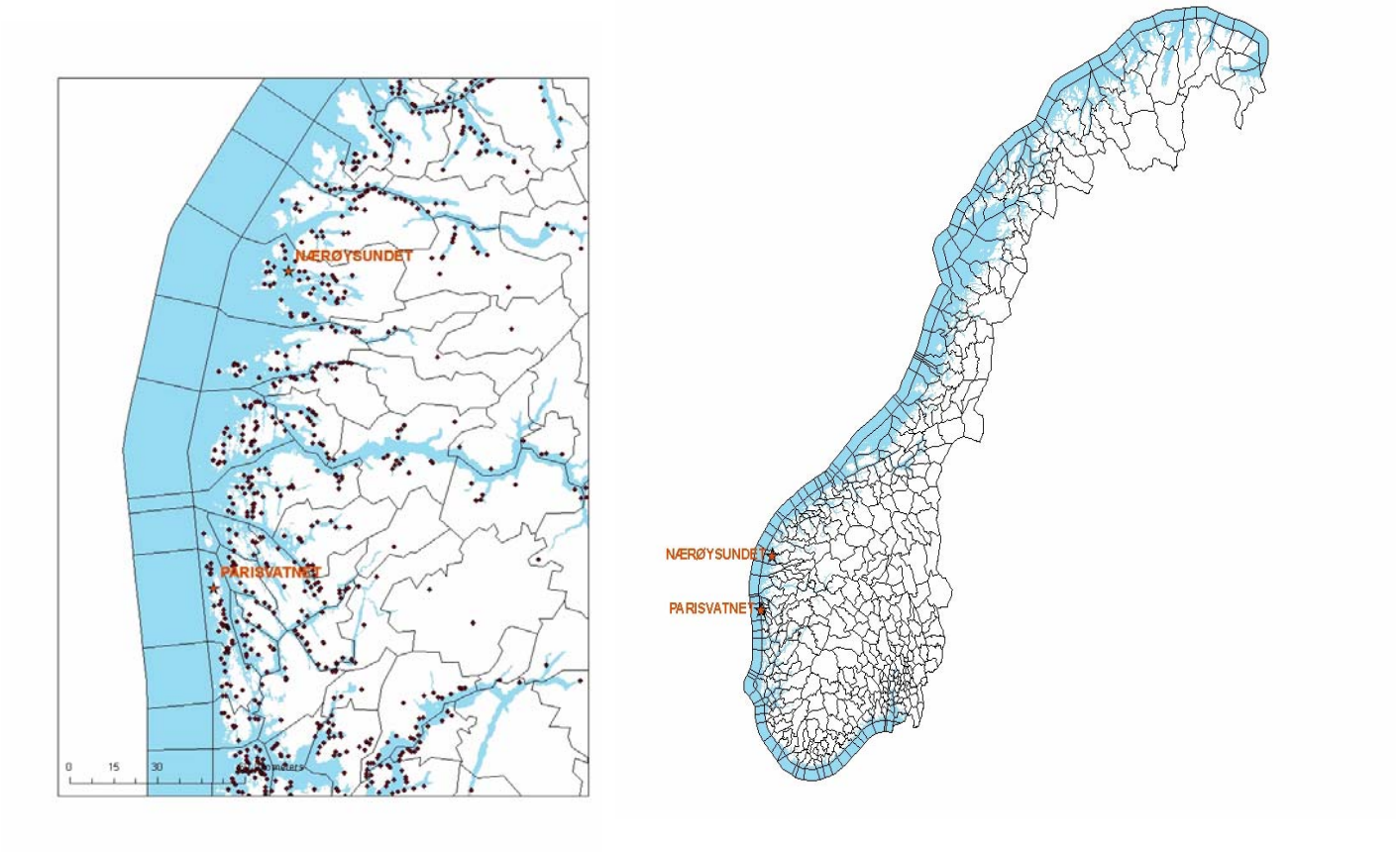

Figure 1 and 2. Nærøysund A/S, the commercial farm, is about 100 km north of Parisvatn. The black dots represent other fish production operations.

Aim

The aim of this paper is to estimate the risk that nodavirus from this commercial cod farm Nærøysund A/S with infected cod will spread to neighbouring cod farms/hatcheries in the fjord system called Hellefjorden/Norddalsfjorden.

Materials and methods

To estimate the qualitative risk of this event happening, the Veterinary Institute of Norway gathered the expert opinions from literature and interviews with the Institute of Marine Research (IMR), Norwegian Food Safety Authorities (Mattilsynet) and Jan Pedersen, the manager of the hatchery at Parisvatn.

The information gathered is laid out in the following sequence.

1. Hazard Identification
2. Hazard Characterization
3. Release Assessment
4. Exposure Assessment
5. Consequence Assessment
6. Risk Characterization

Results

Hazard Identification

Nodavirus is a small (25-35 nm) single stranded RNA virus. The piscine nodavirus is the betanodavirus that infects fishes (Carstens *et al*., 2000).

Hazard Characterization

Yoshikoshi and Inoue first reported in 1990 that nodavirus causes the disease viral encephalopathy and retinopathy (VER) or viral nervous necrosis (VNN) in fishes in the larvae and juveniles of parrot fish.

It's a very serious viral disease affecting larvae and juvenile marine fish of multi species. VER is reported from at least 30 marine fish species in all parts of the world including halibut, turbot and cod. Nodavirus has been isolated from cold-water species such as Pacific cod *Gadus macrocephalus* (Nishizawa *et al*., 1997), winter flounder *Pleuronectes americanus* (Barker *et al*., 2002), Atlantic cod *Gadus morhua* (Starkey *et al*., 2001; Johnson *et al*., 2002), Dover sole S*ole solea* (Starkey *et al*., 2001), and haddock *Melanogrammus aeglefinus* (Johnson *et al*., 2002).

In 2001 Starkey *et al*. reported nodavirus-associated disease in Atlantic cod and Dover sole, both species were hatched from wild stocks. The cod suffering from the disease ranged in weight from 1.5 to 3.5 gram, and showed clinical signs such as whirling behaviour and darkening of skin pigmentation. The mortality was low and estimated to be 2% over a 3-month period.

VER was diagnosed in a halibut hatchery (Austevoll, Hordaland, Norway) in late summer 2006, at a research facility that previously had suffered form the disease in the mid 90ties. The outbreak was followed by a new VER diagnosis in a combined research and commercial growth site for Atlantic cod called Parisvatn (60° 37' N, 4° 48' E).

This site is also owned and operated by same institute running the research facility at Austervoll. The outbreak showed that clinical signs and mortality can happen to cod as large as 24 g. This was the first outbreak of VER in Atlantic cod reported in Norway (Patel *et al*., 2007).

Shortly after this outbreak, during the fall of the same year (2006), nodavirus was detected in cod again when VER was diagnosed in two more commercial cod farms at the west coast and northern part of Norway. This demonstrated again the presence of nodavirus in cod farming as in turbot and halibut. (Hellberg *et al*., 2007). It seemed that nodovirus was appearing in an increasing number of fish farms and in the wild fish species.

Subclinically infected wild fish population might be a major source of infection to the susceptible farmed fish (Barker *et al*., 2002). There have been a few reports on virus detection in Atlantic cod, haddock and winter flounder (Barker *et al*., 2002; Cusack *et al*., 2002; Johnson *et al*., 2002).

Vertical transmission is possible as demonstrated by infected spawners infecting their larvae (Arimoto *et al*., 1992, Mushiake *et al*., 1992).

Horizontal transmission is possible too. Nodavirus transmit easily from diseased fish to susceptible fish groups (Castic *et al*., 2001).

In cod, horizontal transmission is indicated in the three outbreaks recorded in 2006. In all three outbreaks, the cod were infected at an older stage and not at the larvae stage (Hellberg *et al*., 2007).

In Taiwan subclinically nodavirus infected barramundi (*Lates calcarifer*), transported from saltwater to freshwater, were believed to be the source of infection in freshwater species including European eel *Anguilla anguilla* (Chi *et al*., 2003). Triggering factor for the outbreak was believed to be high water temperature.

Stress causes subclinically infected fish to shed large amounts of virus (Chi *et al*., 2003).

Viral load and susceptibility of the fishes is dependent on environmental temperature. Warmer months experience greater chances of an outbreak. Stress lowers the fish immunity (Peters *et al*., 1998, Carballo *et al*., 1995, Chou *et al*., 1999).

The virus survives in the water but does not multiply because of the dilution effect. The concentration is considered seldom to reach an infectious dose to infect a susceptible cod (information given by IMR).

Release Assessment

According to the IMR, about 50% of the 450,000 cod fingerlings were subclinically infected with nodavirus when it was brought to Nærøysund A/S located in the fjord system of Hellefjorden/Norddalsfjorden in 2006.

Under stressful conditions, e.g. high temperature and inappropriate husbandry factors like handling, stocking density, oxygen and ammonia level, the subclinically infected cods could possibly have shed the virus into the environment.

Possible pathways for the nodavirus to spread to the other farms in the fjord are:

a) Subclinically infected cods escape and swim to other cod farms
b) Wild fishes that visited the net cage are infected by the farmed cods; the wild fish could in turn act as a vector and swim to other cod farms.

Given that there is little information about,

a) husbandry practices and stress management of cod grower farm Nærøysund A/S;
b) the biosecurity and escape plans of grower farm Nærøysund A/S;
c) horizontal transmission rate between the infected cods and wild fishes,

the estimated risk of nodavirus being released into the environment in this new fjord, by convention, must conservatively be considered high**.** A conservative approach is generally advisable when insufficient information forces subjective judgement (University of Carolina: Chapter 6 Risk Assessment).

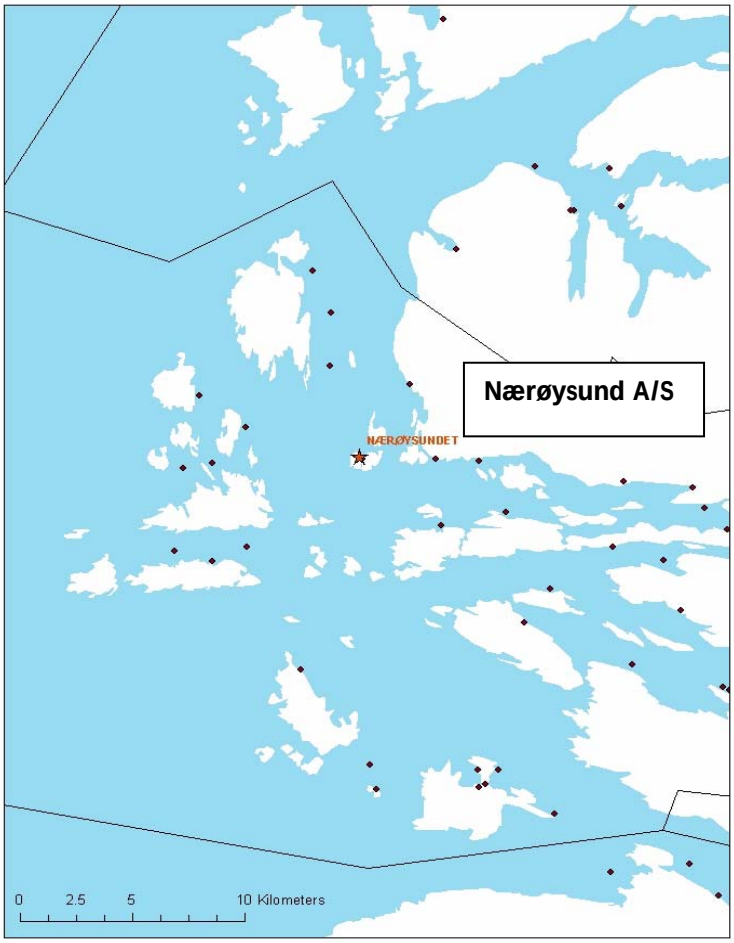

Figure 3. The black represents at least 30 other commercial fish farms or hatcheries within the 10 kilometer radius from Nærøysund A/S.

Exposure Assessment

As there have been no outbreaks of nodavirus in farmed and wild fishes in the fjord system of Hellefjorden/Norddalsfjorden, we make a conservative assumption that the fjord is free from the virus. This assumption would provide a worst-case estimate of exposure risk. These kinds of conservative assumptions, which presume that healthy cod farms are exposed to newly, introduced disease agents, nodavirus in this case, are referred to as "health-protective" assumptions (California Environment Protection Agency: A guide to health risk assessment).

All cod grower farms and hatcheries in the same fjord area are potentially at risk of exposure since the three nodavirus outbreaks in cod in Norway (2006) have shown that unlike halibut, cod is susceptible not just at the larvae stage but at sizes over 5g and up to 1.5kg.

While there is no hard evidence of interactions between wild and farmed cold-water fish, the observation of infected wild fish raises questions of a possible interaction. In Norway the finding of nodavirus in wild adult Atlantic halibut (Aspehaug *et al*., 1999) might suggest there is a hazard in using wild caught animals as brood fish.

Infection of susceptible cods is likely by horizontal transmission through close contact with an infected cod or other infected species (Munday *et al*., 2002) as evidenced by the three outbreaks in 2006 where older cod fishes were infected instead of at the larvae stage.

This could happen if an infected cod escaped from the infected farm and swam near to the other farms. Susceptible cods of these uninfected farms would be exposed.
Infection would take place if the conditions are stressful e.g. high temperature causing the wild fish or escaped cod to shed more viruses. The high temperature or other stressful conditions like husbandry management e.g. high stocking density also lowers the immunity of the susceptible cods.

Given that we don't know what husbandry methods and stress management techniques are practiced at the other commercial fish farms and the likelihood these other farms would be exposed to escaped cods and wild fishes, then by convention, we conservatively would estimate the exposure risk to be **high**.

Consequence Assessment

Hatcheries that become infected may have to destroy their brood stock to avoid producing infected larvae. Larvae infected during spawning could experience high morbidity and mortality.

Morbidity and mortality can also be experienced in cods of all ages and sizes, from larvae to adult. This will represent economic loss to affected grower farms.

Export farms may lose overseas market.

On going surveillance of nodavirus once the fjord becomes endemic would also mean additional overhead production cost.

Conclusion – Risk Characterization

Given the current knowledge available, the overall estimated risk for the spread of nodavirus between the infected cod farm Nærøysund A/S and the other commercial cod farms in the fjord system of Hellefjorden/Norddalsfjorden by convention is conservatively regarded as **high.**

Horizontal mode is the likely mode of transmission when subclinical infected cods escape from Nærøysund A/S or wild fishes infected by Nærøysund A/S, swim to other farms and come in contact with susceptible cods in these other cod farms. Disease infection would take place under stressful conditions e.g. high temperature and poor husbandry practices like having high stocking densities.

There are many questions remaining unanswered:

1. Nodavirus status of the wild fish and other commercial farms in the fjord
2. Biosecurity and the escape plan of the infected farm.
3. Risk factors for horizontal transmission between wild/escaped and farmed fish
4. What difference does shedding of nodavirus from this infected farm, Nærøysund A/S, makes to the surround waters in this new fjord area.

The wide range of susceptible hosts, existence of evidence suggesting vertical and horizontal transmission is possible, the unknown distribution of virus in both farmed and wild population are all reasons to be conservative when risk assessment is involved and that is to assume the worst could happen. More information answering the posed questions may alter the estimation of the risk.

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