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Risk mapping of heart and skeletal muscle inflammation in salmon farming

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ABSTRACT

Heart and skeletal muscle inflammation (HSMI) is an infectious disease causing losses to the Norwegian salmon farming industry due to increased mortality and high morbidity in infected salmon. The disease is listed as a notifiable disease on list 3 (national list) by the Norwegian Food Safety Authority. HSMI is believed to be a viral disease, but the association to the recently discovered Piscine reovirus (PRV) remains unclear. Undoubtedly, other factors interact to determine whether PRV-infected fish develop disease or not.

In this study, logistic regression was used to model the risk of an outbreak of HSMI at the cohort level, by including spatio-temporal risk factors. The data consisted of fish cohorts grown on geo-referenced farms from 2002 to 2010. The risk factors included were: infection pressure, cohort size (maximum number of fish), cohort index (smolt characteristics), cohort lifespan (months in sea) and a geo-index calculated as the position along a local polynomial regression line based on the longitude and latitude of each farm included in the study.

The results showed that the risk of developing HSMI increased with increasing cohort lifespan, increasing infection pressure and increasing cohort size, and was mostly low for cohorts grown on farms in Southern-Norway, high for farms in Mid-Norway and variable for farms in Northern-Norway (based on the geo-index). The final model was used to explore three different scenarios with regards to the risk of developing HSMI, and to calculate the probability for each cohort of developing HSMI, independent of their actual disease-status.

The model suggested that the probability of developing HSMI was much higher in Mid-Norway than in the rest of the country. Even though PRV seems to be widely distributed in the environment, the finding that infection pressure has a large influence on the probability of developing HSMI, suggests that it might be possible to reduce the number of clinical outbreaks, if measures are taken to reduce infection pressure. However, the prospects of controlling the spread of HSMI and reducing clinical outbreaks might be difficult because of indications of large distance spread of the disease.

1. Introduction

Heart and skeletal muscle inflammation (HSMI) is an infectious disease causing losses to the Norwegian salmon farming industry due to increased mortality and high morbidity in infected farmed Atlantic salmon (*Salmo salar*) (Kongtorp et al., 2004a, 2006). The disease has also been reported in the United Kingdom (Ferguson et al., 2005).

HSMI was first identified on the west coast of Norway in 1999 (Fig. 1), from moribund fish sampled and tested using routine diagnostics. These fish had a pathological presentation not previously described and thus it was believed that this was the appearance of a new disease (Kongtorp

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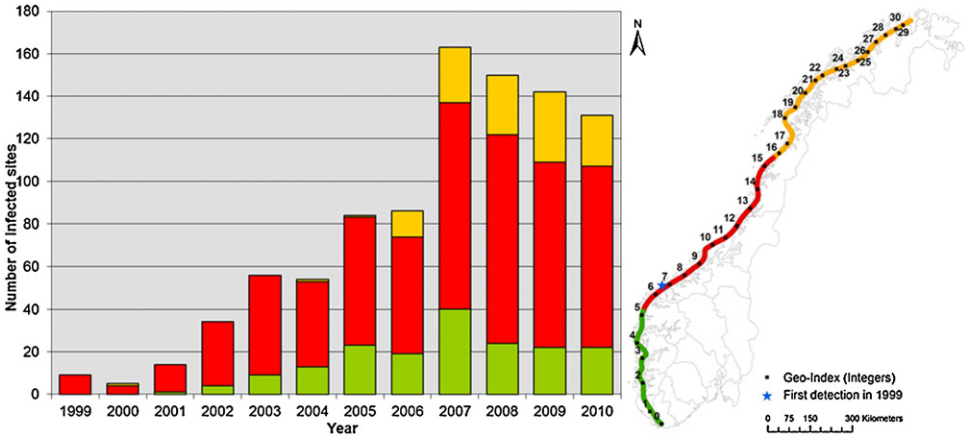

Fig. 1. Number of HSMI-diagnosed cohorts 1999–2010 and map showing the geo-index. Annual number of clinical outbreaks was collated from the laboratory information system of the NVI. Colours on the bars correspond to similar parts of the geo-index on the map: Green corresponds to a geo-index of less than 5.1, red denotes a geo-index of 5.1–15.7 and yellow indicates a geo-index above 15.7 (see text and Fig. 3c). Blue star on the map marks location for the first detection of HSMI in 1999.

et al., 2004b). Diagnosis of HSMI continues to be based on histopathological examination of organ samples with the finding of pathognomonic lesions (Kongtorp et al., 2004b).

After HSMI was first identified in Norwegian salmon farming, the number of clinical outbreaks in farms has increased and the affected geographical area has expanded (Fig. 1, data collated from the laboratory information system of the Norwegian Veterinarian Institute (NVI)). The rapid spread, together with the high morbidity associated with the disease, has led to HSMI being listed as a notifiable disease on list 3 (national list) by the Norwegian Food Safety Authority (NFSA) in 2008. This implies that HSMI diagnoses must be reported to the NFSA, who then have the mandate to impose restrictions on farms experiencing disease outbreaks (Anonymous, 2008). However, specific restrictions are currently not enforced for farms diagnosed with HSMI.

Previously, it has been demonstrated that the causative agent of HSMI is most likely a virus (Eliassen et al., 2004; Watanabe et al., 2006; Kongtorp and Taksdal, 2009). In 2010, a novel reovirus (piscine reovirus, PRV) was identified by the use of high-throughput DNA sequencing of heart tissue from HSMI infected fish (Palacios et al., 2010). This study demonstrated a strong association between PRV and HSMI. However, PRV was also found in clinically healthy fish, with comparably low virus levels (Palacios et al., 2010).

Aldrin et al. (2010) studied risk factors for outbreaks of HSMI in salmon cohorts and found that HSMI detections in previous fish cohorts at given farms was the single most important risk factor. HSMI diagnoses within shared contact networks and in nearby farms were additional important risk factors. The risk of developing HSMI was also elevated in autumn cohorts of smolts, compared to spring smolt cohorts (Aldrin et al., 2010).

A model investigating the effect of infection pressure on the probability of developing Pancreas disease (PD) in farmed cohorts of salmonids has been developed by Kristoffersen et al. (2009). Infection pressure for a given cohort, defined as exposure to infection by proximate infectious farms, had a relatively strong effect on the probability of recording a PD outbreak in a cohort. The model demonstrated that the probability of experiencing a PD outbreak in a given cohort of salmon was low if there were no neighbouring farms with PD, but increased as a function of increasing infection pressure (Kristoffersen et al., 2009).

In the present study, the model framework of Kristoffersen et al. (2009) was adapted to a dataset including all marine cohorts of farmed Atlantic salmon in Norway and all recorded cases of HSMI over the period 2002–2010. The aim of the study was to map important spatio-temporal risk factors for the development of HSMI in Norwegian salmon farming, in order to gain knowledge of their relevance to the possible control of the spread of this disease.

2. Methods

2.1. Data

2.1.1. Fish cohorts

Salmon farming consists of a freshwater phase of smolt production, followed by a marine grow-out phase. The marine production is conducted on certified farm sites authorized by the Directorate of Fisheries (DFF) and geo-referenced in the Aquaculture register (DFF; www.fiskeridir.no). The dominant practice for the marine production is that farms are stocked with cohorts of salmon smolts, which are then grown on this farm site until slaughtered. The farm is then fallowed for a period before stocking with a new cohort of smolts (see Kristoffersen et al., 2009). In the present study, only cohorts that were transferred to marine waters after December 2002 and slaughtered or moved before January 2011, and that were held on the same farm for at least six months, were included.

Cohorts where split into spring smolt cohorts, autumn smolt cohorts, mixed cohorts or relocated cohorts (cohort index) as described in Kristoffersen et al. (2009; Section 2.3).

All farms actively farming salmonids in marine waters must report key production statistics on a monthly basis