Risk map and spatial determinants of pancreas disease in the marine phase of Norwegian Atlantic salmon farming sites

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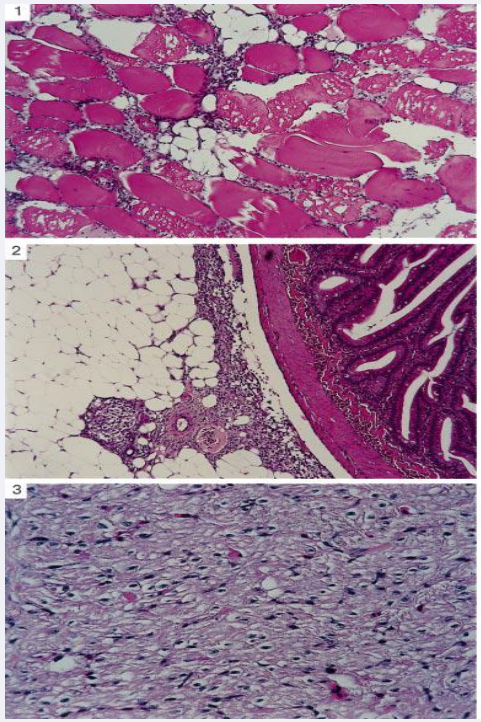
Veterinærinstituttet
Norwegian Veterinary Institute

General information (1/2)

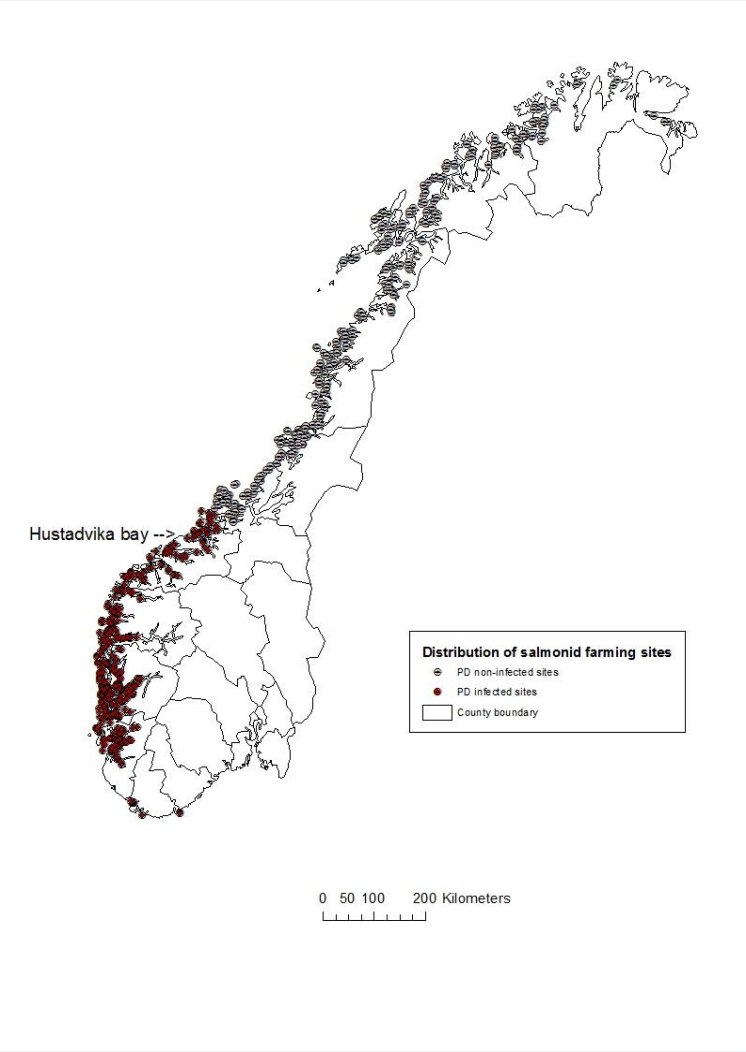
- The pathogenic agent of pancreas disease (PD) is salmon pancreas disease virus (AKA salmonid alphavirus, SAV). The disease is a problem in all the major salmon producing countries in Europe. The onset of PD is favored by unspecified influential environmental factors
- Causing economic losses due to high mortality, interrupted production cycles, reduced feed conversion and flesh quality of farmed fish, etc.

Taksdal et al., 2007



Christie et al., 1998

General information (2/2)



- In Norway, PD is considered endemic in the southern part of the norwegian coastline (the figure showing geographical distribution of farming site with and without PD during 2009-2010)
- Similar to many infectious aqautic diseases, a close proximity to PD infected sites is a risk factor for the disease transmission, and sea currents can greatly contribute to spread of the virus between sites
- Spatial autocorrelation often occurs in outbreaks of infectious diseases. If the spatial correlation exists and is not accounted for, it could lead to biased parameter estimates and overly optimistic standard errors

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Objectives

- To evaluate an effect of *potential factors* contributing to an PD outbreak accounting for spatial congruity of neighboring infected sites
  - *Site location*
  - *Site density*
  - *Smolt cohort*
  - *Local biomass density (LBD)*
  - *PD history*
- To predict the probability of PD occurrence at site level
- To create a quantitative risk map covering the western coast of Norway

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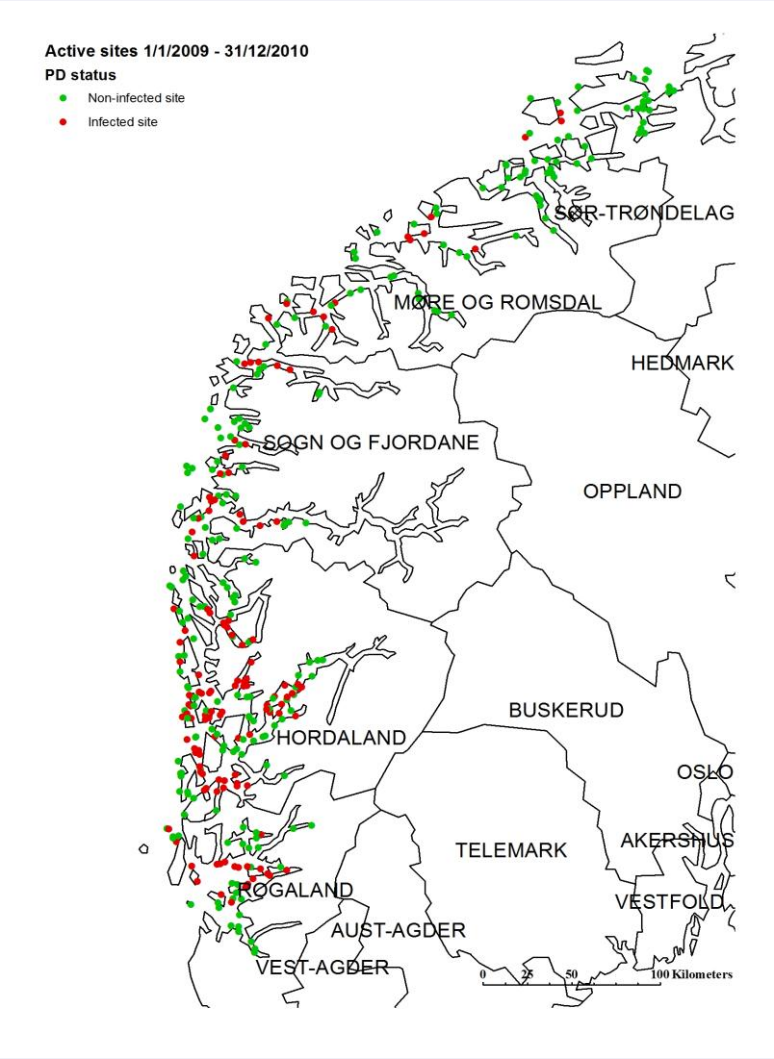
Study population

- Including active Atlantic salmon farming sites located in the coastal area of 6 southern counties of Norway (where most of PD outbreaks have been reported) from 1 January 2009 to 31 December 2010
- According to the inclusion criteria, 359 sites were included.
- Additional dataset of active sites during a period of 2011was used for model validation. The second dataset consisted of 418 farming sites.



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Site location

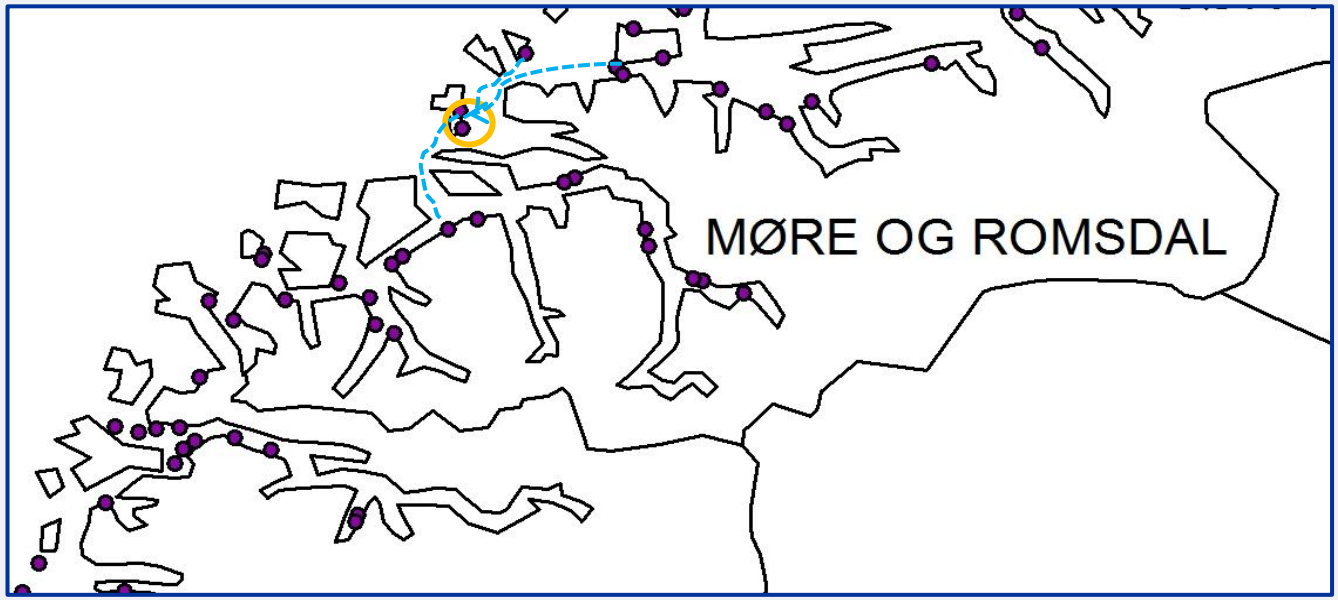
- All operators of Norwegian salmonid farming industry are required to register production statistical data to responsible authorities on a monthly basis. These statistics are linked to a farm site identity, which is geo-referenced in the Directorate of Fisheries (www. fiskeridir.no)

- We used these site identities to evaluate if the site location, based on the latitude, had an impact on the PD occurrence

- In this study, the site latitudes cover the area of 63°39'5,481"N (the farthest north) to 58°12'33,449"N (the farthest south). The value of site latitude was converted to meter prior to analyses

Site density

- Site density for a given site was the number of neighboring sites (excluding the given site) that located within 10-km *seaway distance* of the given site



- In this study, the site density ranged from 1 to14, had mean of 4, and a median of 4.5

Smolt cohort

- A smolt cohort was the group of smolts that were put to sea and reared in sea cages until slaughter
- It was hypothesized that cohorts of autumn smolt were more susceptible to PD occurrence than cohorts of spring smolt due to a smaller starting weight of the fish, a lower seawater temperature and a shorter day length, etc

- If a cohort was put to sea in the period of March-July it was classified as 'a cohort of spring smolt'; otherwise, if a cohort was put to sea in the period of August-February, it was classified as 'a cohort of autumn smolt'

- **Of the 359 study sites, 168 (46.8%) sites had only autumn cohorts; 170 (47.4%) sites had only spring cohorts; and 21 (5.8%) sites had mixed cohorts (both cohorts of autumn and spring smolts)**

Local biomass density (LBD)

- LBD indicates a potential of infection at a given site. This factor depends on average biomass of sites surrounding the given site. We evaluated the effect of LBD on the probability of PD occurrence of each site

- LBD has been estimated for all registered salmon fish farming sites in Norway (*Jansen PA, Kristoffersen AB, Viljugrein H, Jimenez D, Aldrin M, Stien A.* **Sea lice as a density dependent constraint to salmonid farming.** Proc. R. S. B. 2012, doi:10.1098/rspb.2012.0084.published online. 1-9)

- In this study, the LBD ranged from 4.87e+02 to 4.62e+08; had a mean of 2.19e+08; and a median of 2.11e+08. For the analytical purpose, the LBD was transformed using log10, and then back transformed for interpretation.

PD history

- Previous recent history of PD in a nearby area is likely to have an impact on a future probability of PD occurrence. In this study, we evaluated the effect of sites with PD suspected/confirmed in 2008 on PD occurrence in 2009-2010

- Of 359 study sites, 225 (63%) sites were located within 10-km distance of PD suspected/confirmed sites in 2008

Analyses (1/2)

- Univariable/Multivariable logistic regression with a spatial component
  - Dependent variable
    - Sites with/without PD during the study period
  - Independent variables
    - Site location
    - Site density
    - Smolt cohort
    - Local biomass density
    - PD history
- All regression analyses were performed using WinBUGS (windows version of Bayesian inference using Gibbs Sampling)
- Independent variables with a 80% posterior probability interval including zero were excluded from multivariable logistic regression analysis. A stepwise selection based on the Deviance Information Criterion (DIC) was used for selecting the combination of the covariates; the model with lower DIC is preferred to the model with larger DIC

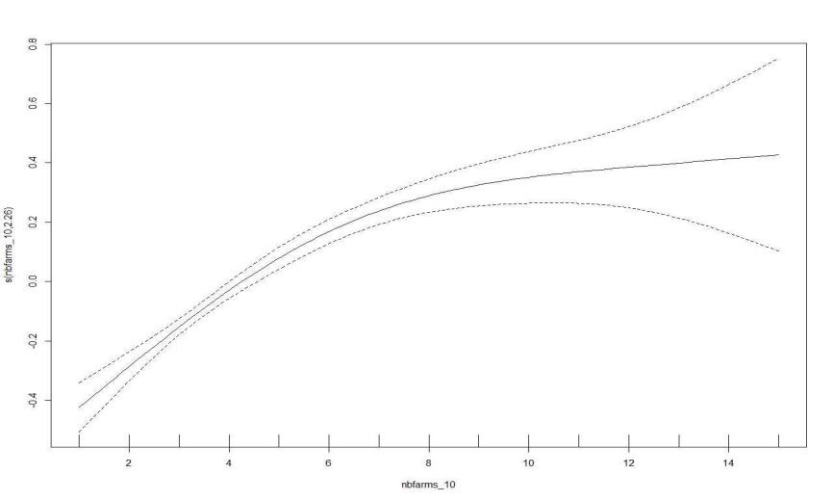
Analyses (2/2)

- The major outcome was PD predicted probability of each site. We presented (in a map) the median value (50th) of the posterior distribution of the probability estimate of PD occurrence

- Model validation
  - Relative operation characteristic (ROC) and calculate an area under the curve (AUC) to check the model fit
  - Compare the estimated probability of PD occurrence and the observed PD status during the study period
  - Compare the PD predicted probabilities based on the final model with the observed PD status in 2011

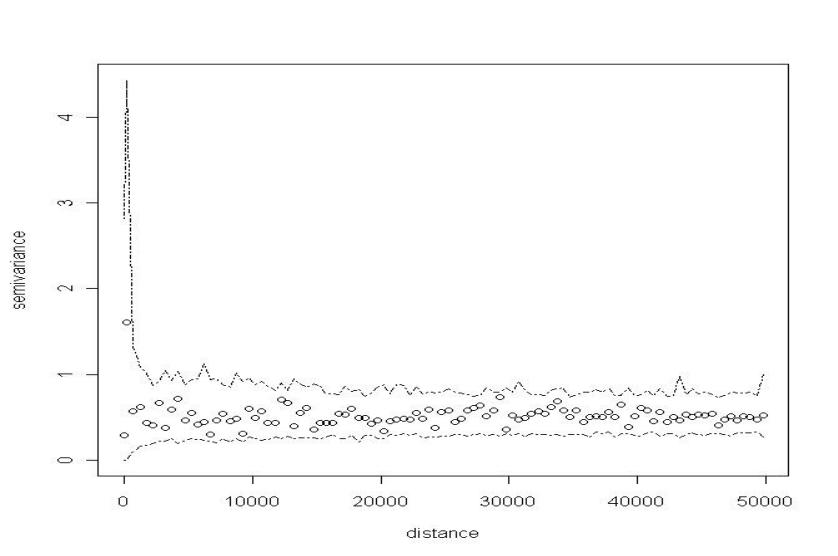
Results (1/4)

- According to our significance criteria, all covariates except the smolt cohort were further evaluated in multivariable logistic regression analysis
- Site density, LBD, PD history were positively associated with increasing risk of getting PD. A significant effect of latitude, with the risk of getting PD increasing as one goes south
- LBD showed a linear positive association for small site densities, but the association was leveled off for the higher site densities

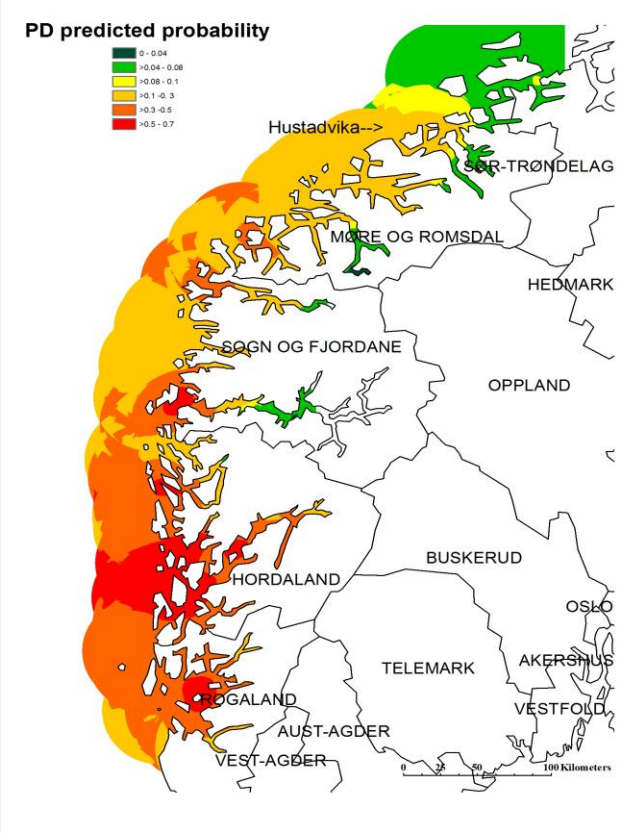


Results (2/4)

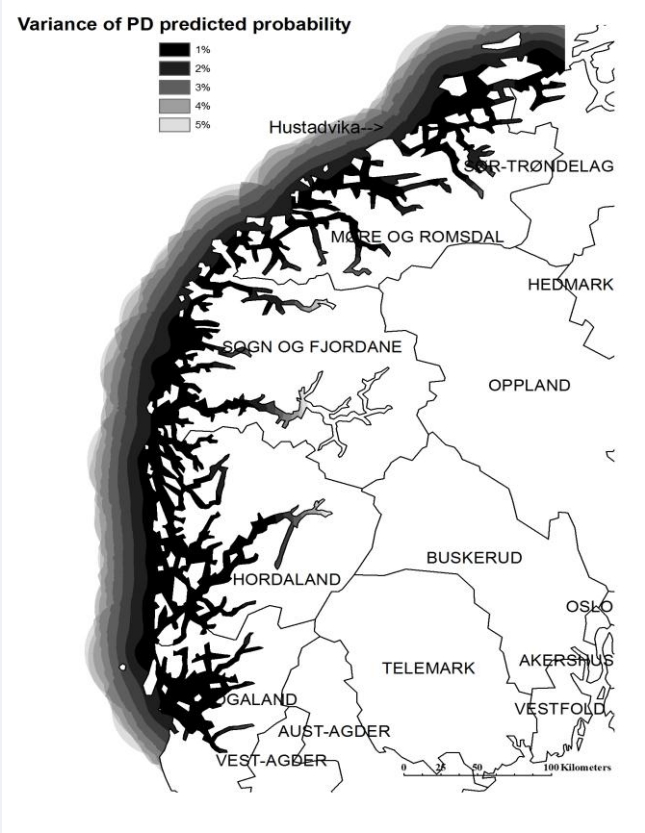
- Final model: site location + site density + LBD + PD history
- Residuals of all fitted models were in turn checked for spatial dependency. To do so, we compared the observed variogram with variogram 'envelopes' that were computed by simulating 999 permutations of the data values across locations
- A plot of empirical semivariogram of model residuals and simulation envelopes confirmed that the spatial pattern of PD cases was well accounted for by the final model



Results (3/4)



PD predicted probability ranged from 0 to 0.75 with a median of 0.4



The variance of the probability estimates ranging from 1% - 5%

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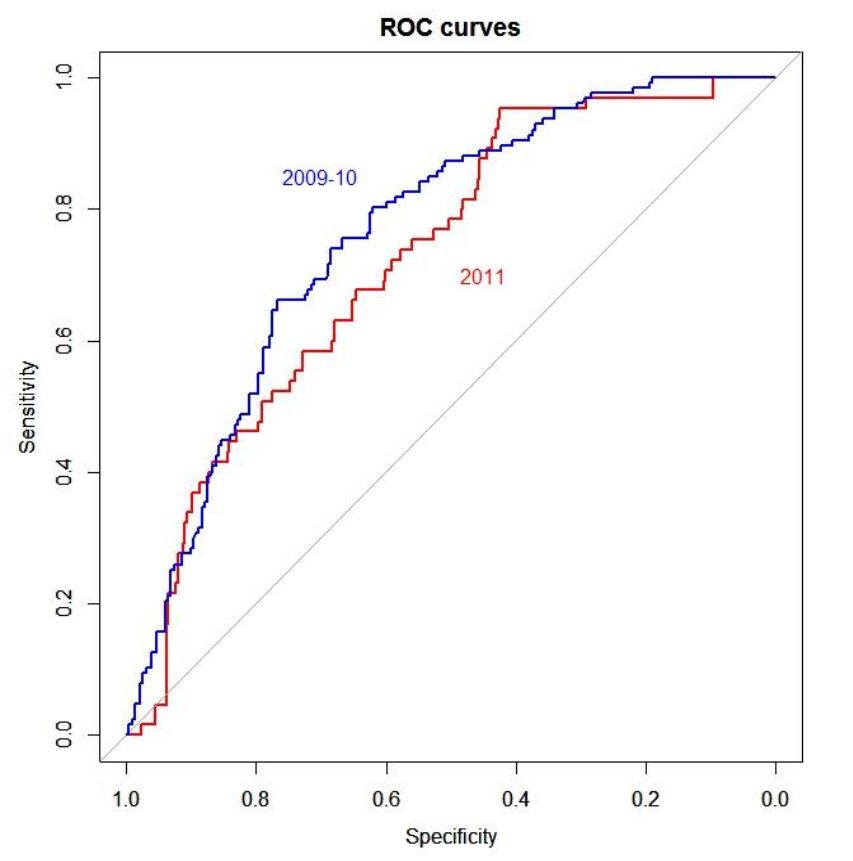
Results (3/3)



- A reasonable predictive capacity of the final model
- For model estimation, the AUC was 0.76 (95%CI: 0.71-0.81)
- For model prediction, the AUC was 0.72 (95%CI: 0.66-0.78)

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Discussion (1/2)

- A non-significant association between the time when smolt were put to sea and the PD occurrence.
- LBD and site density both present a concentration of fish; however, they could yield different interpretations.
- A significant effect of latitude, with the risk of getting PD increasing as one goes south. Interpretation of this result is sensitive as latitude can be correlated with several unmeasured variables related to PD risk, including seawater temperature.
- Exploring the effect of seasonality and seawater temperature on the PD occurrence would be of great interest. A further evaluation of the effect of this variable on the PD occurrence would require a selection of farming sites with a difference in the pattern of seawater temperature, good-quality and comprehensive data, and would be facilitated by a more dynamic time-scale incorporated into the spatial analysis.

Discussion (2/2)

- In our case, despite the spatial clustering of PD infected sites, we did not find a significant improve by adding a spatial component to the final model. This indicates that the predictor variables appropriately accounted for the local spatial correlation

- ROC/AUC's results provided a considerable confidence that the risk map could be used as a tool to select areas with an acceptable probability of PD occurrence for salmon farming sites, and to focus surveillance and control measures on high-risk areas

- Bayesian modeling approach is a flexible tool for accounting for hierarchical levels, such as spatial dependencies. The method allows incorporating previous information providing an appropriate setting for complex models and missing data problem, and the approach yields results in a form of probability distribution that is interpretable intuitively. The model estimates obtained from this present study could be later used as the prior knowledge to update the future prediction of PD occurrence

- Framework of the present study could be applied for spatial studies of other infectious aquatic animal diseases

Thank you for your attention