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The economic benefits of disease triggered early harvest: A case study of pancreas disease in farmed Atlantic salmon from Norway

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ABSTRACT

Pancreas disease (PD) is an important viral disease in Norwegian, Scottish and Irish aquaculture causing biological losses in terms of reduced growth, mortality, increased feed conversion ratio, and carcass downgrading. We developed a bio-economic model to investigate the economic benefits of a disease triggered early harvesting strategy to control PD losses. In this strategy, the salmon farm adopts a PCR (Polymerase Chain Reaction) diagnostic screening program to monitor the virus levels in stocks. Virus levels are used to forecast a clinical outbreak of pancreas disease, which then initiates a prescheduled harvest of the stock to avoid disease losses. The model is based on data inputs from national statistics, literature, company data, and an expert panel, and use stochastic simulations to account for the variation and/or uncertainty associated with disease effects and selected production expenditures. With the model, we compared the impacts of a salmon farm undergoing prescheduled harvest versus the salmon farm going through a PD outbreak. We also estimated the direct costs of a PD outbreak as the sum of biological losses, treatment costs, prevention costs, and other additional costs, less the costs of insurance pay-outs. Simulation results suggests that the economic benefit from a prescheduled harvest is positive once the average salmon weight at the farm has reached 3.2 kg or more for an average Norwegian salmon farm stocked with 1,000,000 smolts and using average salmon sales prices for 2013. The direct costs from a PD outbreak occurring nine months (average salmon weight 1.91 kg) after sea transfer and using 2013 sales prices was on average estimated at NOK 55.4 million (5%, 50% and 90% percentile: 38.0, 55.8 and 72.4) (NOK = €0.128 in 2013). Sensitivity analyses revealed that the losses from a PD outbreak are sensitive to feed- and salmon sales prices, and that high 2013 sales prices contributed to substantial losses associated with a PD outbreak.

1. Introduction

Pancreas disease (PD) is an important viral disease in the marine phase of salmonid aquaculture in Scotland, Ireland, and Norway (McLoughlin and Graham, 2007). The disease is caused by salmonid alphavirus (SAV), of which there are at least six subtypes (Fringuelli et al., 2008). Subtype SAV-3 was until 2010 the only subtype diagnosed in Norway. A separate epidemic associated with subtype SAV-2 evolved in mid-Norway from 2010 (Hjortaas et al., 2013). Norway has (per October 2014) a SAV-3 endemic area from mid-Norway and southwards and a SAV-2 endemic area from mid-Norway and northwards up to the border between the counties Sør-Trøndelag and Nord-Trøndelag.

The transmission of SAV during the marine production phase is described as horizontal (Fringuelli et al., 2008; Kristoffersen et al., 2009; Kongtorp et al., 2010; Jansen et al., 2010a; Graham et al., 2011). Although virus has been detected in asymptomatic wild-marine flat fish and Atlantic salmon (Snow et al., 2010; Biering et al., 2013), infected farmed salmon is considered the main reservoir of SAV (Jansen et al., 2015; Stene et al., 2014; Svåsand et al., 2015). Once a salmon farm is infected, all sea cages will be affected (Jansen et al., 2010b). The farm may stay asymptomatically infected for several months (Graham et al., 2006; Jansen et al., 2010a,b; Stene et al., 2014), before the disease become clinically evident once a critical viral load in the tissue is reached. A clinical PD outbreak can be seen at any time throughout the marine production cycle, on average 9 months after sea transfer (Bang Jensen et al., 2012), but

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is more prevalent during the spring and summer period (Rodger and Mitchell, 2007; Stormoen et al., 2013; Stene et al., 2014).

Pancreas disease causes biological losses that include reduced growth, mortality, increased feed conversion ratio, and carcass downgrading (Aunsmo et al., 2010), all of which lowers production efficiency. The biological losses, together with the extra expenditures associated with the disease, comprise the main direct costs of the disease (Bennett et al., 1999; Bennett, 2003; McInerney et al., 1992). Aunsmo et al. (2010) estimated the direct costs of a PD outbreak (SAV-3) at NOK 15.6 million for a Norwegian salmon farm stocked with 500 000 smolts, using average sales prices for 2007 (21.15 NOK/kg).

Decisions related to management of diseases made by salmon producers are impeded by biologic variation and uncertainty, disease spill over effects to nearby farms and the public good (i.e., marine environment), regulations, knowledge gaps and disagreements of disease properties (Osmundsen et al., 2012). Control measures such as vaccination (Bang Jensen et al., 2012), functional feed, improved genetics, and biosecurity measures are used to control PD. However, knowledge gaps related to the on-farm effects of the control measures (reviewed by Jansen et al., 2015) and the limited amount of scientific work providing actionable knowledge into this challenging decision context (Hamza et al. (2014) is a notable exception), often prevents salmon producers in making cost-effective decisions and compel them to rely more on experiential knowledge (Osmundsen et al., 2012). The management of PD thus require analyses that can investigate the economic implications of control measures, particularly at a farm level to improve producer-level decisions.

Real-time Polymerase Chain Reaction (RT-PCR) analyses of salmon heart tissue provide a sensitive diagnostic tool (laboratory sensitivity 0.01 TCID50 and specificity ≈100%) for SAV-3 (Hodneland and Endresen, 2006), and are used by some salmon producers in the SAV-3 endemic area to monitor the virus levels in their stock. Such screening may be used as a management tool, where increasing prevalence in the sampled fish and a peak in virus levels may serve as an early warning that a clinical outbreak is about to develop (Graham et al., 2007; Graham et al., 2010; Jansen et al., 2010b). With this information, a prescheduled harvest of the farm may be initiated to avoid losses from a clinical PD outbreak. In such a strategy, farms would have to trade off selling smaller fish against a PD outbreak. A strategy of harvesting PD-infected salmon farms prior to clinical disease can also provide additional benefits in reducing infection pressure on nearby salmon farms (Kristoffersen et al., 2009), improve animal welfare (Pettersen et al., 2013) and socioeconomic gain. However, the economic implication for farms using this strategy has not been studied.

The primary objective of the present study was to investigate if, when, and how frequently in the marine production cycle the marginal benefits of a disease-triggered early harvest strategy exceed the marginal costs for a salmon farm relative to undergoing a PD outbreak. A secondary objective was to estimate the direct costs of a PD outbreak on a salmon farm. To explore these questions, we applied partial budgeting in combination with stochastic modelling, with the salmon farm as the unit of economic analysis.

2. Materials and methods

2.1. The model

2.1.1. Model framework

Aunsmo et al. (2010) developed a stochastic model to estimate the economic impacts of diseases in the marine production of Atlantic salmon. The model uses a partial budgeting approach that allows for comparison of scenarios (Dijkhuizen and Morris, 1997). The model was designed to use specific data for salmon production in a form that is generally available in the salmon industry, and to include all possible areas of direct disease losses. In the model, a control farm with base level losses can be compared to a farm with a disease whereby disease-specific effects are combined with the base level losses to estimate the marginal cost of disease. The marginal costs of disease are estimated once the production cycle has ended by comparing the positive effects (i) additional returns and (ii) reduced costs with the negative effects (iii) returns foregone and (iv) extra costs associated with the disease (Dijkhuizen and Morris, 1997). The stochastic model handles uncertain parameters or parameters with biological variation by including the parameters as probability distributions.

The model framework described inAunsmo et al. (2010) was adapted to correspond with the current study. Three scenarios for a typical Norwegian salmon farm in the SAV-3 endemic area were constructed: (i) A baseline scenario, (ii) scenario 1 where SAV virus screening induces a prescheduled harvest before a clinical outbreak of PD and (iii) scenario 2 where a PD outbreak would start at the same time as the prescheduled harvest in scenario 1, but whereby the fish are allowed to stay in the sea until the scheduled harvest. The time point for a prescheduled harvest in scenario 1, and hence a PD outbreak in scenario 2, could be varied in the model (Fig. 1). The baseline scenario was used as the basis for constructing scenarios 1 and 2. The baseline scenario and the differences between scenarios 1 and 2 are described below.

2.1.2. Baseline scenario

The baseline scenario was constructed to reflect a typical farm stocked with 1,000,000 smolts in the SAV-3 endemic area of Norway. Smolts of the same year class were transferred to sea at the same time (production day 1) with an average weight of 0.1 kg and harvested once the average salmon weight reached 5.5 kg round weight. According to an average growth rate table, 484 days are required for salmon to obtain an average weight of 5.5 kg (see Section 2.2).

The variable production costs included feed, insurance, and harvesting costs measured as costs per kg produced salmon (round weight), dead fish handling (silage, storage and transport) as cost per kg dead fish (round weight), procurement of smolts and preventive measures taken against pancreas disease as costs per smolt, and the costs of sea lice treatments and the maintenance of the sea cages as costs per production days, with the latter based on an assumed linear trend (Tables 1 and 2). Prevention costs consist of measures specific to pancreas disease such as using PD-vaccine or implementing protocols for biosecurity, but also include the depreciation costs of specific investments in measures on the land base, boats and the sea site to help avoid and improve management of PD outbreaks.

A table for matching the harvest weight with an appropriate accumulated biological feed conversion ratio was used to estimate the amount of feed needed for the stock to reach the harvest weight (see Section 2.2 and Table 3).

The baseline biological losses included mortality and carcass downgrading at the slaughterhouse (Table 3). The mortality was assumed to be linear and inserted as a fixed value per production day. The biomass of dead fish was estimated by multiplying the cumulative mortality percentage with the number of sea transferred smolts and an average weight for dead fish (Table 3). The average weight for dead fish was estimated for the production cycle of 484 days with an average salmon harvest weight of 5.5 kg. The ratio between the average weight of the dead fish and the average harvest weight were assumed equal throughout the production. The produced biomass was categorized into four quality categories (superior, ordinary, production, and condemned) (Table 3), and the