Agenda item 6.2
For information

Council

CNL(16)46

Advances in understanding the impacts of sea lice on wild Atlantic salmon

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Introduction

Sea lice (*Lepeophtheirus salmonis*) has a widespread geographical distribution, is an important parasite of salmonids and has been a serious problem for the fish farming industry since the 1970s (Finstad et al., 2011; Thorstad et al., 2015). The high density of salmon in cages has provided a high number of potential hosts and promoted the transmission and population growth of the parasite (Torrissen et al., 2013). As a result, salmon farming has been shown to increase the abundance of lice in the marine environment. However, knowledge of parasite infection rates and resulting effects in wild populations of fish is not yet fully understood.

Several studies have demonstrated a link between fish farming activity and sea lice infestations on wild salmonids (Middlemas et al., 2010, 2013; Serra-Llinares et al., 2014, 2016; Helland et al., 2015). Thus, the risk of infection among wild salmon populations can be elevated in areas that support salmon mariculture, although louse management activities can reduce the prevalence and intensity of infection on wild fish (Penston & Davies, 2009; Serra-Llinares et al., 2014).

The extent to which elevated infections of sea lice pose a risk to the health of wild salmon populations has been the subject of extensive research. However, there are many difficulties in quantifying effects at the population level, particularly for fish stocks that are characterised by highly variable survival linked to environmental variables, such as Atlantic salmon (Vollset et al., 2015).

Sea lice - physiological effects on salmonids

Several studies on the effect of sea lice on Atlantic salmon (*Salmo salar*), sea trout (*Salmo trutta*) and Arctic charr (*Salvelinus aplinus*) smolts (reviewed in Finstad & Bjørn 2011; Thorstad et al., 2015) have been performed. Primary (nervous, hormonal), secondary (blood parameters) and tertiary (whole body response) physiological effects, including high levels of plasma cortisol and glucose, reduced osmoregulatory ability and reduced non-specific immunity in the host occur when the lice develop from the sessile chalimus 2 stage to the mobile first preadult stage. Further, sub-lethal tertiary effects, such as reduced growth, reduced reproduction; reduced swimming performance and impaired immune defence have also been reported (see Finstad & Bjørn 2011 for references).

Laboratory studies have shown that 0.04-0.15 lice per gram fish weight can increase stress levels, reduce swimming ability and create disturbances in water and salt balance in Atlantic salmon. In sea trout, around 50 mobile lice are likely to give direct mortality, and 13 mobile lice, or approx. 0.35 lice per gram fish weight might cause physiological stress in sea trout (weight range of 19-70 g). Moreover, around 0.05-0.15 lice per gram fish weight were found to affect growth, condition and reproductive output in sexually maturing Arctic charr (Tveiten et al., 2010).

Laboratory studies have also indicated that infections of 0.75 lice per gram fish weight, or approximately 11 sea lice per fish, can kill a recently emigrated wild salmon smolt of about 15 g if all the sea lice develop into preadult and adult stages (Finstad et al., 2000). Studies of naturally infested wild salmon postsmolts indicate that only those with less than 10 lice survived the infection. This is consistent with field studies on sea lice infections in salmon post-smolts in the Norwegian Sea where more than 3000 post-smolts have been examined for lice, but none observed carrying more than 10 adult lice. Fish with up to 10 mobile lice were observed to be in poor condition with a low haematocrit level and poor growth (Holst et al., 2003). The results have been further verified in the laboratory on wild caught Atlantic salmon post-smolts infected with sea lice and showing the same level of tolerance for sea lice infections (Karlsen et al., in prep.).

These results have been used in Norway to provide estimates of death rates according to lice densities on migrating salmon smolts as a management tool and have been adopted in the Norwegian risk assessment for fish farming (Taranger et al., 2015; Svåsand et al. 2016).

Sea lice monitoring programmes

In Norway, lice infection on wild salmonid populations is estimated through a national monitoring programme (Serra-Llinares et al., 2014, 2016; Taranger et al., 2015; Svåsand et al. 2016; Nilsen et al. 2016). The aim of the sea lice monitoring programme is to evaluate the effectiveness and consequences of zone regulations in national salmon fjords (areas where salmon farming is prohibited), as well as the Norwegian strategy for an environmentally sustainable growth of aquaculture.

Given the difficulties of sampling out-migrating wild salmon smolts, sea trout are commonly sampled and in most cases used as a proxy for potential levels on salmon (Thorstad et al., 2014). Monitoring is carried out during the salmon smolt migration (period 1) and in summer (period 2) to estimate lice levels on sea trout and Arctic charr. The fish are collected using traps, fishing nets, sentinel cages with smolts to investigate infestation rates and surface trawling (Bjørn et al., 2011; Taranger et al., 2015; Svåsand et al. 2016). The results indicate considerable variation between years and sampling locations in the risk of lice-related mortality (Nilsen et al. 2016; Svåsand et al. 2016).

Sea lice - population effects

Several long-term studies and analyses in Ireland and Norway looking at population level impacts of sea lice infestation in Atlantic salmon post-smolts have been performed. These studies have involved the paired release of treated and control groups of smolts (Gargan et al., 2012; Jackson et al., 2013; Skilbrei et al., 2013; Krkošek et al., 2013; Vollset et al., 2014, 2015). These studies assumed that the sea louse treatments were efficacious and that released smolts were exposed to sea lice during the period of the outmigration in which the treatment was effective.

Survival estimated have been based on a statistical analysis of differential survival to adults among release groups (Gargan et al., 2012; Jackson et al., 2013) including odds ratios (Jackson et al., 2013; Skilbrei et al., 2013; Krkošek et al., 2013; Torrissen et al., 2013; Vollset et al., 2015). All studies reported an overall improved return rate for treated versus control salmon, but all showed significant spatial and temporal variability in the magnitude of the treatment effect.

Gargan et al. (2012) reported that the ratio of return rates of treated:control fish in individual trials ranged from 1:1 to 21.6:1, with a median ratio of 1.8:1. Similarly, odds ratios of 1.1:1 to 1.2:1 in favour of treated smolts were reported in Ireland and Norway, respectively (Torrissen et al., 2013). Krkošek et al. (2013) reported that treatment had a significant positive effect with an overall odds ratio of 1.29:1 (95% CI: 1.18 – 1.42). A recent meta-analysis of Norwegian data (Vollset et al., 2015) based on 118 release groups (3989 recaptured out of 657,624 released), reported an overall odds ratio of 1.18:1 (95% CI: 1.07 – 1.30) in favour of treated fish. Further analysis found that the age of returning salmon was on average higher and weight lower in untreated fish compared with treated fish (Vollset et al., 2014; Skilbrei et al., 2013).

The survival of Atlantic salmon during their marine phase has fallen in recent decades (Chaput, 2012; ICES, 2015). This downturn in survival is evident over a broad geographical area and is associated with large-scale oceanographic changes (Beaugrand & Reid, 2003; Friedland et al., 2014). For monitored stocks around the North Atlantic, current estimates of marine survival are at historically low levels with typically fewer than 5% of out-migrating smolts returning to their home rivers for the majority of wild stocks, with lower levels for hatchery-origin fish (ICES 2015). Viewed against marine mortality rates at or above 95%, the 'additional' mortality attributable to sea lice has been estimated at around 1% (Jackson et al., 2013).

However, the impacts of sea lice have also been estimated as losses of returning adult fish to rivers. Such estimates indicate marked variability, ranging from 0.6% to 39% in individual trials (Gargan et al., 2012, Krkošek et al., 2013; Skilbrei et al., 2013). These results suggest that sea lice induced mortality has an impact on Atlantic salmon returns which may influence the achievement of conservation requirements for affected stocks (Gargan et al., 2012).

Vollset et al. (2015) concluded that much of the heterogeneity among trials could be explained by the release location, time period and baseline (i.e. marine) survival. Baseline survival was reported to be the most important predictor variable. When this was low (few recaptures from the control group), the effect of treatment was relatively high (odds ratio of 1.7:1). However, when baseline survival was high, the effect of treatment was undetectable (odds ratio of ~1:1). Vollset et al. (2015) concluded that their study supported the hypothesis that sea lice contribute to the mortality of salmon.

Summary

Sea lice has a widespread geographical distribution, is an important parasite of salmonids and has been a serious problem for the Atlantic salmon farming industry since the 1970s.

Salmon farming has been shown to increase the abundance of lice in the marine environment and the risk of infection among wild salmonid populations.

Laboratory studies have demonstrated that infections of 0.75 lice per gram fish weight, or approximately 11 sea lice per fish, can kill a recently emigrated wild salmon smolt of about 15 g if all the sea lice develop into pre-adult and adult stages.

A number of studies in Norway and Ireland have estimated the relative marine survival of smolts treated to provide lice resistance *versus* control groups and reported an overall improved return rate for treated salmon. There is significant spatial and temporal variability in the magnitude of the treatment effect. When baseline survival (i.e. survival of control group) was low, the effect of treatment was high. In contrast, when baseline survival was high, the effect of treatment was undetectable. These results suggest that sea lice induced mortality has an impact on Atlantic salmon returns, which may influence the achievement of conservation requirements for affected stocks.

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