



NOTE

First report of winter epizootic of salmon lice on sea trout in Norway

Knut Wiik Vollset, Bjørn Torgeir Barlaup

Uni Research – Environment, LFI, Thormøhlensgt. 49 B, 5006 Bergen, Norway

ABSTRACT: Here we report on the first observation of a winter epizootic of salmon lice *Lepeophtheirus salmonis* Krøyer on sea trout *Salmo trutta* Linnaeus in a Norwegian fjord with intensive salmon farming. Trout were sampled and counts of lice in the field were made for 2 consecutive winter seasons with trap nets in 2013 and 2014 just inside and outside the border to the National Salmon Fjord in Sognefjorden, western Norway. The aim of the study was to document potential epizootic outbreaks during the winter months. Following reports and field registrations of high abundance of lice in February and early March 2014, 12 and 14 fish were sampled from the 2 locations between 9 and 24 March and analyzed in the laboratory. Prevalence of sea lice on sampled fish inside and outside the fjord was 100 and 74 %, with a mean abundance of 254.3 and 26.8 and a mean average intensity of 254.3 (max = 759) and 37.5 (max = 188), respectively. Chalimus stages dominated on the fish. In comparison, prevalence and abundance based on field observations in 2013 were low and dominated by adult stages. We suggest that the winter epizootic observed in 2014 and not in 2013 may be a result of the combined effect of production of salmon lice in nearby fish farms and the prevailing environmental conditions.

KEY WORDS: Salmon lice · *Lepeophtheirus salmonis* · Sea trout · *Salmo trutta* · Epizootic · Infestation

INTRODUCTION

Salmon lice epizootics, i.e. infestations exceeding expected natural occurrences, on wild fish are one of the major causes for concern regarding the environmental sustainability of the open net pen salmon farming industry (Gargan et al. 2006, Krkosek et al. 2007, Middlemas et al. 2013). Salmon lice are natural parasites on wild salmonids throughout the Northern Hemisphere (Boxshall 1974, Boxaspen 2006). However, intensive fish farming of Atlantic salmon and rainbow trout has led to an increase in potential hosts. This again has led to a shift in parasite host dynamics, increasing the likelihood for the parasite to complete its life cycle and simultaneously augmenting the chance that wild hosts can become

infested by lethal numbers of parasites (Costello 2006).

Sea trout *Salmo trutta* L. are usually found close to the coast, feeding in shallow nearshore habitats during their sea sojourn. This is also an area where infectious stages of salmon lice aggregate (Penston et al. 2008a,b). The few studies that have registered salmon lice on sea trout in areas with no salmon farming generally report occurrences of high prevalence, but generally low intensity (Tingley et al. 1997, Schram et al. 1998). Epizootics have been registered in areas with fish farming (Heuch et al. 2009, Bjørn et al. 2011, Serra-Llinares et al. 2014). However, typical of these epizootics is that they occur during spring to autumn and often during periods of relatively high temperatures. One undocumented concern has been

*Corresponding author: knut.vollset@uni.no

whether salmon farming has led to an increase in infestation levels in periods of the year when sea trout do not naturally encounter large numbers of salmon lice. In areas without fish farms, salmon lice populations go through a bottleneck during winter months due to low temperature and relatively few hosts (Heuch et al. 2002). In cases where fish farms are present, numbers of hosts can, in theory, curtail this bottleneck and create epizootics on wild fish even at lower temperatures. Here we report on the first observations of winter epizootics of salmon lice *Lepeophtheirus salmonis* on sea trout in Sognefjorden located in western Norway.

MATERIALS AND METHODS

Sea trout were caught using modified trap nets (Barlaup et al. 2013) which consist of a lead net with a mesh size of 20 mm (50 m long and 5 m high) and 2 wings (10 m long and 5 m high), which then leads into a series of funnels and chambers with netting of decreasing size. The funnels have a 15 mm mesh for the first 4 m and 10 mm mesh size for the residence chamber, which is 2.5 m long. The last funnel leads to the residence chamber, where the fish are collected.

Sea trout stocks in some rivers on the west coast of Norway are critically low. Therefore, the sea trout caught in the trap-nets were handled carefully and released gently after visual inspection for mobile and attached stages of salmon lice without using any sedatives (field observations). All other fish species were released with minimal handling. During the survey period, traps were deployed each month for a period of 1–4 wk depending on resources available. In 2013, one trap net were deployed from January at Kvamsøy and then moved to Ligtvor in May (Fig. 1). In 2014, no traps were deployed until late February due to rough weather. In 2014, one trap was deployed in Kvamsøy from late February, while in early March another trap was deployed in Kyrkjebø (Fig. 1). The study was designed so that local personnel could continuously enumerate lice on live sea trout in the field, and take out a random sample of fish for detailed analysis in the laboratory at any signs of an epizootic. Sampled fish (see 'Results' for details) were individually

packed in plastic bags and frozen. The frozen fish were thawed and lice were registered in the laboratory using a magnifying glass. Salmon lice stages were identified according to Hamre et al. (2013). No species of parasitic lice other than *Lepeophtheirus salmonis* were identified on the fish. Length and weight were measured for each fish.

The spatial patterns of sea lice abundance determined on sampled fish in the laboratory in 2014 were identified using a 1-way ANCOVA, considering location (Kvamsøy and Kyrkjebø) as a factor and fish size as a co-variable. The model was run for attached and mobile stages separately (R Development Core Team 2013).

RESULTS

In 2013, relatively low numbers of salmon lice were counted during field observations. In general, only adult stages were recorded from 28 January until 27 March ($N = 58$, intensity = 5.78, max = 26, prevalence = 81 %, Kvamsøy). In May, an increase in the attached stages was reported (4 April to 4 June, $N = 294$, intensity = 19.5, max = 110, prevalence = 13.6 %, Ligtvor). We therefore decided to take a randomized sample from the trap net (i.e. all fish caught were sampled except for fish > 50 cm; the latter were released with minimal handling to avoid killing large and old individuals). Sampled fish were caught between 13

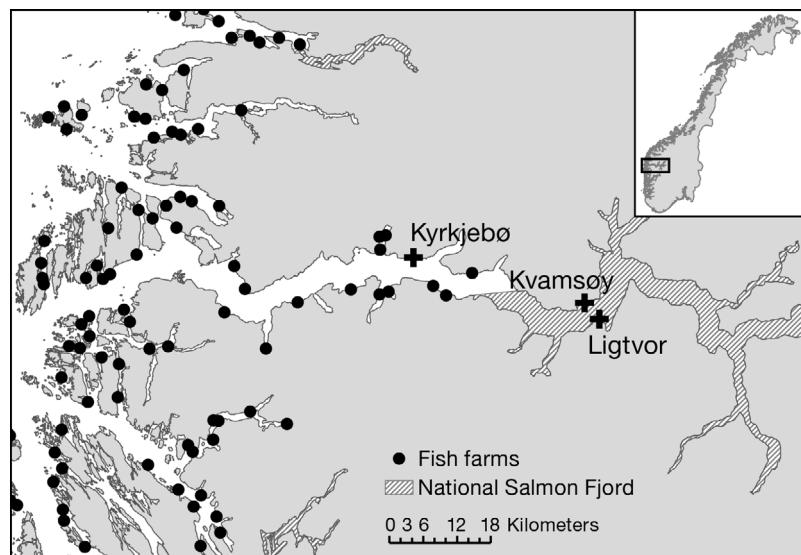


Fig. 1. Sognefjorden. Trap net locations are indicated with a black cross (Ligtvor, 61.10354° N, 6.54044° E; Kvamsøy, 61.12841° N, 6.48671° E; Kyrkjebø, 61.16222° N, 5.91745° E), while farming locations are indicated with black circles. Farming locations are taken from the home page of the Directorate of Fisheries (<http://kart.fiskeridir.no>, accessed 1 April 2014)

May and 8 June. The results from analysis in the laboratory confirmed that there were low numbers of salmon lice on the sea trout during this period ($N = 55$, intensity = 6.16, max = 23, prevalence = 34.5 %).

In 2014, relatively high abundances of attached stages were reported during field observations in early March at both Kvamsøy (1 March to 20 March, $N = 32$, intensity = 23, max = 220, prevalence = 72 %)

Table 1. Salmon lice *Lepeophtheirus salmonis* infestation parameters for sea trout *Salmo trutta* sampled at Kvamsøy and Kyrkjebø, Norway, in March 2014. Prevalence: percentage of fish infected in the sample; abundance: average number of salmon lice in all sampled fish; intensity: average number of salmon lice in infected fish; max: maximum number of lice recorded on a fish; relative intensity is lice per gram fish; %>10 lice: percent of fish with more than 10 lice; %>0.1 relative intensity: percent of fish with a relative intensity >0.1. Values in parentheses indicate SD

Parameter	Kvamsøy	Kyrkjebø
Period	9–20 March	13–24 March
N	12	14
Length (cm)	34.7 (9.4)	31.4 (4.7)
Weight (g)	405.29 (303.8)	263.1 (275.3)
Prevalence	100	73.0
Abundance	254.3 (296.7)	26.8 (50.9)
Median	63	3
Intensity	254.3 (296.7)	37.5 (56.7)
Max	759	188
Relative intensity (median)	0.15	0.01
%>10 lice	75	35.7
%>0.1 relative intensity	58.3	14.3

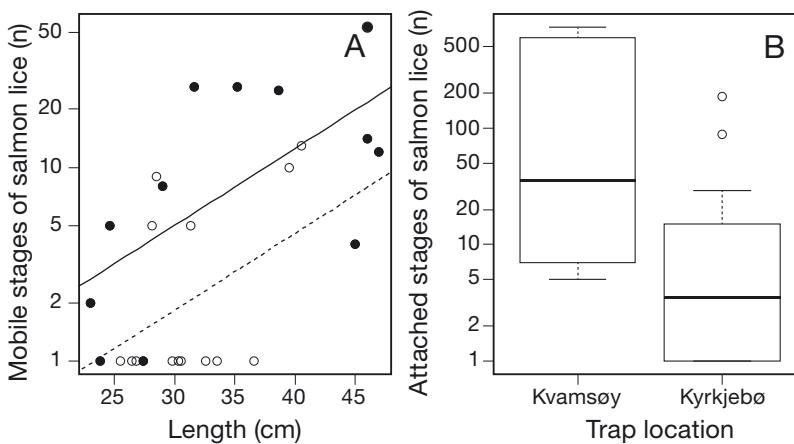


Fig. 2. Salmon lice *Lepeophtheirus salmonis* abundance on sea trout *Salmo trutta* sampled in March 2014 and enumerated in the laboratory. (A) Mobile stages of salmon lice versus length of sea trout, showing the modelled relationship for Kvamsøy (solid line and black circles) and Kyrkjebø (dashed line and open circles). (B) Boxplot of attached stages according to sea trout trap location. Horizontal lines: median, boxes: range between first and third quartile, error bars: range of data, open circles: outliers. Please note that we added 1 to the values to enable log-transformation of the data, and the scale is logarithmic

and Kyrkjebø (12 March to 24 March, $N = 27$, intensity = 16, max = 100, prevalence = 67 %). We therefore took a randomized sample from each of the 2 trap nets (i.e. all fish caught were sampled except for fish >50 cm). Sampled fish were caught between 9 March and 24 March. In Kvamsøy, the prevalence was 100 % ($N = 12$), with a mean intensity of 254.3 (± 296.7 SD; Table 1). Fifty-four percent had more than 0.1 lice g^{-1} and 73 % had more than 10 lice $fish^{-1}$. Some of the individuals had very high infestation levels, with a maximum of 759 lice on a 351 g fish. The stages were dominated by chalimus 1 (53.3 %) and chalimus 2 (37.8 %). There were relatively few preadults (4.0 %) and adults (1.2 %). Copepodites were also low in number (3.6 %), but we cannot be certain that some of these were not wrongly characterized, as copepods can be overlooked due to the high number of chalimus stages on some of the fins. In Kyrkjebø, the prevalence was 73 % ($N = 14$), with a mean intensity of 37.5 (± 56.7 SD, max = 188; Table 1). Fourteen percent had more than 0.1 lice g^{-1} and 36 % had more than 10 lice $fish^{-1}$. Similarly to Kvamsøy, the stages were also dominated by chalimus 1 (11.7 %) and chalimus 2 (52.9 %). However, there was also a high percentage of preadults (24.4 %), with relatively few copepodites (2.7 %) and adults (2.7 %).

There were more attached stages (ANCOVA, $F_{1,23} = 8.51$, $p < 0.05$) and mobile stages (ANCOVA, $F_{1,23} = 11.01$, $p < 0.05$) on the fish sampled in Kvamsøy compared to Kyrkjebø. For mobile stages, the number of lice increased with the length of the fish

(ANCOVA, $F_{1,23} = 6.78$, $p < 0.05$). However, this was not the case for attached stages (ANCOVA, $F_{1,22} = 1.05$, $p > 0.05$; Fig. 2).

DISCUSSION

Infestations on sea trout similar to those observed in March in 2014 have been recorded during the spring and summer months in areas with high farming activity (Heuch et al. 2009, Bjørn et al. 2011, Serra-Llinares et al. 2014), and anecdotal information suggests that epizootics can also occur in areas without fish farms during periods of high water temperature and low freshwater run-off. The surface temperature (within 1 m) at the fixed hydrographic station in Sognesjøen (outer region of Sognefjorden) during January

and February was 6.4 and 3.5°C in 2013 and 6.1 and 5.7°C in 2014 (6.3 and 5.5°C on average for the period 2000–2012, www.imr.no), respectively. Consequently, the temperature was well below temperatures that routinely occur during the summer and early autumn months in Sognefjorden (July average = 15.4°C). According to the model by Stien et al. (2005), it will take more than 28 d for individuals to reach the chalimus 1 stage at 5.7°C. This suggests that the production of the main proportion of the lice observed on the fish occurred in January or February. Natural salmon lice intensity during winter months on sea trout is usually not above 3 lice per fish, with a prevalence seldom exceeding 20% (Schram et al. 1998, Rikardsen 2004). Consequently, the prevalence and abundance observed here are above normal and can be defined as a winter epizootic.

One likely source of salmon lice on sea trout in Sognefjorden is lice produced on salmon farms. Correlations between lice counts and biomass in farms and counts of lice on sea trout have been corroborated in various studies (Middlemas et al. 2013, Serra-Llinares et al. 2014). In general, the correlation is dependent on the distance from the fish farms, decreasing from 0 to 30 km from the closest farm, but with large variation around this cut-off point (Middlemas et al. 2013). The source of this variation is most likely that the interaction between infestations on wild and farmed fish is dependent on a number of factors, such as behavior, local topography and currents (Brooks 2005). In our study, the infestation levels were higher on fish from the location furthest from fish farms within the National Salmon Fjord (Kvamsøy). This location is also further into the fjord, and the high infestation levels on these fish may be a result of individuals moving towards lower salinity water to avoid further infestations or behaviorally regulate osmoregulation (Birkeland & Jacobsen 1997).

The effects on the populations of sea trout from salmon lice epizootics during winter months are uncertain. Sea trout can descend rivers throughout the year (Jonsson & Jonsson 2009). While some individuals only stay in the ocean for days to months during spring and autumn, some sea trout also reside in the ocean throughout the winter, and in a few cases up to several years before ascending (Jonsson & Jonsson 2009, Jensen & Rikardsen 2012). This sea sojourn strategy may be an important component of the life history strategy of sea trout in order to ensure population stability. In some rivers and creeks, sea trout are only found in the river during the spawning season, residing most of the time in the estuary or in marine waters (Knutsen et al. 2004, Olsen et al.

2006). This is most likely because the freshwater habitat can be variable and in some cases detrimental. For example, habitats may temporally dry out during recurrent drought events, and in northern latitudes, smaller watersheds can freeze and become uninhabitable during the winter months (Limburg et al. 2001, Jensen & Rikardsen 2012). Consequently, increased salmon lice infestation during the winter months may be detrimental for some populations and life history strategies in sea trout.

The general trend in reports from sea lice counts from fish farms in Norway has been a decrease in the abundance of lice during spring months in the last decade, following an increased focus on lowering the production of salmon lice during the migration of salmon smolt (Jansen et al. 2012). However, simultaneously, an increase in the number of lice during the winter months has been reported in the last several years (Jansen et al. 2012). The present study is the first report of a winter epizootic of salmon lice on sea trout in Norway. No surveillance exists to document how frequent such winter epizootics are along the Norwegian coast. We highly recommend a more thorough investigation to document the severity of such outbreaks on wild fish.

Acknowledgements. We are in debt to the work done by Sogn Villakråd. Special thanks to B. Meel for organizing and M. Jacobsen, O. Giskeødegaard, T. Kyrkjebo and A. Frivik for voluntary fieldwork. The authors also acknowledge the work done by the editor and 2 anonymous referees in the process of improving and publishing the article.

LITERATURE CITED

- Barlaup BT, Gabrielsen SE, Loyland J, Schlappy ML, Wiers T, Vollset KW, Pulg U (2013) Trap design for catching fish unharmed and the implications for estimates of sea lice (*Lepeophtheirus salmonis*) on anadromous brown trout (*Salmo trutta*). Fish Res 139:43–46
- Bjørn PA, Sivertsgård R, Finstad B, Nilsen R, Serra-Llinares RM, Kristoffersen R (2011) Area protection may reduce salmon louse infection risk to wild salmonids. Aquacult Environ Interact 1:233–244
- Birkeland K, Jakobsen PJ (1997) Salmon lice, *Lepeophtheirus salmonis*, infestation as a causal agent of premature return to rivers and estuaries by sea trout, *Salmo trutta*, juveniles. Environ Biol Fish 49:129–137
- Boxaspen K (2006) A review of the biology and genetics of sea lice. ICES J Mar Sci 63:1304–1316
- Boxshall GA (1974) Infections with parasitic copepods in North-Sea marine fishes. J Mar Biol Assoc UK 54:355–372
- Brooks KM (2005) The effects of water temperature, salinity, and currents on the survival and distribution of the infective copepodid stage of sea lice (*Lepeophtheirus salmonis*) originating on Atlantic salmon farms in the Broughton Archipelago of British Columbia, Canada. Rev Fish Sci 13:177–204

- Costello MJ (2006) Ecology of sea lice parasitic on farmed and wild fish. *Trends Parasitol* 22:475–483
- Gargan PG, Poole WR, Forde GP (2006) A review of the status of Irish Sea trout stocks. Blackwell Publishing, Oxford, UK
- Hamre LA, Eichner C, Caipang CMA, Dalvin ST, Bron JE, Nilsen F, Boxshall G, Skern-Mauritzen R (2013) The salmon louse *Lepeophtheirus salmonis* (Copepoda: Caligidae) life cycle has only two chalimus stages. *PLoS ONE* 8:e73539
- Heuch PA, Knutsen JA, Knutsen H, Schram T (2002) Salinity and temperature effects on sea lice over-wintering on sea trout (*Salmo trutta*) in coastal areas of the Skagerrak. *J Mar Biol Assoc UK* 82:887–892
- Heuch PA, Bjørn PA, Finstad B, Asplin L, Holst JC (2009) Salmon lice infection of farmed and wild salmonids in Norway: an overview. *Integr Comp Biol* 49:E74
- Jansen PA, Kristoffersen AB, Viljugrein H, Jimenez D, Aldrin M, Stien A (2012) Sea lice as a density-dependent constraint to salmonid farming. *Proc R Lond Soc B Biol Sci* 279:2330–2338
- Jensen JLA, Rikardsen AH (2012) Archival tags reveal that Arctic charr *Salvelinus alpinus* and brown trout *Salmo trutta* can use estuarine and marine waters during winter. *J Fish Biol* 81:735–749
- Jonsson B, Jonsson N (2009) Migratory timing, marine survival and growth of anadromous brown trout *Salmo trutta* in the River Imsa, Norway. *J Fish Biol* 74:621–638
- Knutsen JA, Knutsen H, Olsen EM, Jonsson B (2004) Marine feeding of anadromous *Salmo trutta* during winter. *J Fish Biol* 64:89–99
- Krkosek M, Ford JS, Morton A, Lele S, Myers RA, Lewis MA (2007) Declining wild salmon populations in relation to parasites from farm salmon. *Science* 318:1772–1775
- Limburg KE, Landergren P, Westin L, Elfman M, Kristiansson P (2001) Flexible modes of anadromy in Baltic sea trout: making the most of marginal spawning streams. *J Fish Biol* 59:682–695
- Middlemas SJ, Fryer RJ, Tulett D, Armstrong JD (2013) Relationship between sea lice levels on sea trout and fish farm activity in western Scotland. *Fish Manag Ecol* 20: 68–74
- Olsen EM, Knutsen H, Simonsen JH, Jonsson B, Knutsen JA (2006) Seasonal variation in marine growth of sea trout, *Salmo trutta*, in coastal Skagerrak. *Ecol Freshwat Fish* 15:446–452
- Penston MJ, Millar CP, Davies IM (2008a) Reduced *Lepeophtheirus salmonis* larval abundance in a sea loch on the west coast of Scotland between 2002 and 2006. *Dis Aquat Org* 81:109–117
- Penston MJ, Millar CP, Zuur A, Davies IM (2008b) Spatial and temporal distribution of *Lepeophtheirus salmonis* (Kroyer) larvae in a sea loch containing Atlantic salmon, *Salmo salar* L., farms on the north-west coast of Scotland. *J Fish Dis* 31:361–371
- R Development Core Team (2013) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria
- Rikardsen AH (2004) Seasonal occurrence of sea lice *Lepeophtheirus salmonis* on sea trout in two north Norwegian fjords. *J Fish Biol* 65:711–722
- Schram TA, Knutsen JA, Heuch PA, Mo TA (1998) Seasonal occurrence of *Lepeophtheirus salmonis* and *Caligus elongatus* (Copepoda: Caligidae) on sea trout (*Salmo trutta*), off southern Norway. *ICES J Mar Sci* 55:163–175
- Serra-Llinares RM, Bjørn PA, Finstad B, Nilsen R, Harbitz A, Berg M, Asplin L (2014) Salmon lice infection on wild salmonids in marine protected areas: an evaluation of the Norwegian 'National Salmon Fjords'. *Aquacult Environ Interact* 5:1–16
- Stien A, Bjørn PA, Heuch PA, Elston DA (2005) Population dynamics of salmon lice *Lepeophtheirus salmonis* on Atlantic salmon and sea trout. *Mar Ecol Prog Ser* 290: 263–275
- Tingley GA, Ives MJ, Russell IC (1997) The occurrence of lice on sea trout (*Salmo trutta* L.) captured in the sea off the East Anglian coast of England. *ICES J Mar Sci* 54: 1120–1128

Editorial responsibility: Bengt Finstad,
Trondheim, Norway

Submitted: April 2, 2014; *Accepted:* August 18, 2014
Proofs received from author(s): September 16, 2014