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Comparison of gillnet and trap in relation to retention of salmon lice *(Lepeophtheirus salmonis)*, size selection of sea trout *(Salmo trutta)* and catch efficiency

Comparing the two most used fishing gear in "National Salmon lice monitoring Program"

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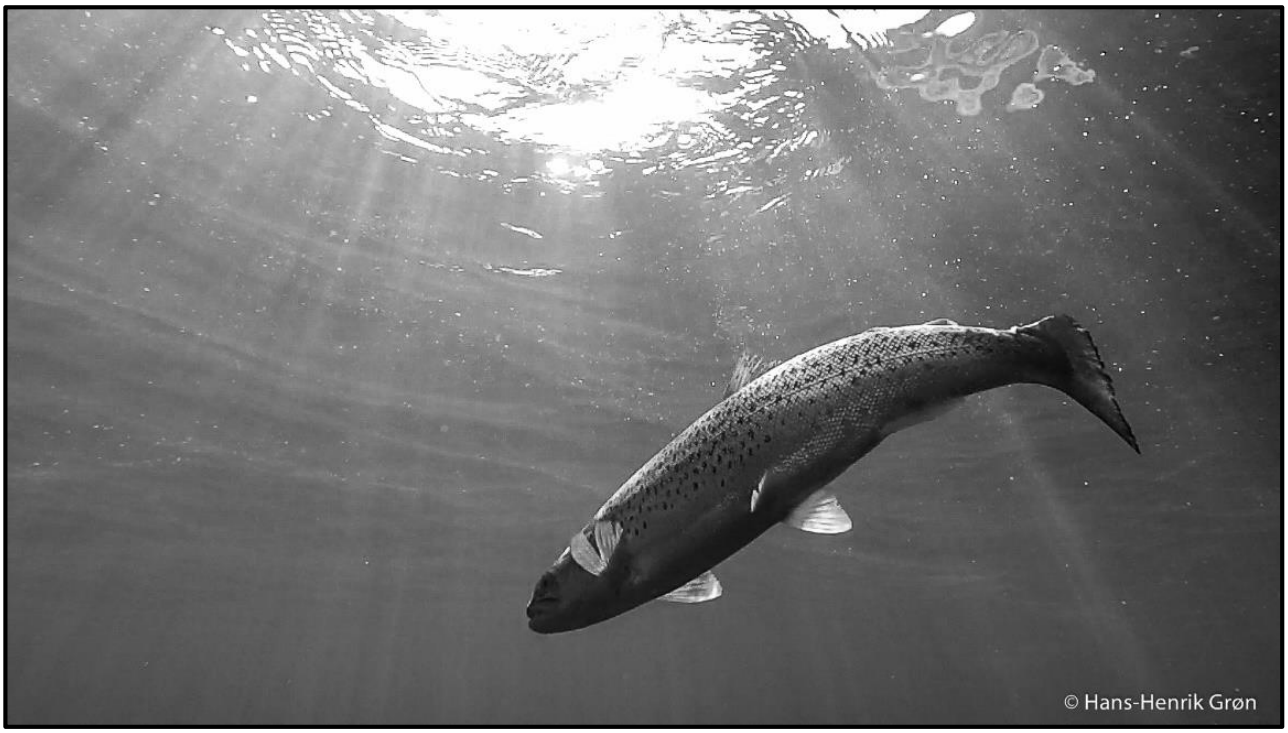

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Abstract

Salmon lice *(Lepeophtheirus salmonis)* are marine ectoparasites commonly found on salmonid species, where the infection levels on wild salmonids have dramatically increased the latest decade. Sea trout *(Salmo trutta)* is being used in salmon lice monitoring studies (e.g. NALO) where different sampling gears are used. The interaction between sea trout and lice is complicated, and therefore methodology studies are highly important to see how much fishing gear can affect estimates of prevalence, abundance and intensity of salmon lice on wild sea trout. It is also important to know the size selection of sea trout in different gears, because different size groups can experience different probability of being infected with lice. This is a methodology study that has three main objectives; (1) Elucidate the impact of fishing tools in relation to estimates of prevalence, abundance and intensity of salmon lice. (2) To see if the trap is size selective in catch, and (3) look into the efficiency of gillnets and trap. The study was conducted in Bjørknesvika on the southwest coast of Norway, and fish were sampled by using gillnets and a trap every other day. The prevalence of salmon lice on wild caught sea trout was not statistical significant between fishing gears and was on average 71% in gillnets vs. 75% in the trap. The mean abundance was significantly higher on sea trout caught in the trap than in gillnets (mean = 18 vs. mean = 7.9, respectively). Sea trout caught in gillnets were significantly smaller than sea trout caught in the trap (191.4 ± 75.6 mm vs. 205.2 ±71.6 mm, respectively). Gillnets were most efficient, representing 81,2% of the total catch where 15 and 17,5 mm mesh sizes caught 89 % of the gillnet catch. To conclude, the study showed that gillnets have significant impact on estimates of abundance and intensity of salmon lice, especially on pre-adult and adult lice by scraping away individuals. The study also showed that there is a probably that the trap are slightly size selective of sea trout, but it needs more investigation. The sampling gear in NALO are not yet ideal for the purpose and future modifications and investigations should be done to find a gear that is efficient, easy to deploy and handle, not size selective in catch and does not induce loss of salmon lice.

Keywords: *Salmon lice; Lepeophtheirus salmonis; sea trout; Salmo trutta; parasitology; gillnets; trap; management study; monitoring; national salmon lice monitoring program.*

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1.0 Introduction

Salmon lice *(Lepeophtheirus salmonis)* are marine ectoparasites commonly found on salmonids (Jones & Beamish 2011), and use sea trout *(Salmo trutta)*, salmon *(Salmo salar)* and Arctic char *(Salvelinus alpinus)* as hosts in Norway (Finstad & Bjørn 2011). In the last few decades, salmon lice infections on wild populations of salmonids have dramatically increased in abundance and annual epidemics have been reported the last 20 years from Norway (Finstad & Bjørn 2011, Serra-Llinares et al. 2014). The increases are most likely related to the use of open cages in salmon farms along the Norwegian coast, that have increased the availability of susceptible hosts for the parasite (Butler 2002, Serra-Llinares et al. 2014). More available hosts over years have caused higher production of planktonic salmon lice larvae in fish farms and the possibility the larvae lice have to drift out into the wild environment has also affected wild populations of salmonids (Butler 2002, Bjørn et al. 2011). This is especially the case on the south-west coast of Norway where the abundance of salmon farms is high (Thorstad et al. 2015). In these areas the density of planktonic salmon lice larvae in the wild can reach several orders of magnitude higher than in areas without fish farms (Butler 2002, Serra-Llinares et al. 2014).

Although salmon lice are a natural parasite, the infection levels found today on wild populations of salmonids are unnaturally high. The first epizootic of salmon lice was registered in salmon farms in Norway during the 1960s, and the same pattern was also found in Scottish salmon farms in the 1970s (Thorstad et al. 2015, Pike & Wadsworth 1999). In Ireland, sea trout in bad health were observed in 1989-1991 with high burdens of lice, returning prematurely back to the river and brackish waters (Tully, Poole & Whelan 1993). The same phenomenon with premature return of fish was also registered in Norway in the 90s by for example Birkeland (1996). Also, other investigations in Norway during early 90s showed high levels of salmon lice on wild salmon smolts (Finstad et al. 2011).

Salmon louse is divided into five phases: Nauplius, Copepodid, Chalimus, Preadult and Adult (Thorstad et al. 2015), where each phase consists of one or two life stages (see appendix 1) (Costello 2006, Hayward et al. 2011, Thorstad et al. 2015). The two first phases, nauplius and copepodid are free-living, planktonic and last for 1-2 months (Thorstad et al. 2015). They can be dispersed over long distances, perhaps up to 100 kilometers, depending on the water currents

(Asplin, Boxaspen & Sandvik 2011). Copepodid is the infective stage of salmon lice, and have to find a host for developing into the remaining, parasitic phases (Thorstad et al. 2015). Salmon lice die after few hours to days or weeks in freshwater, depending on the life-stage (Finstad, Bjørn & Nilsen 1995), and the lice are absent in water with low salinity (Pike & Wadsworth 1999).

It is the rasping mouthparts of salmon lice that can cause damage to the host by feeding on the skin, mucus, underlying tissue and blood (Costello 2006). The applied damages may cause osmoregulatory difficulties or failure, increased risk for secondary infections of viruses and bacteria, and increased physical stress (Thorstad et al. 2015). In some cases, high burdens of lice can lead to fish mortality (Bjørn & Finstad 1998, Dawson et al. 1998). High infection of lice will also reduce fish strength and therefore increase predation risk for the fish (Thorstad et al. 2013). It is also difficult to calculate the threshold limit for salmon lice before it leads to severe damage or mortality for salmonids, but Bjørn and Finstad (1997) concluded that relative abundance over 1.0 lice per gram fish or 50 preadult/adult lice may lead to mortality for small (60g) sea trout. Wells et al. (2006) also concluded that 12-13 mobile lice (preadult and adult lice) could activate non-lethal stress responses in sea trout smolts. The research on this threshold has led to a precautionary principle of limiting wild sea trout stocks to less than 10 mobile lice per fish the first year in sea (Finstad & Bjørn 2011).

The increased presence of salmon lice has especially negative consequences for wild populations of sea trout, because they reside in coastal areas with a potentially high density of salmon lice throughout their marine migration (Butler 2002). In contrast, Atlantic salmon migrate more directly to the open sea, away from the bulk of lice and will only be affected for a few weeks of their migration (Thorstad et al. 2010). Trout is a highly adaptable species and has a wide life history variation, where the species lives in lakes, rivers and in the sea (Jonsson & Jonsson 2011, Klemetsen et al. 2003)(see appendix 2). Whole populations of trout can either remain stationary in freshwaters (called brown trout), or migrate to the sea if it is possible (called sea trout). However, in many populations where both strategies are possible, it is likely to be a mix of those two extremes (Jonsson & Jonsson 1993, Klemetsen et al. 2003, Solomon 2006). There can also be individual differences within populations, where individuals from the same parents can become either brown- or sea trout (Jensen & Rikardsen 2012). Therefore there are only small genetic differences between anadromous-, and stationary individuals in a population of trout (Jonsson 2006). The types of variation between and within populations in

plasticity can change to the most beneficial in relation to reproductive potential over time (Solomon 2006). This means that if the conditions in the sea change to more beneficial; it will favor the migratory strategy and may induce higher numbers of sea migrating trout. The opposite may also be the case; if the conditions in the sea worsen, e.g. because of higher abundance of salmon lice, then this will favor stationary freshwater strategies more than the sea migrating path.

In the sea, sea trout stay in coastal waters during their marine migration, usually close to the surface (within the upper 1-3 meters), but also take deeper dives (Rikardsen et al. 2007a). The swimming distance from home river varies between populations and can span more than several kilometers (Berg & Berg 1987), but they seldom migrate out of the fjord systems and into the open sea (Jonsson & Jonsson 2011).

Because of the increasing problem with high infection levels of salmon lice on wild populations of salmonids, the government has decided to monitor the situation, and since 1992 The Marine Institute of Norway, Norwegian Institute for Nature Research and others have been systematically monitoring the salmon lice situation on wild populations of sea trout (Finstad & Bjørn 2011). Today this is called the "national salmon lice monitoring program" (NALO). The purpose of NALO is to monitor the increased presence of salmon lice on wild populations of salmonids, specifically to estimate the abundance of salmon lice on sea trout as an environmental indicator to give management advice with respect to aquaculture, and to elucidate the correlation between salmon farms and the abundance of salmon lice (Thorstad et al. 2015). The government has also implemented other strategies for salmon farmers that include mandatory reporting of lice, legal limits of lice in aquaculture, synchronic delousing and fallowing of farms within management areas (Serra-Llinares et al. 2014).

NALO is often based on several different fishing methods. Some of the methods are direct like gillnets, large trap, collecting fish with trawling and electric fishing. Other methods are indirect like deployment of cages with sea trout in sea (Serra-Llinares et al. 2014, Barlaup et al. 2013). The most frequently used sampling gears are gillnets and a specially designed sea trout trap (see material and methods for description). Gillnets are efficient, cheap, easy to use, fits into several locations where for example trap does not work (Bjørn et al. 2007). The negative sides of gillnets is the mechanical damages on fish skin that often makes catch and release impossible. It is also likely that the mechanical damages to skin will lead to loss of lice, especially for

mobile stages (pre-adult and adult lice) (Barlaup et al. 2013). This can probably be prevented to a certain extent by shortening the deployment time between each gillnet check (Serra-Llinares et al. 2014). The trap is specifically designed for catching sea trout (Barlaup et al. 2013). It is preferred in large monitoring studies (e.g. NALO), because fish can swim into the catching chamber with minimum mechanical damages and caught fish can be released after lice-counting (Barlaup et al. 2013). Traps are also considered to be a good gear for catching unharmed fish in freshwater lakes (Hayes 1989, Jackson & Harvey 1997), but traps also have negative sides. They are logistically demanding to deploy and handle, not possible to use everywhere, not as efficient in catching sea trout as gillnets and loss of lice during treatment is likely to happen (Thorstad et al. 2015). Sea trout in the catching chamber are also in danger of being eaten by bycatch. Both gillnets and traps are static gears, so both gears relay on the swimming behavior of the fish for catch. This means that the two sampling gears probably do not catch the most infected hosts, because infections of salmon lice can affect swimming efficiency. Therefore, the probability to catch individual fish partly rely on the abundance of lice (Finstad et al. 1995).

It is important that the sampling methods for sea trout are reliable. Unfortunately this is difficult to achieve because there is a large variation in life history among sea trout, individual behavior and interactions between host and parasite are complicated (Thorstad et al. 2015). Different size groups of sea trout can experience different probability of being infected with salmon lice and they can experience different abundances of lice (Jensen & Rikardsen 2008). Therefore, it is important to cover as many life stages as possible of sea trout in a representative manner. Salmon lice are also, as many other parasites, aggregated within the host population and this can introduce a skewed distribution where some individuals have huge burdens of lice (Nagasawa et al. 1993). The complexity of the interaction between salmon lice and sea trout often requires a large sample size for describing the statistical relationship between the production of lice larvae and the abundance of lice on wild populations (Thorstad et al. 2015). The methodological choices are also highly important where choice of fishing gear, fishing location and time can affect salmon lice estimate of abundance, intensity and prevalence. For example, can sampling sea trout nearby or in estuaries select for individuals with only high abundance of lice, because sea trout with high infection often prematurely return to the river (Bjørn, Finstad & Kristoffersen 2001). In this case, the abundance of lice will be overestimated. The opposite may also be the case, because in estuaries also recently migrated fish from freshwater can be caught. If these individuals are highly represented in the catch, then the

measurements of salmon lice are likely to be underestimated, because those individuals have not resided in sea long enough to be infected with lice (Bjørn et al. 2001).

The ideal sample method for estimating prevalence, abundance and intensity of salmon lice on wild sea trout, should be easy to carry out under varied weather-, sea- and seasonal conditions. The sampling method should not be selective on different size groups of sea trout, sampling should be efficient, not lead to lice loss under treatment and not harm the fish. The monitoring program aims for non-lethal sampling methods in the future due to decimated trout populations. That is why it will be especially important to know how and how much the fishing method can affect salmon lice estimates of prevalence, abundance and intensity.

This study aims to compare the two most commonly used sampling methods in NALO, the gillnets and traps. The study has three main objectives:

- To elucidate the impact of fishing gears in estimating the prevalence, abundance and intensity of salmon lice on sea trout.
- To see if there are differences in size selectivity of sea trout between gillnets and the trap.
- To compare the efficiency in sea trout catch between gillnets and the trap.

The study was conducted as much as possible, according to how sampling in NALO is done today in order to compare and apply the results into NALO in the future.

2.0 Materials and methods

2.1 Study area description

The study was carried out in a 400 meter wide bay, Bjørknesvika (59°39'3.5" N, 5°48'5.4" E), located in outer Etnefjord, a fjord that stretches in from Hardangerfjorden on the southwest coast of Norway (fig. 1).

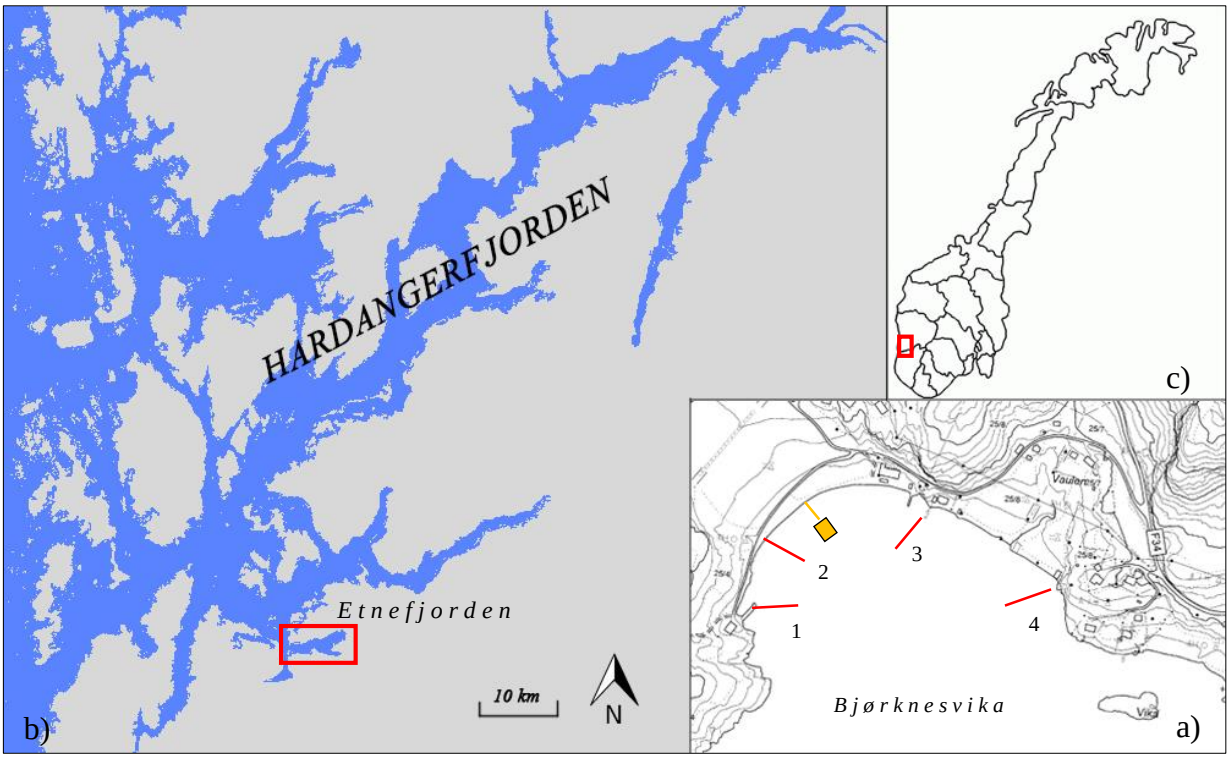

Figure 1: *Geographical map over the study area and surroundings. a) Bjørknesvika with the four different gillnets and trap locations. Red lines marks gillnets and the yellow shape marks trap location. b) Etnefjord and Hardangerfjorden. c) Norway.*

Bjørknesvika is a well-known fishing spot for sea trout by locals and have been used by NALO several years. The bay have shallow areas close to land with vegetation of different seaweed, grass and sandy bottom. Because the sea trout home range extend the whole bay, the probability of catching an individual is equal for all different gillnets and trap locations within the bay (Thorstad et al. 2004). The four different gillnet and trap locations were also expected to experience the same salinity and temperature variance during the season. To check this, measurements with a Castaway CTD device once a week on all gillnet locations was done and four DST tags at 0.5-, 1.5-, 3- and 5 m depth in the middle of the bay was deployed (see appendix 8).

2.2 Study design

The study was conducted in three different periods from 18/5-30/5, 8/6-20/6 and 13/7-25/7 in 2015. The procedure was the same in all three periods, where catching method changed every other day and the total of fishing days in each period was 12, six days with trap fishing and six days with gillnets fishing. One replica consists of one day fishing with trap followed by one day fishing with gillnets, and this was conducted as follows; The trap was set up before 6 p.m. and then active for 20-24 hours. Gillnets were then deployed from 6 - 12 p.m. on the day the trap fishing ended (fig. 2). After one replica, it was a break in the fishing until the afternoon on day three, when replica two started. The trap was deactivate before fishing with gillnets started by removing the leading net on the trap. In this way, the trap did not fish when the gillnets were fishing. When replica two started, the leading net was set back. Alternating between the two methods was considered the best possible design to prevent confounding effects of time as much as possible.

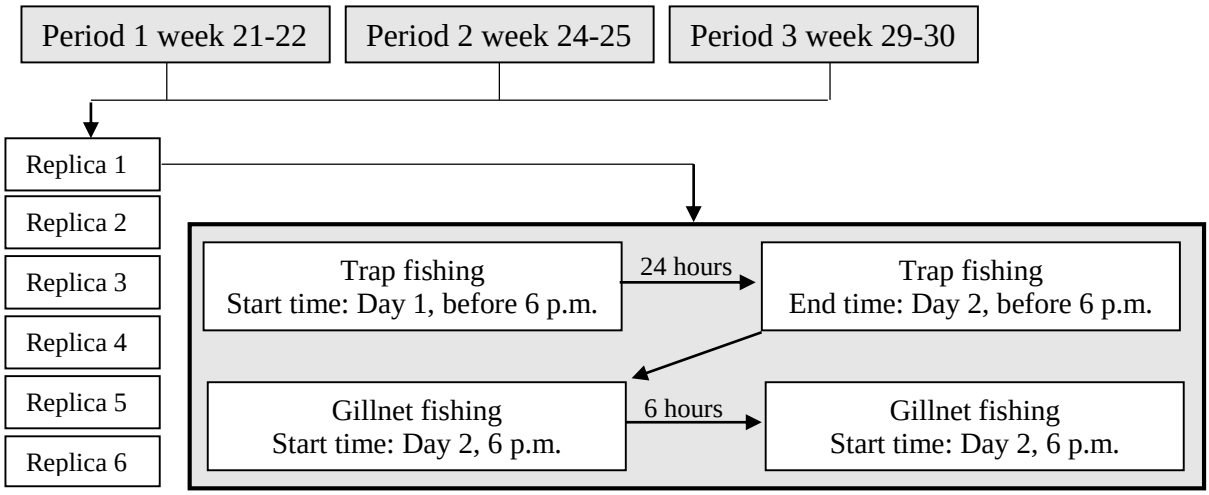

Figure 2: *Schematic overview of the study design with the three different periods. Each period consisted of six replicas where each replica consisted of both trap- and gillnets fishing.*

2.3 Custom-made trap

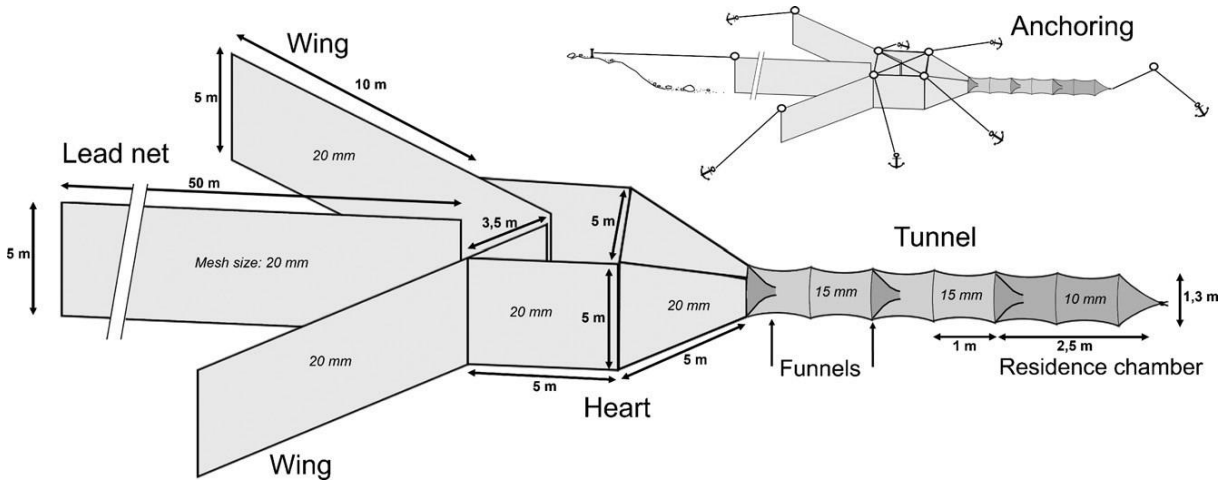

Figure 3: *The custom-made sea trout trap. [From:* (Barlaup et al. 2013)]

The custom-made trap is designed for catching sea trout (fig. 3). It takes between one to three hours for two persons in a boat to deploy the trap, and the trap can be left out for up to two weeks depending on water clarity. The trap has to be washed between each time to work properly.

The trap is attached to the shore with a 50 m long and 5 m deep floating leading net with 20 mm mesh size, at a 90˚ angle to shore. The other end of the leading net is attached to a square box (5 m x 5 m x 5 m) called the "heart". On each side of the heart, a 10 m long and 5 m deep wing is attached at a 45˚ angle towards the shore. The wings forms the vertical entrance to the heart. Both wings are attached to land or bottom with a rope and an anchor. From the heart, the trap goes over to a section of round funnels, decreasing in size. The funnel section is 5 m long and ends up in the last section that consists of three consecutive round chambers. The two first chambers have 15 mm mesh size and the last chamber is the residence chamber and has a 10 mm mesh size. The fish stay in the residence chamber which is 2.5 m long and 1.3 m in diameter. The whole trap is attached with a total of eight anchors, one on the leading net, one on each wing, four on the heart and one on the residence chamber. If the trap is placed into deep water, additional floaters on each corner of the heart can be used.

The trap was checked once per 24 hours and the catch was carefully taken out from the residence chamber with a knotless handheld landing net. In the boat, the fish were stored in a dark water tank with an oxygen supply (fig. 4). The bycatch was registered and released immediately. Before lice counting and registration of other measurements, the captured sea trout was anesthetized with Benzocaine (1 g per 10 L) in a separate tank. The number of salmon lice was counted, the fish was weighed down to the nearest 0.1 gram and the fork- and total length of the fish was measured down to nearest millimeter. The fish caught in the trap got a BIOMARK FDX-B HPT12 tag throughout the midventral body wall, just posterior to the pectoral fins, into the abdominal cavity with a BIOMARK MK25 implanting gun for recapture registration. After treatment, the fish were placed in a third water tank for recovery before released after 15-30 min.

The salmon lice counting was done according to the standardized method used in NALO; - the number of copepodids, chalimus, preadults, adult females and adult males were counted on a morphological basis according to Johnson & Albright (1991). During counting, a headlamp with strong light was used and the fish was held in a small white squared bucket filled with seawater (fig. 5). The lice that fell off during counting was also counted and then removed before the next fish.

Figure 4: *Typical setup during the count.*

Figure 5: *Clear, bright light in the counting bucket.*

2.4 Gillnets

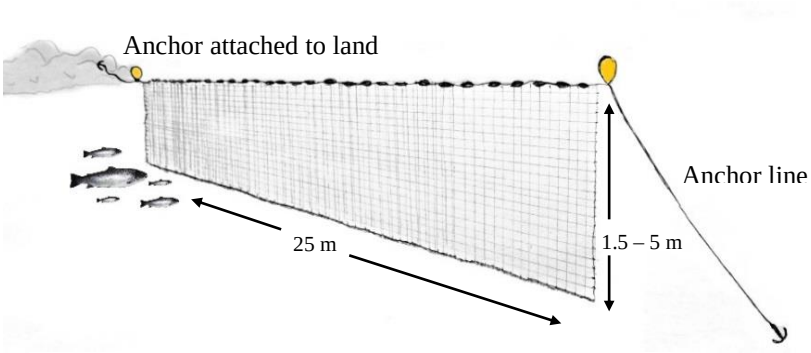

***Figure 6**: Gillnet setup with one anchor to the shore and one to the bottom.*

***Table 1**: Overview of the gillnet mesh sizes and depths used in the present study.*

Mesh size	Gillnet depth
15 mm	5 m
17.5 mm	5 m
21 mm	1.5 m
26 mm	2.5 m

The gillnets was 25 m long floating nets with four different mesh sizes, and depths (tab. 1). The different nets were randomly deployed on the four different gillnet spots at a 90˚ angle to shore. One end was attached to land with an anchor, and the other end had a rope attached to the anchor line (fig. 6). The nets were checked three times during a six-hour period at intervals of 1.5 hour where the nets were taken up on the last round. The fishing started some hours before the sunset, because it is conceivable that bright light could make the nets more visible for the fish and this would negatively affect the catch. This is also how it is done in NALO.

The sea trout caught in nets were rapidly cut out with scissors to prevent loss of salmon lice, killed with a blow to the head and placed in a plastic bag. Each caught fish got a unique number and which net the fish was caught in was registered. I also registered capture place, where the nets were divided into sections (upper 2.5m/lower 2,5m and inner/middle/outer section of the gillnets). Thereafter, was the same measurements as for the fish caught in the trap taken. The fish were checked for recapture with a *BIOMARK HPR PLUS* pit tag reader. In addition, bycatch, tide and weather conditions were registered every fishing day.

2.6 Statistical analysis

Statistical analyses were done with R studio (R Core Team (2015)) and Quantitative Parasitology 3.0 (Reiczige *et al.* 2013). Figures are made in both R studio and Microsoft excel 2013.

Dataset from Bjørknesvika and Etnefjorden 2012-2015

Salmon lice infection on wild sea trout in Etnefjorden have been systematically monitored over several years with trap fishing. Due to the low sample size in the trap from the present study in Bjørknesvika was an older dataset of all trap captured fish from Etnefjorden 2012-2015 include into the study. There were three reasons for doing this; (i) to compare sea trout captured in gillnets from the present study in Bjørknesvika with sea trout captured in traps from whole Etnefjorden 2015 (N = 618). (ii) to compare sea trout captured in gillnets from the present study in Bjørknesvika with sea trout captured in traps from a combined dataset from 2012-2015 (N = 4306). (iii) The third reason was to see if there were any variation in abundance of salmon lice between- and within years.

Parasitological terms

There are three commonly used parameters in parasitology describing the relationship between parasites and hosts (Bush et al. 1997). Prevalence (P), is the number of hosts infected with one or more individuals of a particular parasite species (a) divided by the number of hosts examined for that parasite specie (N) (Bush et al. 1997). Prevalence are normally given as a percentage.

$$P = a/N \times 100$$

Mean abundance (A), is the total number of individuals of a particular parasite species in a sample of a particular host species (b) divided by the total number of hosts of that species examined that including both infected and uninfected hosts (N). (Bush et al. 1997)

$$A = b/N$$

Mean intensity (I), is the average intensity of a particular species of parasite among the infected members of a particular host species (Bush et al. 1997). It is the total number of parasites of a particular species (b) found in a sample divided by the number of hosts infected with that parasite (n).

$I = b/n$

Both mean abundance and mean intensity are given with 95% confidence intervals for the population by the Bootstrap (BCa) method with 2000 bootstrap replications (here after referred as BCa).

Abundance of salmon lice

The abundance of salmon lice on sea trout captured in the gillnets and the trap did not follow a normal distribution (Shaprino-Wilk test; gillnets $p = 2.2 \times 10^{-16}$, trap $= 8.62 \times 10^{-8}$, Appendix 5) therefore was a Wilcoxon rank-sum test (WRS) used to test if there was any statistical differences in abundance of salmon lice on sea trout captured in the different fishing gears. WRS test is a non-parametrical hypothesis test that can be used when the normal distribution assumption of a two-sample t-test cannot be met (Whitlock & Schluter 2009). A non-parametric test makes fewer assumptions than standard parametric methods about the distributions of the variable. This method uses the rank of the measurements to test whether the frequency distributions of two groups are the same. If the distributions of the two groups have the same shape, then the test compares the locations of the two groups (Whitlock & Schluter 2009).

There is reason to believe that fishing gears can affect the different phases of lice differently and in different quantity as Barlaup et al. (2013) suggested. To check this, was the lice divided into three groups: (i) larvae group consisting of copepodid- and chalimus phases, (ii) mobile group consists of pre-adult and adult phases and (iii) total group consisting of all salmon lice phases (copepodid, chalimus, pre-adult and adult). The WRS tests was applied on all three groups.

Generalized linear model with negative binomial distribution

Since mean abundance are affected by many other factors, not just fishing gear, that is the only explanatory variable in Wilcoxon rank-sum test, was additionally a generalized linear model with a negative binomial distribution (GLM.nb) conducted. By assessing over-dispersion using Pearson residuals one could find that a GLM with Poisson distribution was over-dispersed. Since the data was over-dispersed with variance/mean rations over one by a Pearson residuals test, a GLM with negative binomial parameter, *theta*, was included in the model as a measure of aggregation. Wilson and Grenfell (1997) suggested using negative binomial distribution

because macro parasites often are highly aggregated within a host population. By doing the same Pearson residual analysis for negative binomial distribution, was the variance/mean rations good and close to one. GLM.nb with abundance of lice as response variable and fishing gear, fish length and period as the explanatory variables were done to see if the explanatory variables had significant importance when trying to estimating abundance of salmon lice on sea trout. An interaction was also included into the model between fish size and period, because there is expected that the fish would grow during summer and that post smolts migrate to the sea during spring or early summer.

Size selection of sea trout in the trap

Length distribution of sea trout captured in gillnets and trap was tested for normality with a Shaprino-Wilk test and by data explorations with visualizing plots. The results revealed that fork length on sea trout from the trap and from gillnets was not normally distributed (Shaprino-Wilk test; gillnets: p =2.2×10^{-16}, trap: p = 3.9×10^{-8}, Appendix 6 & 7). Since the data did not follow a normal distribution, a Wilcoxon rank-sum test (WRS) was applied to test if the fish size of sea trout caught in gillnets and trap was statistically different. Sins it was a low sample size in the trap (N = 43), was the same analysis also done in two other way: (i) Compering fork length distributions on sea trout caught in gillnets from Bjørknesvika against all fish caught in traps from Etnefjord 2015 (N = 618). (ii) Comparing fork length distributions on sea trout caught in gillnets from Bjørknesvika against all fish caught in traps from Etnefjorden 2012-2015 (N = 4316).

Catch comparison and catch per unit effort

Sea trout catch comparison between gillnets and trap was done in two ways. First, calculations of catch efficiency in percent of total catch, defined as six hour gillnet fishing with four different gillnets vs. 24 hour trap fishing with one trap. Secondly, catch per unit effort (CPUE), defined for gillnets and trap as "fish per gillnet per hour" and "fish per trap per hour", respectively. CPUE was also calculated for the total bycatch for both gears. I also calculated another CPUE only for gillnets to compare the sea trout catch in different mesh sizes. This was done because the gillnets used had different areas. CPUE for gillnet comparison was defined as "fish per $100\ m^2$ gillnet".

3.0 Results

3.1 Estimates of prevalence, abundance and intensity of salmon lice

Prevalence

The overall prevalence of salmon lice on wild caught sea trout was similar between gillnets and the trap with 71% vs. 75% respectively, and was not statistical significant (chi-square test: p = 0.57, fig. 7). The prevalence varied slightly between the three study periods from 56-87% in gillnets and 64-84% in the trap, but it was no trends. The differences in prevalence between gears in each period were not significant, as shown by the overlapping 95% confidence intervals (fig. 7).

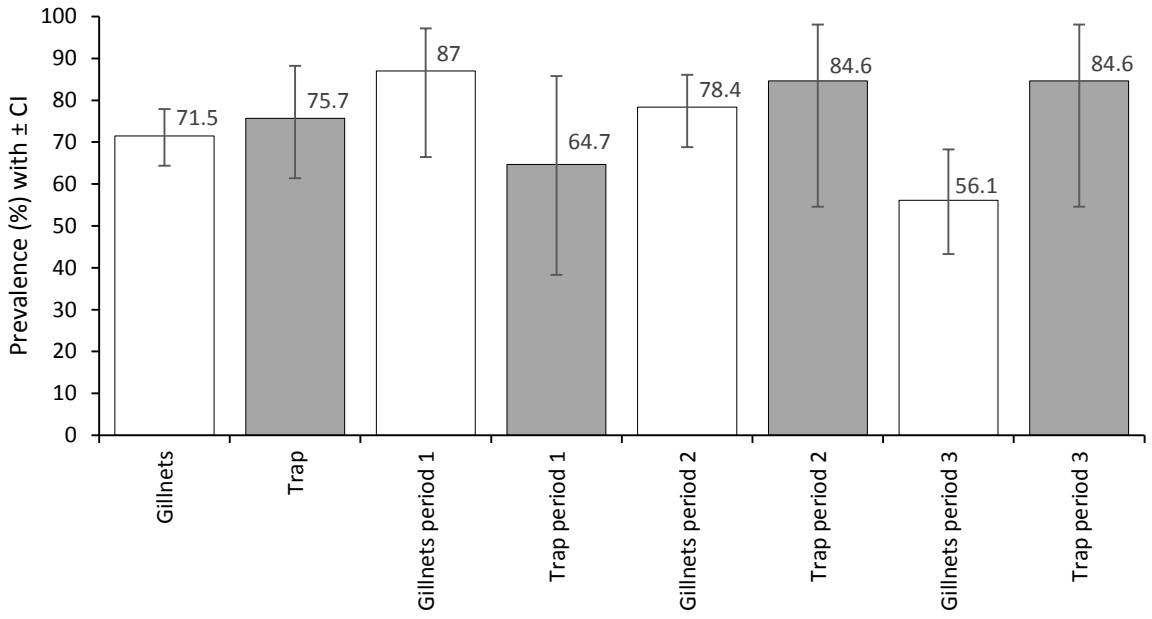

Figure 7: *Prevalence of salmon lice on wild caught sea trout in Bjørknesvika 2015 for the total catch and for the three different periods separately, for both gillnets and the trap (with traditional Clopper-Pearson confidence interval).*

Abundance and intensity

The mean abundance of salmon lice was higher on sea trout captured in the trap with mean abundance on 18 vs. 7.9 in the gillnets, when comparing all salmon lice phases combined. This different was also statistical significant (Wilcoxon rank-sum test: p = 0.01, fig. 8). Dividing the total group of salmon lice into larval phases (copepodid, chalimus I and II) and mobile phases (pre-adult, adult male and female), revealed that there was a difference between the gears regarding the retention of different phases of salmon lice. The mean abundance of lice in the larvae group was 6.7 on sea trout captured in the trap and a bit lower on sea trout caught in gillnets with mean abundance on 5.3, but the differences was not statistically significant (Wilcoxon rank-sum test: p = 0.42, fig. 8). The mean abundance of lice in the mobile group was 11.3 on sea trout caught in the trap and much lower on sea trout captured in gillnets with mean abundance on 2.15. The differences was statistically significant (Wilcoxon rank-sum test: p = 0.00008, fig. 8).

The same pattern could be observed when comparing mean intensity among the groups (total, mobile, sessile). Mean intensity of salmon lice, CI and p-values can be seen in appendix 3.

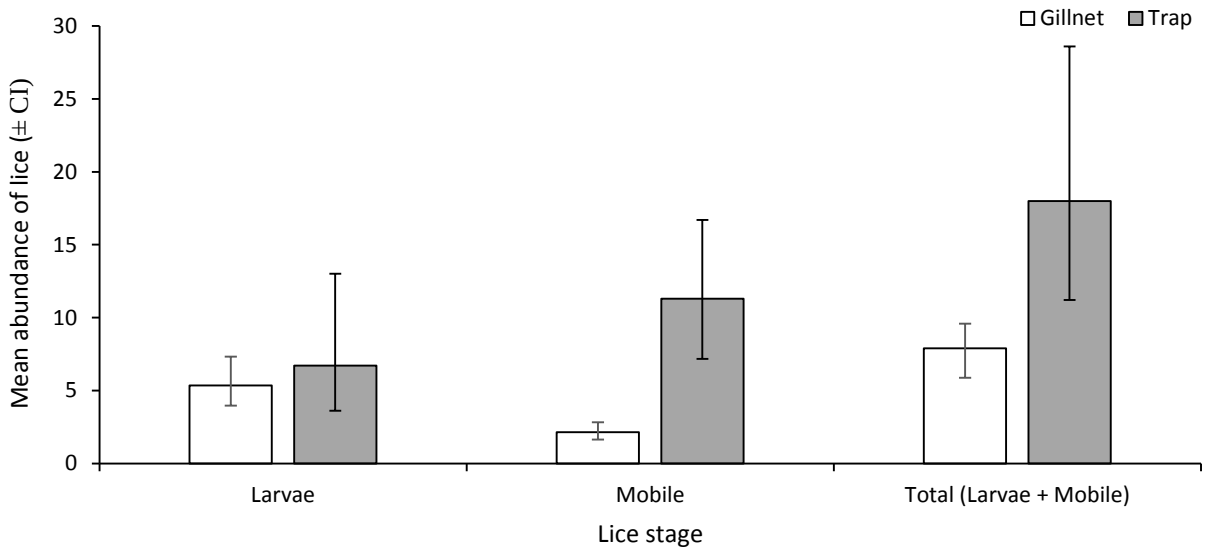

Figure 8: *Mean abundance of salmon lice on wild sea trout caught both in gillnets and trap from Bjørknesvika 2015. The salmon lice are divided into three groups, larvae group (copepodid and chalimus I and II phases), mobile group (preadult and adult male and female) and total group consist of all salmon lice phases (with 2000 Bootstrap BCa confidence interval).*

Mean abundance of salmon lice in Etnefjorden 2012-2015

By dividing the dataset of salmon lice on sea trout caught in Etnefjorden from 2012-2015 into years and weeks could one see that the abundance of salmon lice on wild sea trout varied a lot between- and within years. The highest mean abundance was in week 25-27 for all years, but the magnitude varied a lot between years, where 2013 and 2015 was in general a low infection years compared to 2014 and 2012 when there were much higher infections (fig. 9).

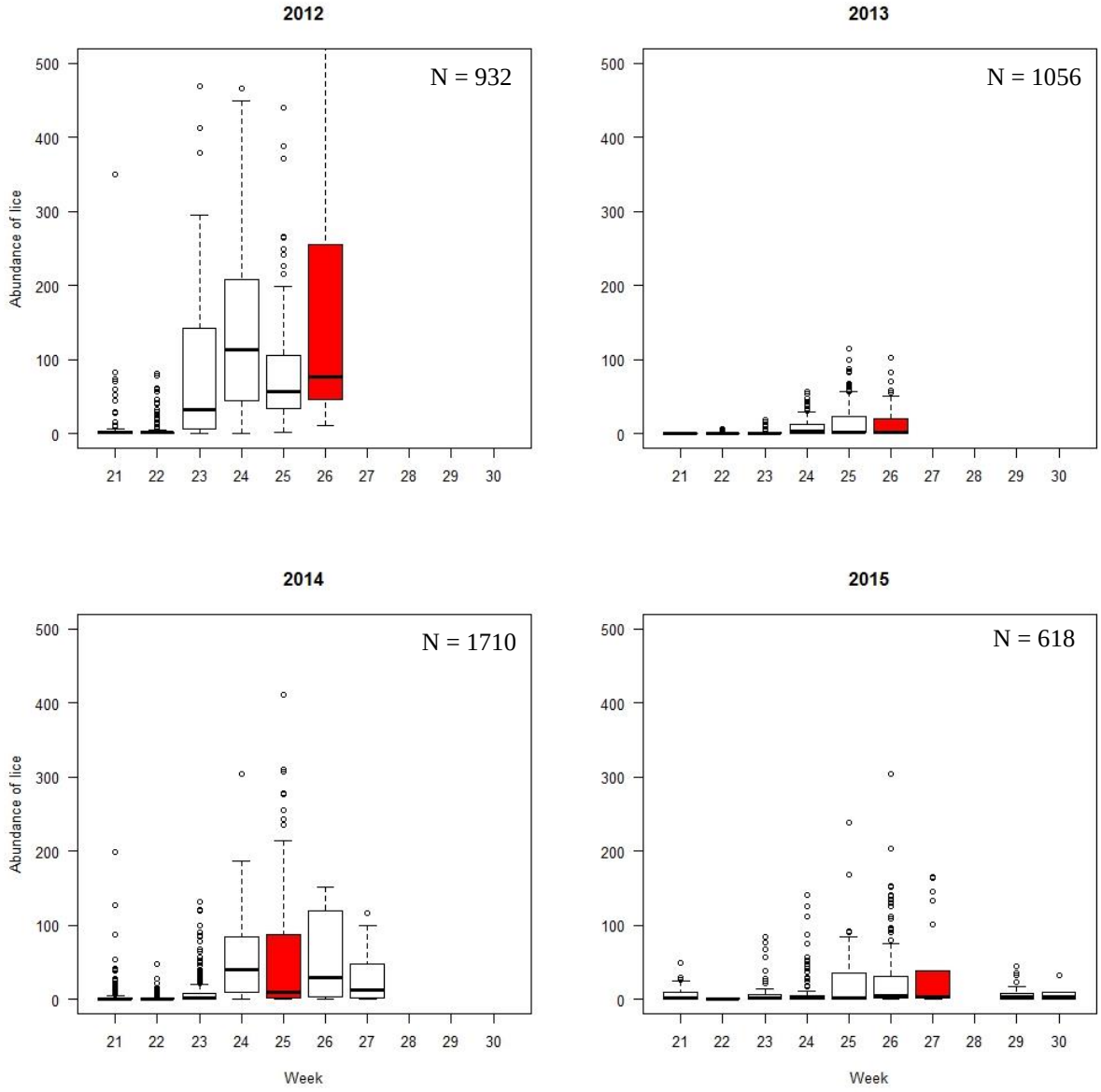

Figure 9: *Boxplot over weekly mean abundance of salmon lice on wild sea trout caught in trap from 2012, 2013, 2014 and 2015 with median line, first- and third quantile, maximum- and minimum abundance, and outliers. The red box illustrating the week with highest mean abundance during the sampling season of wild sea trout.*

Generalized linear model with negative binomial distribution

The generalized linear model with negative binomial distribution (GLM.nb) gave evidence that fishing gear, fish size and period are significant explanatory variables for the abundance of salmon lice on wild caught sea trout (tab. 2). The abundance of salmon lice was higher on sea trout captured in the trap than on sea trout captured in gillnets (fig 10a). The abundance increased with increased sea trout length, for both fishing tools (fig. 10b). There was a significantly higher abundance of salmon lice in period two, compared to period one and three (fig. 10c). There is also a statistical significant interaction between fish size and period two and sea trout length varied between periods (fig. 10d).

Table 2: *Output from GLM.nb test, d.f: 228, R^2 = 0.20.* * = significant p-value with α = 0.05.*

Covariates	Estimate	Std. error	p-value
Gillnets, Period 1	-1.538	0.745	0.0390 *
Trap	1.082	0.261	3.58e-05 *
Fish size	0.010	0.002	6.45e-05 *
Period 2	3.353	0.834	5.90e-05 *
Period 3	1.919	0.984	0.0512
Fish size * period 2	-0.007	0.003	0.0208 *
Fish size * period 3	-0.005	0.004	0.2476

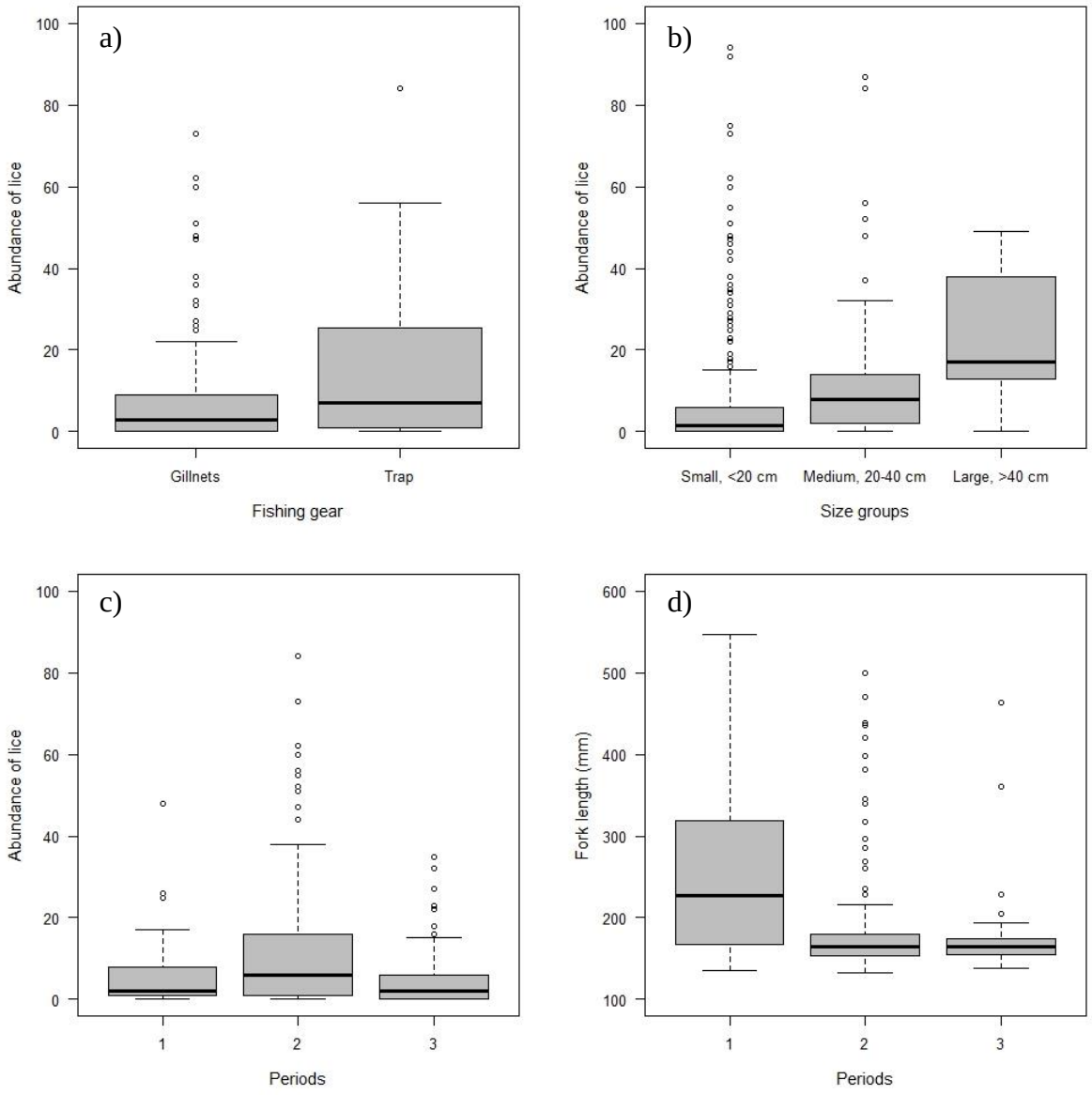

Figure 10: *Visual plots of the four explanatory variables in the GLM.nb model with median line, first- and third quantile, maximum- and minimum abundance, and outliers. a) Abundance of lice on sea trout caught in gillnets and the trap. b) Abundance of lice in different sea trout size groups (small, medium and large) for both fishing gears combined. c) Abundance of lice on sea trout in the three different periods for both fishing gears combined. d) Variation in sea trout fork length between periods for both fishing gears combined.*

3.2 Size selection of sea trout in gillnets and the trap

Fish sample

The total catch during the study was 229 sea trout, where by far most of the fish was captured in gillnets (tab. 3). The smallest catch difference between the gears were observed in period one, and the largest difference occurred in period two. The catch of sea trout in the trap was quite stable between the periods, but the catch in the gillnets varied between periods (tab. 3).

Table 3: *Sample size (N) of sea trout, mean sea trout size in fork length with SD, median in fork length, and size range from smallest to largest sea trout in each period and for total catch from gillnets and trap in Bjørknesvika.*

Bjørknesvika 2015	**Sample size (N)**	**Mean (mm) ± SD**	**Median (mm)**	**Size range, Min – max (mm)**
Period 1, Trap	17	207.7 ± 58.7	185	158 - 361
Period 1 Gillnets	23	284.5 ± 101.2	296	136 - 547
Period 2, Trap	13	238.3 ± 102.7	180	143 - 436
Period 2 Gillnets	97	182.9 ± 69.3	162	132 - 500
Period 3, Trap	13	168.8 ±11.9	172	150 - 186
Period 3, Gillnets	66	171.5 ± 46.2	164	138 – 463
Total catch, Trap	43	205.2 ± 71.6	178.0	143 - 436
Total catch, Gillnets	186	191.4 ± 75.6	164.5	132 - 547

Recapture from tagged sea trout

The recapture rate in gillnets from pit-tagged trap fish was only three out of 43 tagged fish (6.9%), whereas none was recaptured in the trap.

Size distributions in fishing gears

The mean fork length for sea trout caught in the trap was 205.2 mm, ranging from 143 mm to 436 mm (fig. 11). The mean fork length for fish caught in all four gillnets during the three periods pooled together was somewhat smaller with 191.4 mm, ranging from 132 mm to 547 mm. The differences between size distribution between gears were statistically significant (Wilcoxon rank-sum test: p = 0.0006). The size distribution revealed that 72% of all trap caught fish and 80.1% of all gillnet caught fish were between 140-200 mm in fork length (fig. 11).

Figures, mean sea trout size in fork length with SD, median in fork length, and size range from smallest to largest values of sea trout captured in the trap in 2012, 2013, 2014 and 2015 can be seen in appendix 4 & 7.

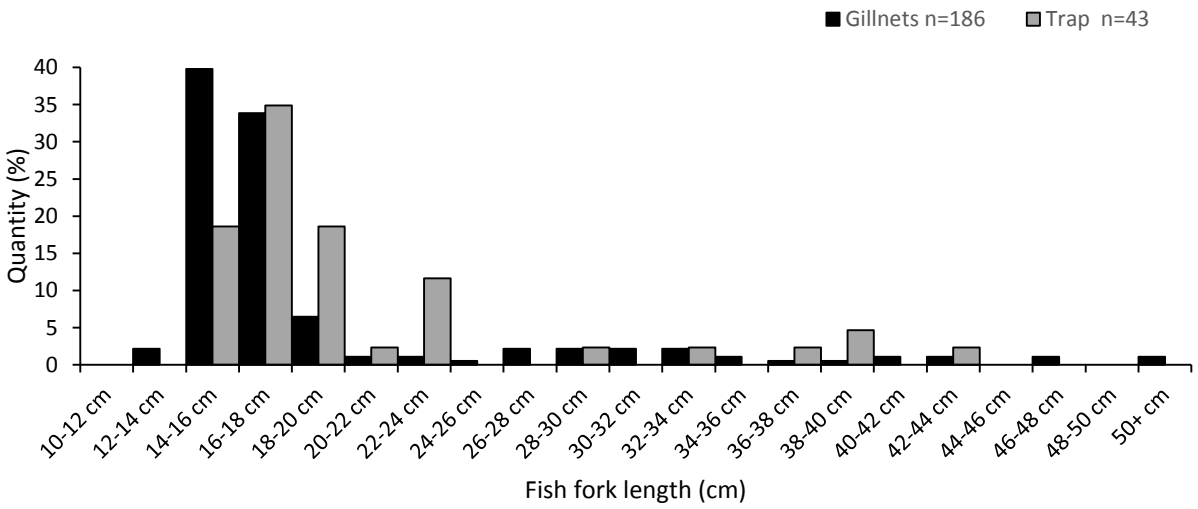

Figure 11: *Fork length distribution of sea trout from gillnets and trap in percent of total catch from Bjørknesvika 2015.*

The same analysis was also conducted on the old dataset from Etnefjorden where two tests were done; (i) For sea trout caught in gillnets from the study in Bjørknesvika compared to trap captured sea trout from whole Etnefjorden 2015 (N = 618) this was statistical significant (Wilcoxon rank-sum test: p = 0.03). (ii) and for sea trout caught in gillnets from the study in Bjørknesvika compared to sea trout caught in traps from whole Etnefjorden 2012-2015 (N = 4306) this was not statistical different (Wilcoxon rank-sum test: p = 0.09, Appendix 4 & 7).

3.3 The efficiency of gillnets and trap

Catch comparison and catch per unit effort

Catch efficiency in percent of catch (defined here as six hours gillnet fishing with four different gillnets vs. 24 hours trap fishing with one trap) varied between fishing gear both in the total catch and in each period, both for sea trout and for bycatch (fig. 12, tab. 3 & 4). The differences in catch between the fishing gears were lowest in period one, but were large in period two and three (fig. 12). The gillnets were overall most efficient, representing 81.2% of the total catch. Including fishing time into the analysis (CPUE), reveals that fishing with one gillnet is five times more efficient than one trap, but the effectiveness varied between the periods where CPUE differences were smallest in period one (fig. 13).

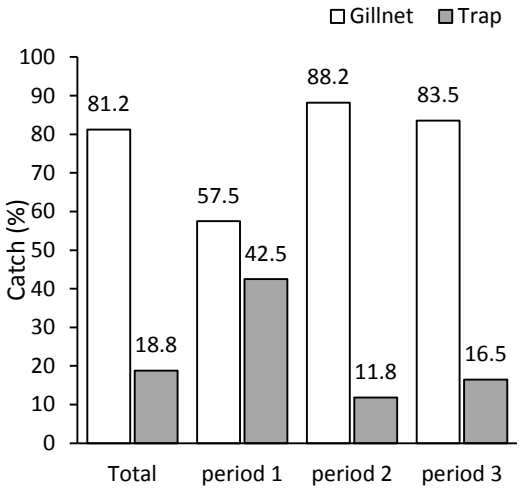

***Figure 12**: Gillnets and trap catch in % of total catch in each period and totally where the periods are combined. Catch efficiency where calculated out of six replica with six hour gillnet fishing with four different gillnets vs. 24 hour trap fishing with one trap.*

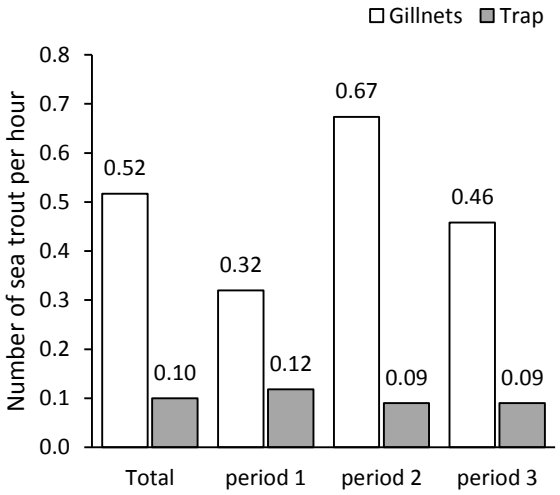

***Figure 13**: Catch per unit effort (CPUE) for total catch and for the three different periods. CPUE are defined for gillnets and trap as "fish per gillnet per hour" and "fish per trap per hour", respectively.*

Bycatch

The bycatch in gillnets and the trap showed that the fishing gears catches many different species and it is a tendency that the trap are slightly more species selective then gillnets where trap caught 8 species vs 11 species in the gillnets (tab. 4). The amount of each species differed remarkably between fishing gear where the trap captured mainly pollock *(Pollachius virens),* while nets mainly captured mackerel *(Scomber scombrus),* pollock *(Pollachius pollachius),* herring *(Clupea harengus)* and wrasse (Labridae) (fig. 14).

Table 4: *Overview of bycatch from gillnets and the trap in total and in the three different periods from Bjørknesvika 2015.*

Bycatch in Gillnet and Trap								
Fish species	**Period 1**		**Period 2**		**Period 3**		**Total**	
	Gillnets	Trap	Gillnets	Trap	Gillnets	Trap	Gillnets	Trap
Mackerel *(Scomber scombrus)*	93	0	271	0	121	1	485	1
Horse mackerel *(Trachurus trachurus)*	0	0	0	0	10	0	10	0
Pollock *(Pollachius virens)*	0	0	1	2	13	0	14	2
Pollack *(Pollachius pollachius)*	29	45	39	191	62	25	130	261
Garfish *(Belone belone)*	5	2	0	15	0	2	5	19
Herring *(Clupea harengus)*	42	5	44	3	3	0	89	8
Grey gurnard *(Eutrigla gurnardus)*	3	0	1	0	1	0	5	0
Righteye flounders (Pleuronectidae)	2	0	2	0	4	0	8	0
Wrasse (Labridae)	78	1	111	0	115	0	304	1
Mullets (Labridae)	0	0	2	0	2	0	4	0
Whiting *(Merlangius merlangus)*	5	0	1	0	0	0	6	0
Cod *(Gadus morhua)*	0	1	0	0	0	0	0	1
Salmon *(Salmo salar)*	0	0	0	1	0	1	0	2

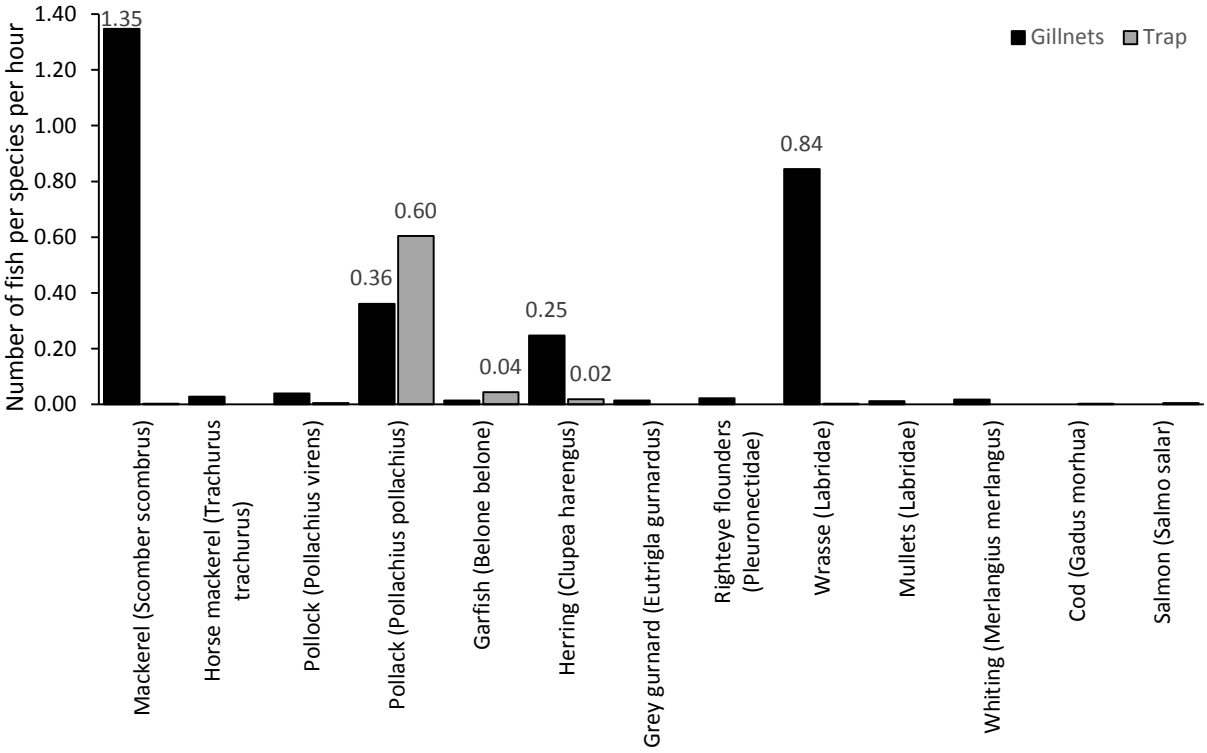

Figure 14: *Catch per unit effort (CPUE) for total bycatch in both fishing gears. CPEU are defined for gillnets and trap as "fish per gillnet per hour" and "fish per trap per hour", respectively.*

Gillnets

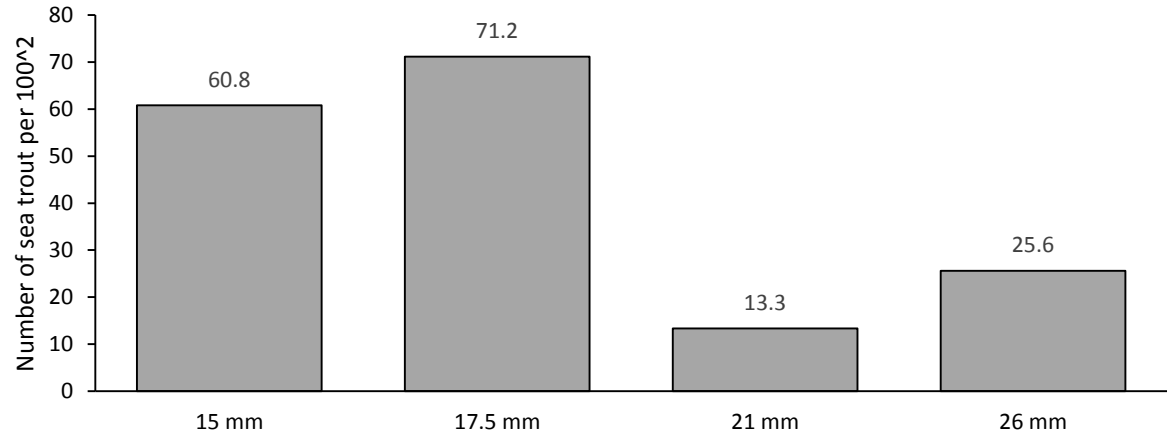

Figure 15: *Catch per unit effort in the different mesh sizes where all three periods are combined. CPUE is calculated as amount of fish per* 100 m^2 *net. N = 186*

The catch efficiency was different between the mesh sizes although they fished over the same time in each period, where most fish was caught in 17.5 mm mesh sizes (fig. 15). Only 11% were caught in the two largest mesh sizes and the rest, 89 %, of the catch was caught in the two smallest. Gillnets were size selective in relation to the mesh size; the mean size ± SD in 15-, 17.5-, 21-, and 26 mm, was in ascending order 173.8 ± 64.5 mm, 174.3 ± 36.1 mm, 277.6 ± 85.2 mm, 344.8 ± 96 mm (fig. 16).

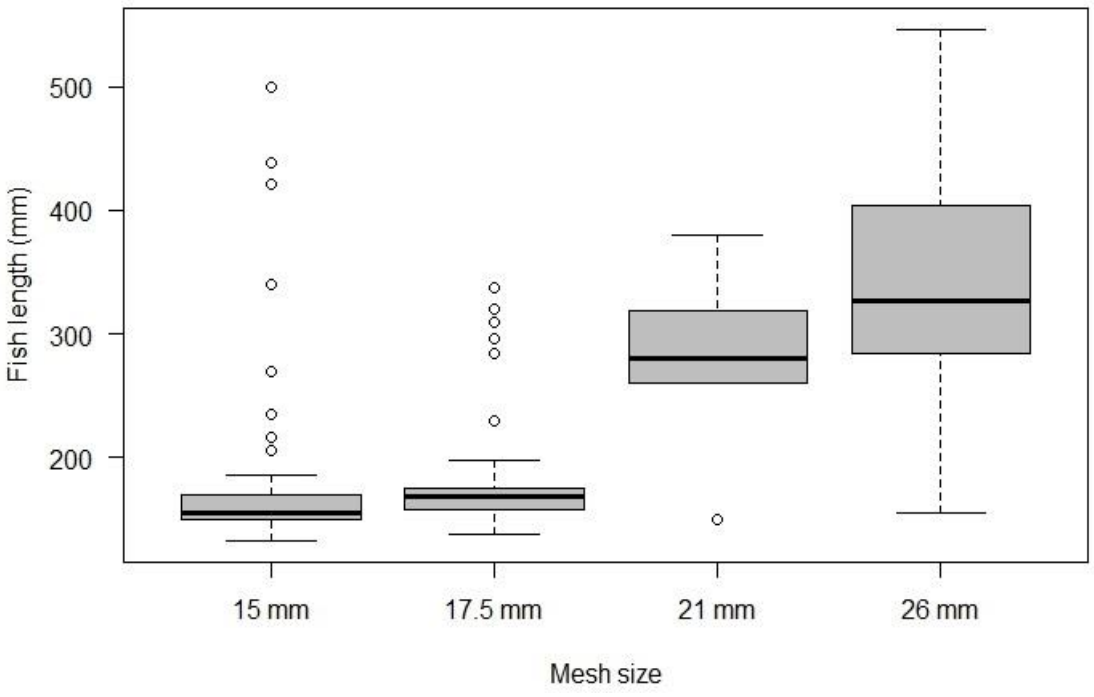

Figure 16: *Box plot of sea trout length in the four different mesh sizes with median line, first- and third quantile, maximum- and minimum fork length with outliers, N = 186.*

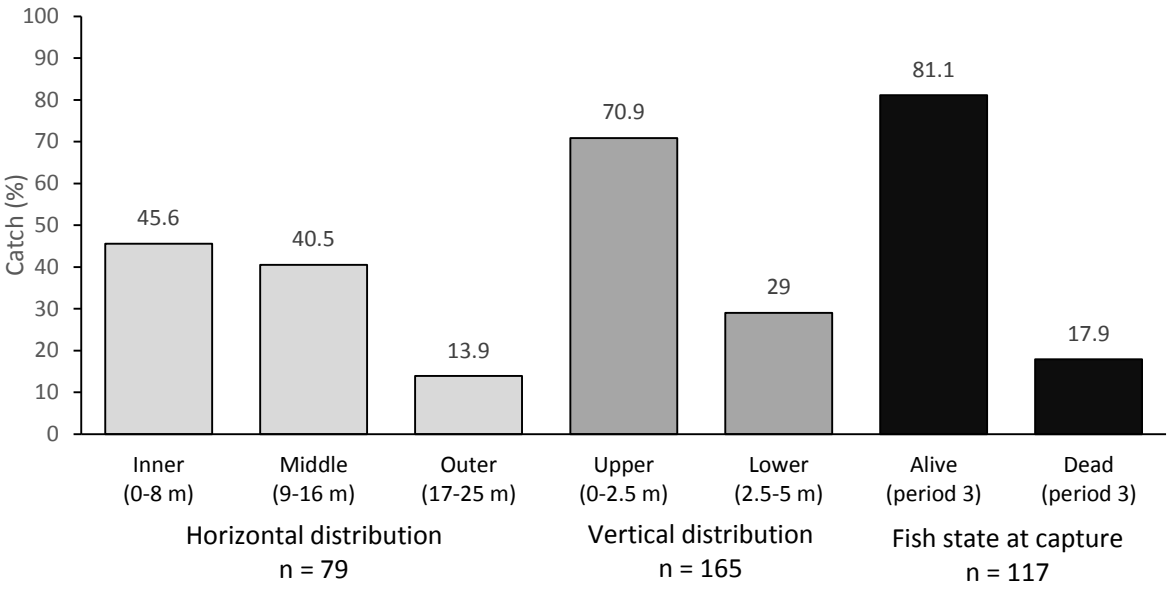

Figure 17: *The graph shows the horizontal distribution of sea trout catch (inner-, middle- and outer section), the vertical distribution of sea trout catch (upper and lower section) and state of sea trout before collection (alive and dead) for sea trout caught in gillnets from Bjørknesvika 2015.*

45 % of the sea trout caught in gillnets was captured in the first 8 meters from shore, decreased somewhat in the middle section (40%) and was lowest in outermost part, 14%. (fig. 17). It was a tendency that most of the sea trout caught in gillnets were captured in the uppermost 2.5 m of the water column (74%, fig. 17). This however changed between the periods where catches deeper than 2.5 meters increased during period two and was highest in period three (35%, fig. 18). The temperature also increased during the periods (fig. 18, extended temperature and salinity charts can be seen in appendix 8). Most of the sea trout were alive when they were cut out of the nets, only 18% were dead (fig. 17). This investigation however, was only done in late period two and period three at the highest measured temperatures.

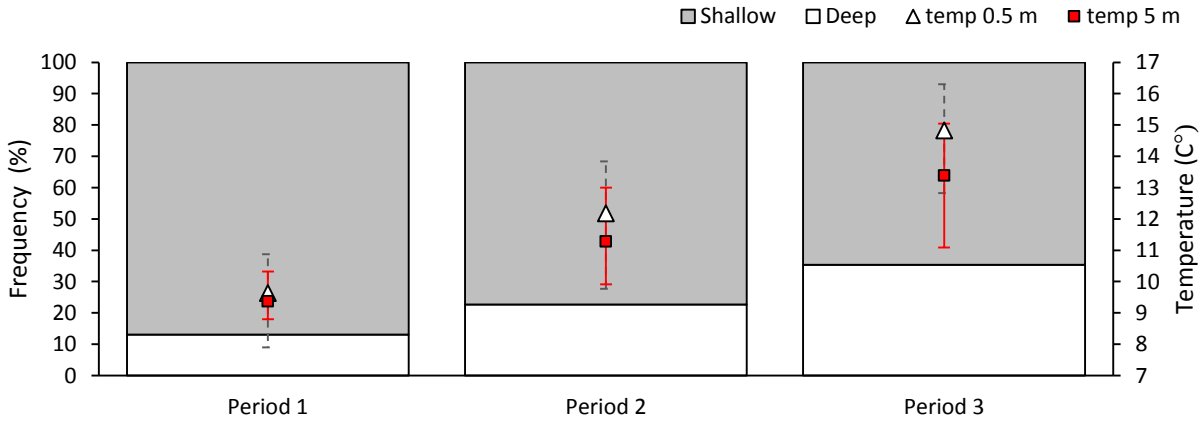

Figure 18: *Vertical distribution (upper 2.5m vs. lower than 2.5m) of sea trout catch during the periods. Mean temperature during the periods are given at 0.5 m (white triangle with dotted lines), and 5 m (red square with solid lines) depth with maximum and minimum temperature, N = 165.*

4.0 Discussion

4.1 Impact of fishing gear on prevalence, abundance and intensity of salmon lice

The results show that different fishing gear affect salmon lice abundance, intensity and prevalence differently, where sea trout captured in the gillnets had a lower abundance of salmon lice than sea trout captured in the trap, but the prevalence was equal between gear. In addition, other factors like fish size and sampling time have great importance when trying to estimate abundance of salmon lice on a population of sea trout.

The differences observed in abundance of salmon lice between sea trout captured in gillnets and traps, revealed that abundance was significantly lower on fish captured in the gillnets. It was especially lice in the mobile group (pre-adult and adult lice) that caused this difference. It is probably the scraping effect from the gillnets on the fish skin that not only harms the fish, but also likely causes the lice loss (Barlaup et al. 2013). This will affect estimates of abundance, intensity and prevalence by lowering the number of lice on each caught fish and will lead to an underestimation when trying to describe infection levels on a population of sea trout, when using gillnets as sampling method. The impact from gillnets on the mobile group of lice is large enough that it is also affecting the parasitical parameters when analyzing the total group of lice (all salmon lice phases). However, the abundance of lice in the larvae group (copepodids and chalimus I and II) did not turn out to be significantly different between sea trout captured in gillnets and trap. Copepodids and chalimus I and II are attached to the host with a filament (Costello 2006) and this probably prevents the lice of these phases to fall, swim, or jump off like lice in the mobile group. Another reason can be the location of the lice on the host where lice on the head, operculum and on the sides of the fish may be more vulnerable to gillnets than lice attached on the fish fins. Copepodids and chalimus stages are often found on the fish fins while mobile lice are often spread all over the fish, but could often be aggregated on the vulnerable places, on the head, operculum and on the sides (Jaworski & Wolm 1992, Tucker et al. 2000, Tucker et al. 2002). This could be an additional factor for lice loss and explain the observed differences in salmon lice abundance between different phases of salmon lice. Regardless of how the lice loss happens, it implies that the estimates of lice in the larvae group are likely to be more exact according to the real infection of salmon lice on a sea trout than lice in the mobile group, when using gillnets as sampling method. This is because the estimate is equal in both fishing gears and this indicating that the estimate in the larvae group are good.

The loss of pre-adult- and adult lice in gillnets is difficult to avoid. The fish are probably losing the lice relatively fast, maybe within minutes after capture, when the fish are most active. A fish caught in the nets becomes immediately stressed and tries to escape by burst swimming and hard shakes. This is one of the main differences between fish caught in gillnets and trap, because fish in the trap remains relatively calm and do not struggle in the same way as in gillnets (Barlaup et al. 2013). The results of this study concurs with Barlaup et al. (2013) who concluded that it is likely to underestimate salmon lice abundance when sampling with gillnets. However, they did not check the nets as regularly as the present study, but let the nets be out for around 10-12 hours before collecting the catch. The fact that both studies find the same losses of lice strengthens the conclusion that (i) number of copepodid and chalimus I and II remains the same over time on sea trout caught in gillnets and (ii) that the loss of pre-adult and adult lice happens quickly after entanglement and may lead to biased abundance- and intensity estimates of salmon lice.

Prevalence was not effected by fishing gear and was equal between gillnets and trap. Prevalence is only dependent on the presence of one or more lice on each host (Bush et al. 1997). Therefore, the only way gillnets can affect prevalence is if the scraping effect from the net removes all lice on the host. This is probably only likely if the individual host has one or a few lice. It is more likely that the trap can have an impact on prevalence, because pre-adult and adult lice have the possibility to jump off and swim to another host in the resident chamber, infecting a new host that originally did not have any lice (Thorstad et al. 2015). As far as I know, nobody has done any research on this field and this is a knowledge gap that should be filled if trap fishing is going to be the future of NALO. Sometimes this has been suspected to be the case in previous NALO monitoring. A hypothetical example of this problem is: if there are 14 smolts with one or two mobile lice per fish and one large fish with 100 mobile lice in the resident chamber of the trap. Then it could be that most of the mobile lice on the smolts originally came from the large fish. Smolts caught in early summer have probably only been in the sea for a few weeks and acquired copepodids on those individuals have not yet had time enough to develop into pre-adult or adult lice.

Implications to management

Bjørn et al. (2001) suggested that one way to avoid loss of pre-adult- and adult lice on sea trout captured in gillnets is to check the nets regularly. This may be possible, but the present study indicates that the lice loss happens to fast for preventing this without monitoring one or a few

gillnets at the time. However, this is not efficient work and the chances of losing the fish are high when trying to take the captured fish out immediately after capture. In NALO a fishing team of two uses normally 6-10 gillnets at the same time. This increases the efficiency of sea trout catch, but also salmon lice loss, because it takes too long to check the nets. Loss of salmon lice is also likely to be correlated with the time the fish stay in the net. In this study, I checked the four nets at 1-1.5 hour intervals to resemble the time used when fishing with 6-10 gillnets. Therefore, these results are comparable to gillnet fishing in NALO. This means that previous reports of salmon lice estimates on sea trout caught in gillnets probably are underestimated, at least for pre-adult- and adult lice, because the salmon lice loss probably happens fast. Based on the results of this study the underestimation could be as much as half of the actual infection.

Dividing the salmon lice into groups when analyzing the interaction between host and parasite as it is done today, seems to be a good solution to get a more correct estimate of parasitological parameters of salmon lice for a population of sea trout. This allows having more focus on the larvae group, because the attached copepodids and chalimus I and II on sea trout are good indicators on the amount of planktonic salmon lice larvae in both space and time. This give a more precise measurement of lice infections in a location (Thorstad et al. 2015), because the copepodid and chalimus stages last for several days to weeks depending on the water temperature (Johnson & Albright 1991), and in the same time, the host has probably not covered large swimming distances. This means that lice larvae on a sea trout likely have attached to the fish close to the fishing location or nearby. Moreover, the relationship between salmon lice abundance on sampled sea trout and the infection pressure is likely to be better estimated if the earlier stages of lice are studied more closely in the analysis. This because individual lice can have very different developmental times (Stien et al. 2005).

By focusing more towards the abundance of the larvae group, the statistical estimates will be less affected by fishing gear than if all salmon lice phases are analyzed together (total group). Mobile lice have been on the host for several weeks to months (Johnson & Albright 1991). Therefore, it is difficult to know where the fish have been infected and if the fish are a representative sample in space and time according to the location. Attached larva lice indicates recent infections, mobile lice indicates earlier infections and the relationship between larva- and mobile lice describes the change of infection over time. Dividing lice into groups will give a more detailed description of the interaction and allow for comparing gillnets and trap together, because you will see the effect gillnets have on the mobile group of lice. The untested,

hypothetically problem with jumping lice in the resident chamber of the trap can also be corrected for by dividing the analysis of salmon lice into groups.

Other factors affecting salmon lice estimate

Salmon lice infection on wild sea trout in Etnefjorden varies between- and within years and 2015 was, in general, a low infection year compared to 2014 and 2012. This is probably related to the synchronized fallowing of fish farms in Hardangerfjorden, as a management strategy to reduce harm to farmed salmon from salmon lice, reduce negative effects on wild population of salmonids and to prevent resistant lice. Some studies have shown correlations between production cycles of farmed salmon and salmon lice levels on wild salmonids (Penston & Davies 2009). This means that infection levels of salmon lice differ between years in Etnefjorden. The infection levels of salmon lice on wild sea trout can also differ within years. This could be explained by fact that temperature increases through the summer and that lice development is faster at higher temperatures (Johnson & Albright 1991, Boxaspen 2006). That is why one often see the highest infection levels during the summer in week 25-27 in Etnefjorden when the sea temperatures are high.

The present study showed results that suggested fish size as predictor of lice was important, where abundance of lice tended to increase with increasing fish size. There could be several reasons for this: different size groups of sea trout have different behavior in the sea, where for example smolt often stay close to the littoral zone during feeding migration (Lyse, Stefansson & Fernö 1998), whereas older and lager veterans roam in all parts of the fjords (Jensen & Rikardsen 2008). Larger sea trout have also a tendency to migrate earlier to sea then smolt (Berg & Berg 1989). This means that large sea trout stay often longer in the sea than smolts and therefore have greater chance to be infected with lice. Surface ratio to body size is also bigger on large fish than small fish, giving larger fish the potential to host more lice (Jaworski & Wolm 1992, Todd et al. 2006). Whatever the reason, this means that different size groups of sea trout can experience different probabilities to be infected with salmon lice and they can experience different abundance of lice (Jensen & Rikardsen 2008). This shows how important the choice of sampling time and size selection are for a monitoring program when trying to estimate salmon lice infection on a population of sea trout.

To conclude, this study showed that gillnets have significant impact on the estimate of abundance and intensity of salmon lice, especially on pre-adult and adult lice by scraping away

individuals. The estimate of salmon lice on sea trout caught in the trap seems to be more credible in relation to the real infection levels of salmon lice. On the other hand, although it is not tested, there is reason to believe that the trap can affect prevalence, because mobile lice have the possibility to jump between hosts in the resident chamber. Therefore, should the salmon lice estimates of abundance and intensity regardless of sampling method, be analyzed in separate groups depending on salmon lice phases (larvae- and mobile group), in addition to analyzing all lice phases together (total group) to get a more detailed estimate of salmon lice on a population of sea trout in a location. The abundance of lice in the mobile group is unpredictable and one cannot know how representative the estimate is for a location. Attached larvae lice indicates recent infections, mobile lice indicates earlier infections and the relationship between larva- and mobile lice describes the change of infection over time and this is why pre-adult and adult lice are of important, although the abundance of those are underestimated, at least when using gillnets as sampling gear.

4.2 Size selection of sea trout in gillnets and the trap

To describe the dynamics between host and parasite in the best manner it is important to sample sea trout from as many different life stages as possible. This is because different size groups of sea trout can have different behavior in the sea (Jensen & Rikardsen 2008). Smolt often reside in the littoral zone during feeding migration (Lyse et al. 1998), whereas older and lager veterans roam in all parts of the fjords (Jensen & Rikardsen 2008). In general, sea trout seem to prefer coastal areas close to land (Jensen et al. 2014). Different behavior will affect the chance of being captured and maybe more importantly the chance of being infested with salmon lice, because salmon lice are unequally distributed in the sea (Penston et al. 2004). Huse & Holm (1993) suggested that copepodids occur in greater abundance in the upper 6 m of the water column than below this, to a depth of 20 m. Laboratory experiments have also showed that salmon lice copepodids exhibit positive phototaxis (Wootten et al. 1982, Johannessen 1977) and have a tendency to aggregate near salinity boundaries (Heuch 1995). This means that the probability to be infected relies partly on where the fish resides during most of its marine migration. Therefore, it is important to know if the fishing gear is size-selective in sea trout catch or not. If the fishing gear is size selective, it will also be important to know the typical selection of catch and what this means for the estimates of salmon lice. Sampling gears with no size selection in sea trout catch is the ideal sampling gear for catching sea trout from as many different life stages as possible (Thorstad et al. 2015).

The size distributions of catches from gillnets and trap from Bjørknesvika were statistical significantly different from each other. However, by comparing the mean, median, maximum- and minimum fish size values between fish caught in gillnets and trap, both for the present study in Bjørknesvika and for the combined dataset from Etnefjorden 2012-2015, it appears to be equal size distributions between the gears (see appendix 4 & 7). A reason for this mixed outcome, might be low sample size in the trap (N = 43) in relation to coincidences outcome. Therefore, was the same analysis conducted for larger groups where sea trout captured in gillnet from the present study was compared to sea trout captured in traps from whole Etnefjorden 2015 and for a combined dataset from all trap captured sea trout from Etnefjorden 2012-2015. The result from these tests also indicates a mixed outcome, but it is a possibility that the trap are size selective in catch. This can be due to different behavior between sea trout where for example smaller smolt have a chance to swim straight through the leading net of the trap. The leading net consists of 20 mm mesh size and by compering mean sea trout size in the different gillnets indicates this that fish smaller than 20 cm do not get caught in 21 mm gillnets. This suggests that the smallest sea trout have a chance to swim through the leading net of the trap. Probably only few individuals do so, because the material of the leading net is made of much thicker and visible materials that may scar most of the fish and force them to follow the leading net instead. Either way, there is a chance that the trap is slightly selective in catch, where the trap probably does not catch the smallest fishes in an equal amount as the gillnets.

Another reason that can explain the statistical significant differences between sea trout distribution in the gillnets and the trap can be the choice of gillnets where, ideally, multi-mesh gillnets had been the best choice to test size selection between the gears. It was a compromise to use four different gillnets instead, to best resemble the monitoring program in the best manner and to be able to compare the mesh size used in NALO against those not used to check the efficiency between different mesh sizes. The mesh size chosen was, therefore, probably too roughly divided. For example, could 3 mm intervals from 15-35 mm mesh sizes be a better choice, because more gillnets with smaller intervals in mesh size would catch sea trout in a more representative way.

If the differences in size distributions between gears resulting from low sample in the trap or choice of mesh sizes and not a true selection in the trap, then this study strengthens the conclusion from Barlaup et al. (2013), that the trap is not a size selective fishing gear and does not favor some size groups. Barlaup et al. (2013) compared sea trout distributions between

gillnets and the trap, but they had 14-, 16- and 19 mm mesh sizes. They did not detect any differences in sea trout distributions between sea trout caught in gillnets and the trap.

To conclude in this investigation, it is necessary to look into the biological significance between size distributions of sea trout captured in gillnets and trap from the present study. By looking at the density histograms (Appendix 7), there seems to be no biological importance in relation to estimates of salmon lice, because the differences are not large. The differences are probably not large enough to have an effect due to the fact that different size groups of sea trout have different behavior and, therefore, different probability to be infected with salmon lice (Penston et al. 2004). It is also a chance that the trap is slightly selective in catch, where small fish may not be captured in equal amount as gillnets, because small sea trout can swim through the leading net.

4.3 The efficiency of gillnets and trap

Size selection in gillnets

In some parts of Norway sea trout populations have significantly declined over the past two decades (Anon 2010), and in several areas trout populations are critically low (Thorstad et al. 2015). It is therefore important to minimize the impact of monitoring on mortality for wild populations of sea trout. By fishing with mesh sizes on gillnets that are 20 mm or more, one targets the part of the population that is most important for conservation, the veterans- and mature sea trout. The veterans have survived the many bottlenecks that are related to sea-migrating behavior and they have a higher survival rate than smolt (Berg & Jonsson 1990). Berg & Jonsson (1990) for example, observed a sea survival rate of 37% the first year for smolt during an average period of 70 days. They also observed higher survival rates (56-68%) for repeat-migrant fish (Berg & Jonsson 1990). In general, 10–50% of smolts and 50–80% of fish that have been to sea one or more times before reaching "veterans" survive the sea migration each year (Rikardsen et al. 2007, Berg & Jonsson 1990). Therefore is it reasonable to believe that the mature sea trout, especially veterans, are of higher importance than smolts to maintain a sustainable sea trout population. This means that the gillnet fishing in the monitoring program should be conducted with smaller mesh sizes than what is used today (21 and 26 mm), because those mesh sizes catches the part of the population that one want to preserve the most.

Another reason to use smaller mesh sizes is the fact that today's use of mesh sizes excludes the part of the population that is most abundant (smolt) from 14-20 cm. 15-17 mm mesh sizes catch sea trout from the smallest part of the sea-migrating population. A part of the population with a high mortality rate where smolt is most exposed to predation during the first weeks after reaching sea (Dieperink et al. 2001, Aarestrup et al. 2014). Therefore, there is reason to believe that a part of the catch sampled, will not survive anyway if one use gillnets with mesh sizes on 15-17 mm. It is two hypothesis about the effect of harvest (Allen, Miranda & Brock 1998). (i) Harvest and natural mortalities operate additively and (ii) population compensate for harvest mortality by reducing rate of natural mortality (Allen et al. 1998). This means that mortality from gillnets can be more compensatory than additive in relation to the natural mortality if gillnets with small mesh sizes are being used. An example for this can be what Allen et al. (1998) discussed, that mortality of northern pike may be compensatory for fish smaller than 40 cm total length, but additive for larger fish. This can also be the case for sea trout where harvest on mature sea trout probably are additive and harvesting on smolt are compensatory.

To conclude, if you want to sample a representative size distribution from a whole sea trout population from a fjord, the best way to accomplish this is with gillnet mesh sizes that catch all sizes of sea trout evenly. If you want to focus on smolts, because the mortality caused by gillnets probably is compensatory, then you take away the largest mesh sizes, but by doing this you will not get a representative sample. This will therefore be a compromise, but today gillnet fishing in NALO is done in a size selective way where often only 21 and 26 mm mesh sizes have been used. Since it is selective gillnet fishing in today's NALO than the present study suggest to use smaller mesh sizes, because (i) you increase the efficiency of a fishing team by having a higher capture rate of sea trout and (ii) you are not affecting the sea trout populations as much, because a part of your catch is probably compensatory.

Division of gillnets

The division of gillnets into zones revealed that most of the sea trout was swimming close to land and got caught in the innermost part of the gillnets. All four gillnet spots had the same characteristic bottom where the depth slowly got deeper. After 5-10 meters, it was a rapid shore slope to deeper water. The sea trout are probably following that slope for feeding (Bjørn et al. 2001). This is relevant for NALO, because the results suggest that different parts of the gillnets are more efficient than others. However, this is likely to change with location and sampling time. If you fish in a location with immediately deep water you are probably only going to catch

sea trout within the first eight meters, and by choosing a location with slowly deeper water or same depth within the gillnets length then you will fish with the whole gillnet and not only the innermost part. This will create more efficient catches, because the whole gillnet is being used. Another solution is to deploy the nets along the shore at a specific depth, but by doing this you risk the fish swimming along the net and not being captured.

The gillnet depth is also important in relation to catch efficiency. One-and-a-half meter deep gillnets are easier to handle and take less time to check than for example a five-meter deep net. However, a five-meter deep gillnet also catches the deep-swimming sea trout. By dividing the gillnets into upper, and lower water columns I found out that the sea trout utilize deeper waters later in the season, probably because of higher water temperature. This may be related to the optimum growth temperature range for trout where the fish prefers temperature around 12-13 °C (Elliott 1975). These investigations are relevant to the monitoring program where choice of gillnet depth should vary during the season. When the water temperature in the upper two-and a-half meter reaches 14-15 °C, deeper than two-and-a-half meter gillnets should be used. This will increase catch efficiency.

Bycatch

One goal for large monitoring programs (e.g. NALO) is to try to release as many fish as possible. This is easily done in the trap where almost the entire bycatch survives. Fish caught in gillnets have high mortality rates, although the rate varies between species and depends partly on the time the fish is tangled in the net (personal observations). Another severe aspect with the bycatch is the risk of predation from large piscivores on small sea trout smolt in the trap. Although I did not do any more extended registration than a few stomach investigations of randomly selected, large piscivores, several times I registered pollock and cod that had been eating sea trout smolt, probably from the catching chamber. The predation risk is low in gillnets and consists mainly of seagulls that dove to take the fish. The diversity of species was also different between fishing methods, where gillnets had higher diversity and amount of individuals than the trap. This is important because the ideal sample method should be selective on species and only catch sea trout. Therefore, trap is a more suitable fishing gear than gillnets regarding bycatch, because it is more selective on species and has a lower mortality rate both for sea trout and for bycatch.

Time

The time used between the gear differs remarkably. In NALO a team of two spend around two hours to prepare gillnet fishing, are actively fishing for six to eight hours, and use one to two hours to clean 10 gillnets with logistics. In total 9 - 12 hours. The trap, on the other hand, takes around two hours to prepare, one to three hours to deploy, one to many hours to check (depending on the amount of sea trout), one to three hours to take up from the sea and two to six hours to clean. In total 7 – 20 hours, but when deployed, it can fish up to two weeks. So both gears are time consuming, but gillnets are the most active fishing form. In NALO a fishing team has time to fish with both gears during a day, so the question is: does the time used on both gears justify the amount of sea trout captured? The answer is yes for gillnets, which have high and predictable catches, but is uncertain for the trap. The question depends on how long the fishing team is going to stay in one location and that in turn is often related to how many sea trout are required. In the past, a lower limit of 40 sea trout per location has been practiced. This means that the trap probably only fish in two days before the team reaches this limit, if both gears are used, because gillnets are very efficient. In this case, trap will be too demanding, time consuming and too heavy a workload to be justified in relation to a catch that probably are low and unpredictable. On the other hand, if you have a monitoring station and are monitoring over weeks, then traps could be a better choice than gillnets, because you are not relaying on fast, large and predictable catches.

To conclude, the trap should therefore be modified, to lower the workload or replaced by a new trap that works better in relation to catch efficiency, deployment and handling. Gillnets on the other hand should also be replaced by a fishing gear that is equally efficient, not size selective, does not affect salmon lice estimates and makes catch and release possible. To sum it up, the sampling gear in NALO is not yet ideal for the purpose and future modifications and investigations should be done to find a better sampling gear.

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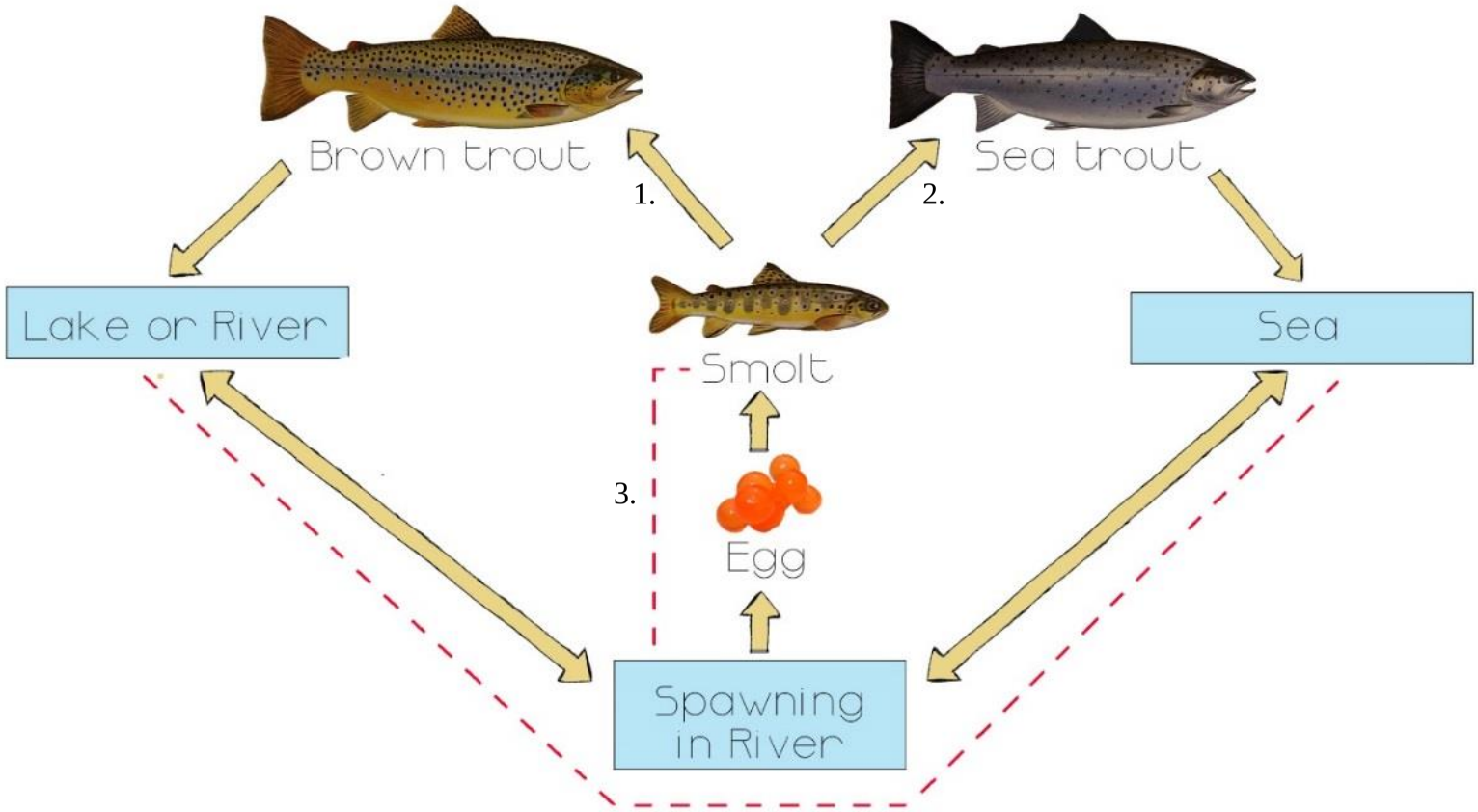
6.0 Appendix

Appendix 1: *Illustration of the five phases of salmon lice lifecycle. Naupilus is the first phase and consist of two stages. Copepodid is the second phase, is the infective stage and consists of one stage. Chalimus is the third phase, the first parasitic phase and consist of two stages. Preadult is the fourth phase and consists of two stage. The last phase is adult. The eight different stages are separated by a moult and change in cuticle layer. Graphic designer: Hans-Henrik Grøn*



Appendix 2: *Life cycle for trout with the different life strategies. Both sea trout and brown trout spawn in rivers in autumn with each other. The egg hatches the following spring. The smolt have three possible paths: 1. Become a freshwater trout (brown trout) and live in lakes or rivers. 2. Undergo smoltification and swim to sea as a postsmolt and become a sea trout. 3. This path is for males and they can undergo early maturation at small size, and then spawn as "sinking" precocious males. A sea trout can become stationery freshwater trout and a freshwater trout can become sea trout throughout the life as illustrated with red dotted line. Graphic designer: Hans-Henrik Grøn*

Appendix 3: *Overview of mean abundance, mean intensity and Wilcoxon rank-sum test of salmon lice on wild sea trout caught both in gillnets and trap in Bjørknesvika 2015. Here the salmon lice are divided into three groups; larvae group (copepodid and chalimus I and II phases), mobile group (preadult and adult male and female) and total group consisting of all salmon lice phases (with 2000 Bootstrap BCa confidence interval*.

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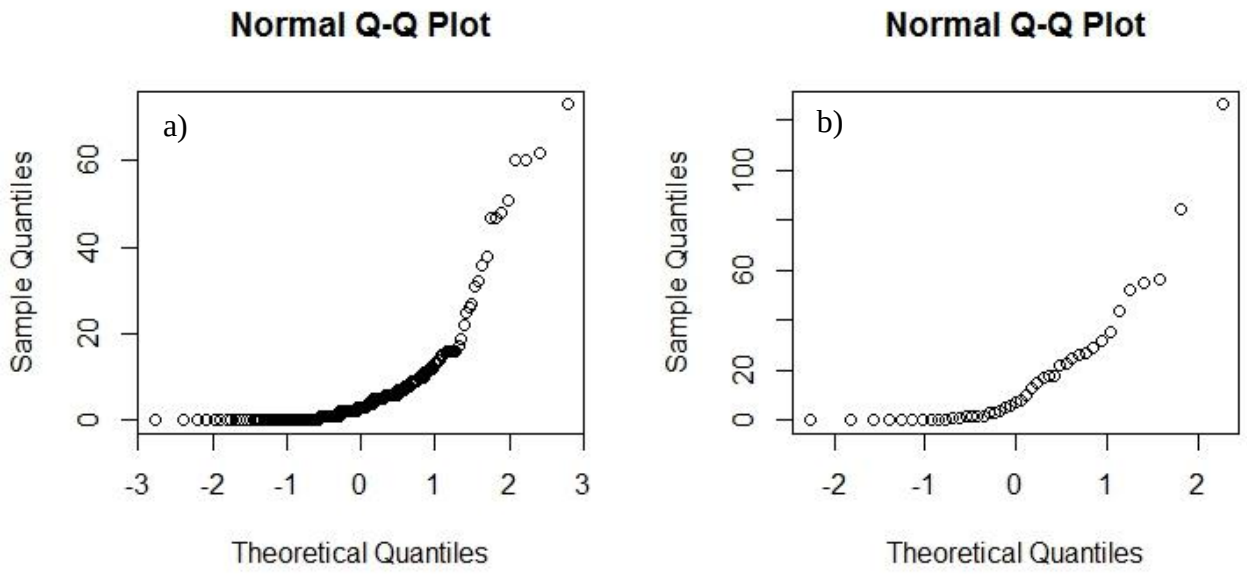
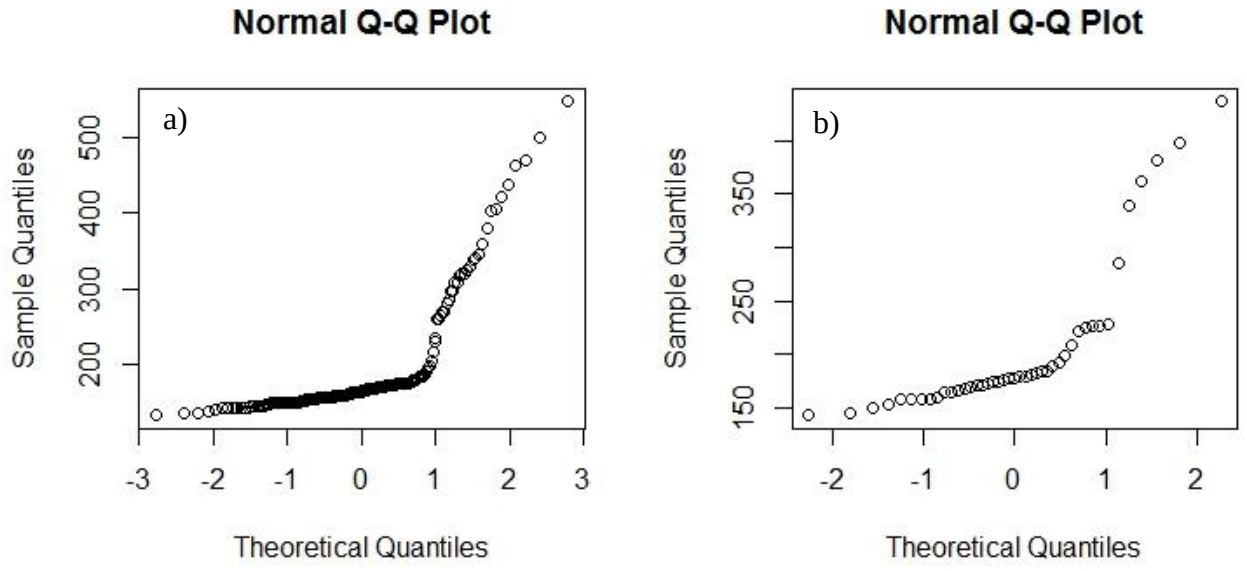
		Mean intensity (95% CI)	**Mean abundance (95% CI)**	**Wilcoxon rank-sum test on abundance**	**Wilcoxon rank-sum test of intensity**
Gillnets	Larvae lice	*9.94 (7.58-12.9)*	*5.34 (3.96-7.33)*	*Larvae lice p = 0.4296*	*Larvae lice p = 0.8723*
	Mobile lice	*4.81 (3.81-6.21)*	*2.15 (1.64-2.82)*		
	Total lice (Larvae + mobile)	*10.5 (8.34-13.2)*	*7.9 (5.87-9.59)*	*Mobile lice p = 8e-05*	*Mobile lice p = 2.596e-05*
Trap	Larvae	*11.1 (6.43-22.2)*	*6.72 (3.61-13)*		
	Mobile lice	*17.3 (11.8-24.6)*	*11.3 (7.16-16.7)*	*Total lice p = 0.0137*	*Total lice p = 0.00252*
	Total lice (Larvae + mobile)	*23.4 (16.1-35.4)*	*18 (11.2-28.6)*		

Appendix 4: : *Sample size (N) of sea trout, mean sea trout size in fork length with SD, median in fork length, and size range from smallest to largest sea trout for total catch from gillnets and trap in Bjørknesvika and of sea trout caught in traps from Etnefjorden 2012, 2013, 2014, 2015.*

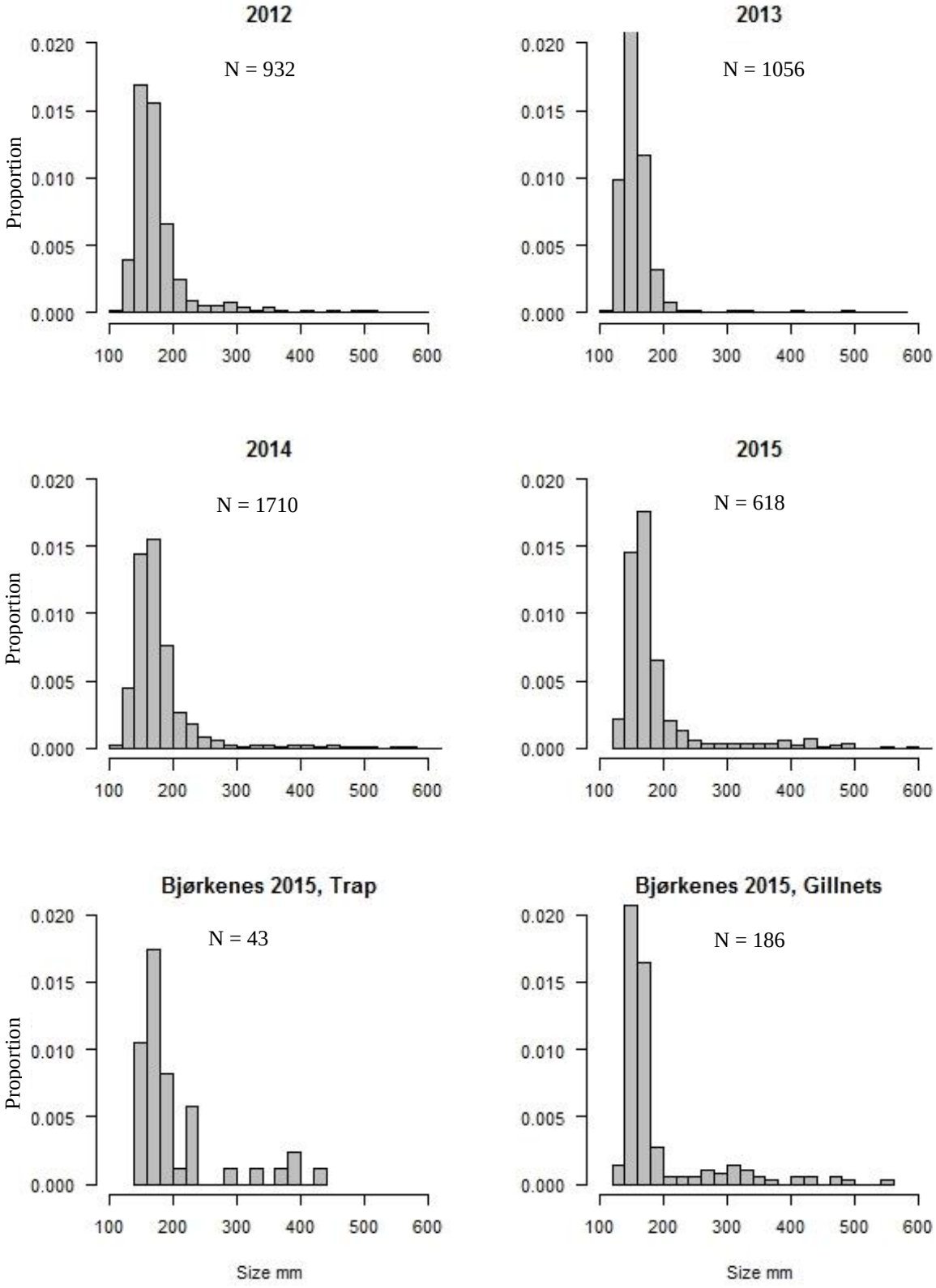
Bjørknesvika 2015	**Sample size (N)**	**Mean (mm) ± SD**	**Median (mm)**	**Size range, Min – max (mm)**
Total catch, Trap	43	205.2 ± 71.6	178.0	143 - 436
Total catch, Gillnets	186	191.4 ± 75.6	164.5	132 - 547
Etne 2012	932	178.3 ± 53.2	165	108 - 590
Etne 2013	1056	158.8 ± 35.0	153	119 - 575
Etne 2014	1710	179.8 ± 55.2	164	101 - 716
Etne 2015	618	193.5 ± 79.9	169	123 - 659



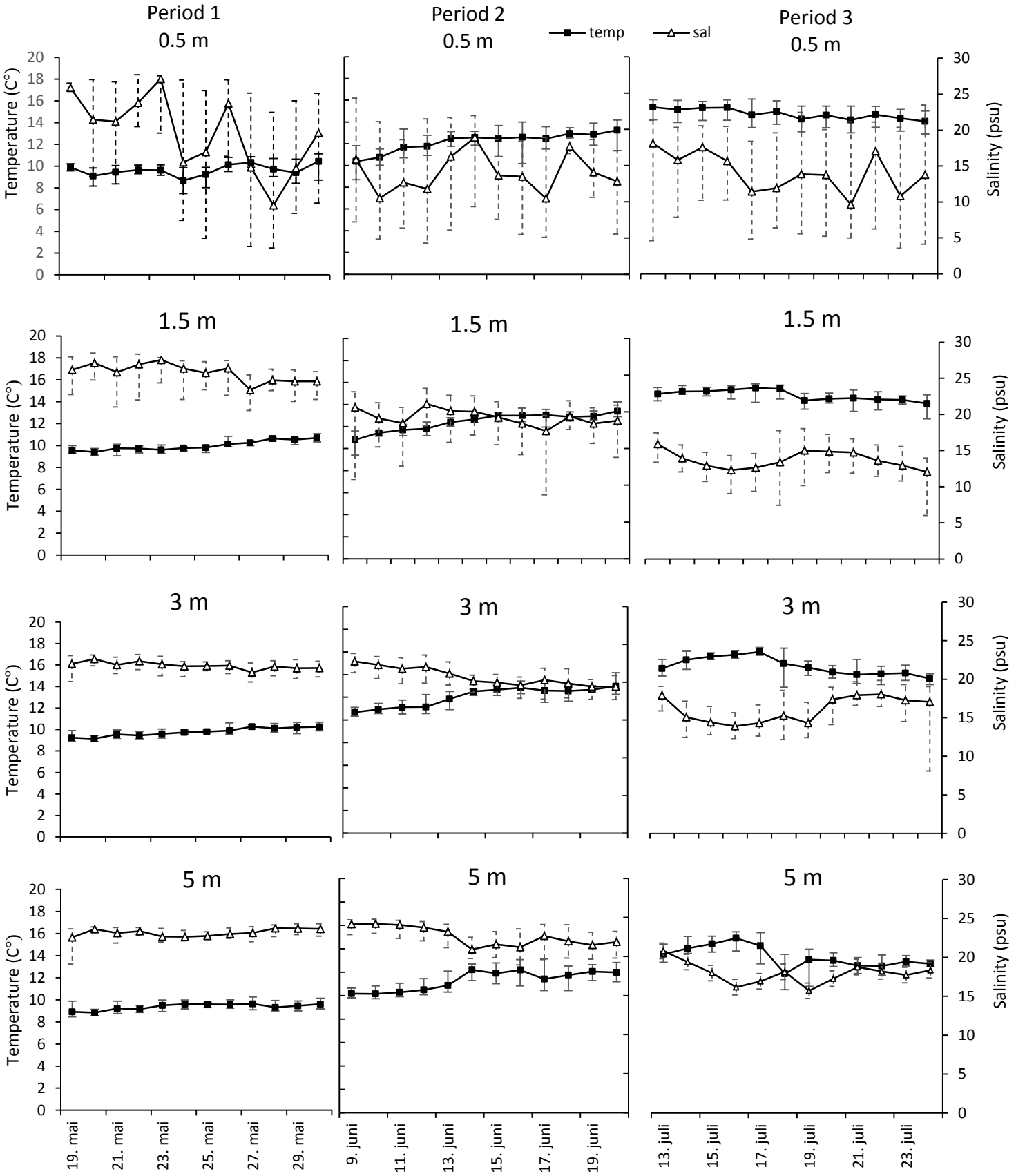
Appendix 5: *Visual plots of abundance of lice on sea trout caught in gillnets (a) and trap (b) to check for normality. Shaprino-Wilk test; gillnets:* $p = 2.2 \times 10^{-16}$*, trap:* $p = 8.62 \times 10^{-8}$.



Appendix 6: *Visual plots of fork length distributions from sea trout caught in gillnets (a) and trap (b) to check for normality. Shaprino-Wilk test; gillnets:* $p = 2.2 \times 10^{-16}$*, trap:* $p = 3.9 \times 10^{-8}$.



Appendix 7: *Fork length distributions of trap captured sea trout in Etnefjorden 2012, 2013, 2014 and 2015. The figure also shows fork length distribution of sea trout from trap and gillnets only from Bjørknesvika 2015.*



Appendix 8: *The figures shows temperature and salinity at 0.5-, 1.5-, 3-, and 5 m depth with maximum and minimum value, in period one, two and three from Bjørknesvika 2015.*