The possible use of lumpfish to control *Caligus elongatus* infestations on farmed Atlantic salmon: a mini review

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Abstract

In this mini review, we have systematized current knowledge about numbers of *C. elongatus* on farmed Atlantic salmon in relation to use of lumpfish as cleanerfish. The review was prompted by reports of unusually large numbers of sea lice identified as *C. elongatus* infesting farmed salmon in northern Norway, Faroese Islands and Iceland and the urgent need to investigate if common lumpfish can be used to reduce the numbers on farmed Atlantic salmon by active grazing on this sea lice species. Available data from Norway clearly indicates that lumpfish grazes on *C. elongatus* and that it is possible to enhance this grazing with the assistance of live-feed conditioning prior to sea-pen transfer and with selective breeding. Observations from Iceland, Faroese Islands and Scotland also indicate that lumpfish can be effective in lowering infestations of *C. elongatus* on salmon. Overall, present mini review reveals that lumpfish can actively contribute to lower numbers of *C. elongatus* on farmed Atlantic salmon.

Keywords Sea lice • *Caligus elongatus* • Lumpfish • Salmon farming • Welfare

Introduction

The sea lice *Lepeophtheirus salmonis* and various Caligus species, are ectoparasites of marine finfish (Copepoda: Caligidae). They have a major impact on salmonid aquaculture worldwide (Igboeli et al., 2012, 2014) causing losses of over €440 million in Norway annually (Abolofia et al. 2017). The lice live on the mucus, skin and blood of the fish resulting in wounds if not removed. Lice occur naturally on salmon in sea water and were described as early as in the middle of the 18th century (Torrissen et al., 2013). However, the problems have escalated with commercial production of Atlantic salmon (*Salmo salar* L) and rainbow trout (*Oncorhynchus mykiss* Walbaum) in sea cages. The effectiveness of medicinal treatments as bath or orally may be affected by the development of reduced sensitivity leading to the reduction in treatment efficacy. Therefore, more emphasis is being given to mechanical treatments such as thermolicing or by high pressure wash. Biological control using cleaner fish that pick the sea lice from salmonids has been effective in reducing lice numbers and is being adopted widely by the salmon farming industry. As a cold-water cleaner-fish alternative, the common lumpfish *Cyclopterus lumpus* L. is currently used to control sea lice infestations (Imsland et al. 2014a-c, 2015a-b).

The parasitic copepod family Caligidae comprises more than 30 genera (Kabata 1979; Hemmingsen et al. 2020) and more than 450 species (Dojiri and Ho 2013). Members of two of these genera – *Lepeophtheirus* and *Caligus* - have achieved notoriety by having the greatest economic impact of any group of parasites in salmonid fish mariculture (Costello 2006) and have become collectively known as “sea lice”. Although this notoriety is mainly due to the particularly serious impact of the species *L. salmonis*, members of the genus *Caligus* are also implicated. Johnson et al. (2004) estimated that in marine and brackish water fish cultures, 61% of copepod infestations are caused by members of the family Caligidae, 40% of which are caused by species of *Caligus* and 14% by species of *Lepeophtheirus.* A major difference between *L. salmonis* and *Caligus* spp. lies in their host specificities. *L. salmonis* is essentially a parasite of salmonid fish (Kabata, 1979), whereas many *Caligus* spp. tend to be much less host specific (Kabata 1979; Pike and Wadsworth 1999) and has been found on >80 fish species (Kabata, 1979). In the central and northern parts of Norway, high *C. elongatus* Nordmann abundance on farmed fish frequently occurs in autumn (Øines et al. 2006). Infections have been assumed to be connected to passing schools of pollock *(Pollachius pollachius* L.), saithe (*Pollachius virens* L.) or herring (*Clupea harengus* L.) (á Norði et al. 2015).

Mature stages of *C. elongatus* are smaller than mature *L. salmonis* (Piasecki 1996) with both sexes of equal sizes (around 6 mm). *C. elongatus* is much better swimmer than *L. salmonis* and can re-infect other fish species if removed from the original host (Øines et al. 2006; Hemmingsen et al. 2020). Hence, can mature *C. elongatus* infect from species like lumpfish or saithe, which may help to explain the observation of rapid increase in *C. elongatus* in sea pens in certain periods of the year (Heuch et al. 2007) especially in Northern Norway. Lumpfish are now extensively used as cleaner fish in Northern Norway (Imsland et al., 2018), Ireland (Bolton-Warberg 2018), Scotland (Treasurer et al. 2018), Iceland (Steinarson and Árnason 2018) and the Faroese Island (Eliasen et al. 2018), but to this date there exists no systematic knowledge, or guiding lines, on the effect of lumpfish on *C. elongatus.* Earlier research have clearly indicated that lumpfish prefer the adult female *L. salmonis* (Imsland et al., 2014a, c; 2016; 2018), but lumpfish in sea pens can be classified as strongly opportunistic (Imsland et al., 2014c) and the fish do not restrict themselves or rely on a single food source if others were present. They may, therefore, readily graze on mature sea lice males as well as *C. elongatus.*

In this mini review we aim to summarize findings from both small- and large-scale trials with lumpfish where grazing on *C. elongatus* has been reported in order to give recommendations on the possible use of lumpfish to combat *C. elongatus* on Atlantic salmon in sea pens.

Different density of lumpfish: effect on occurrence of *C. elongatus* on Atlantic salmon in small –scale studies

Imsland et al. (2014a) investigated the efficacy of lumpfish grazing on attached *C. elongatus* on Atlantic salmon at two different lumpfish densities (10 and 15%). *C. elongatus* were counted every two weeks during the trial period (54 days). To investigate the stomach content of the lumpfish a gastric lavage was performed.

The results showed that on day 38, the 15% stocked cages had significantly lower average numbers (0.72) of *C. elongatus* per salmon compared to both the control (1.18) and the 10% stocked cages (1.37) (Tukey's multiple test, $P < 0.05$, Fig. 1). Similarly, on day 54, the 15% stocked cages had significantly lower average numbers per fish (0.78) compared to both the control cages (1.35) and the 10% stocked cages (1.02) (Tukey's multiple test, $P < 0.05$).

Discussion: effect of lumpfish on occurrence of C. elongatus on Atlantic salmon in small-scale

Both visual inspection and gastric lavage indicated the consumption of *C. elongatus* in the Imsland et al. (2014a) trial. The average number per fish varied throughout the trial period, although on day 54 both the 10% and 15% stocked cages had 25% and 42% fewer *C. elongatus* lice than the controls strongly indicating that the presence of lumpfish lead to lower infestations of *C. elongatus* on the Atlantic salmon present. The results from the gastric lavage method used to assess food choices in lumpfish displayed the presence of *C. elongatus* in the stomachs of several fish throughout the study period. The proportion of lumpfish with sea lice (*L. salmonis* and *C. elongatus)* increased from10% on day 11 to 28% on day 54. The number of lumpfish-eating lice may in fact be much higher as these values were only determined from lavaging fish every 14 days throughout the trial period. The number of days between sample points allowed for lumpfish to consume sea lice and fully digest them thus only *giving* a snapshot on the lice eating. However, the relatively large increase in numbers of lumpfish found with ingested sea lice in their stomachs suggests that the level of grazing intensified throughout the study period. This may be indicative of some form of learning or habituation of lumpfish, so this was investigated in a follow-up trial (see below).

Habituation of lumpfish by feeding live feeds prior to transfer to Atlantic salmon net-pens: effect on occurrence of *C. elongatus*

Imsland et al. (2019) established two groups of individually tagged lumpfish in land-based tanks. One group received marine pelleted feed (MF group) whilst the other received a mix of pelleted feed, live adult Artemia and frozen sea lice (LF group). After this period 60 lumpfish from each group were tagged and transferred to small scale sea pens with 300 Atlantic salmon in each sea pen and occurrence of *C. elongatus* on the salmon was investigated for 62 days.

Imsland et al. (2019) found that on day 34, there were significantly less *C. elongatus* stages on salmon from both the LF and the MF groups compared to the control (SNK post hoc test, $P < 0.05$, Fig. 2). On day 62 there was significantly less *C. elongatus* found on salmon from the LF group compared to the control group (SNK post hoc test, $P < 0.05$) as there was 38% less *C. elongatus* found on salmon reared with the LF lumpfish compared to the MF lumpfish.

Discussion: effect of habituation of lumpfish on occurrence of C. elongatus

In the study of Imsland et al. (2019) the levels of *C. elongatus* were significantly different between the control group and the LF group indicating that the dietary treatment influenced the lumpfish`s ability to effectively forage on *C. elongatus* as lumpfish conditioned prior to sea pen rearing were nearly 40% more efficient in grazing *C. elongatus* compared to controls. These results provided further support to previous studies, where it was indicated that lumpfish do graze on *C. elongatus* (Imsland et al. 2014a). *C. elongatus* is not included in Norwegian legislation, and there is therefore no legal limit as to how high levels of infestation of *C. elongatus* are tolerated before treatment is initiated, but the species has an economic impact in the production cycle of salmon (Boxaspen 2006). There have been some concerns with regards to using lumpfish as a cleaner fish, as the fish is considered to be a preferred host by the *C. elongatus* (Heuch et al. 2007; Mitamura et al. 2012), and that the lumpfish has the potential to act as a vector for *C. elongatus* that can infect the salmon, both with *C. elongatus* and diseases transferred by the lice (Powell et al. 2017). These concerns can be reduced if the lumpfish will grace indiscriminately on both species of lice and by using domesticated lumpfish free from *C. elongatus* when introduced into the sea cages.

Lumpfish grazing on *C. elongatus*: possible parental control

Possible heritable component of *C. elongatus* grazing was investigated in two recent trials (Imsland et al. 2016; Imsland et al. unpublished data).

Family study 1.

Imsland et al. (2016) investigated possible parental control in grazing of *C. elongatus in* nine families of lumpfish distributed in duplicates among nine small sea cages each stocked with 400 Atlantic salmon. During the trial period (78 days) gastric lavage was performed every two weeks to assess the feeding preferences of individual lumpfish.

Although the *C. elongatus* infestation rate was very low in the study of Imsland et al. (2016, Fig. 3), the percentage of lumpfish found to have consumed *C. elongatus* varied significantly between the families possibly indicating a parental control of *C. elongatus* grazing.

Family study 2.

In this study (Imsland et al., unpublished data) 10 families of lumpfish (N=480) with a mean (± SD) weight of 46.5 ± 4.3 g were distributed among ten sea cages (5x5x5 m) each stocked with 400 Atlantic salmon with a mean (± SD) weight of 387.3 ± 10.3 g. For each family, 20 lumpfish were stocked into one of 10 seacages and 20 into another cage thus establishing duplicate treatments for each genetic family giving two families stocked per cage. During the trial period (73 days) gastric lavage was performed every two weeks to assess the feeding preferences of individual lumpfish.

Consumption of *C. elongatus* varied (Fig. 4) between families and was found in the stomach of seven of the ten families on day 18. Percentage lumpfish that had consumed *C.*

elongatus varied between 2-11% on day 18. On day, 62 between 5 and 40% of the lumpfish were found with *C. elongatus* in their stomach. Families 5 and 6 (half-siblings, same father) had the highest consumption of *C. elongatus* throughout the study (Fig. 4).

Discussion: Is lumpfish consumption of C. elongatus a heritable trait?

Given the differences recorded in consumption *C. elongatus* in both family trials (and other natural sources, see Imsland et al. 2016 for details) it seems that some lumpfish may be more predisposed in actively seeking out natural food sources, including *C. elongatus,* as compared to eating feed pellets and this behaviour may well have a genetic basis. It is well known that behavioural traits respond to both natural and sexual selection. Fish from families 5 and 6 in the second trial, where consumption of *C. elongatus* was much more pronounced, shared the same father but had different mothers and given that these differences had a degree of genetic influence then it would appear more likely that this difference was passed through paternal rather than maternal lines. Recent studies have indicated both maternal (Royle et al. 2012) and paternal (McGhee and Bell 2014) effect on offspring behaviour via epigenetic alterations to the genome.

Results from both family trials indicated that consumption of *C. elongatus* can vary between families. The families with the highest consumption of *C. elongatus* (trial 1 – family 2; trial 2 – families 5 and 6) were also those families with highest consumption of *L. salmonis*. Although energy rich salmon pellets were available results show that family 2 in trial 1 and families 5 and 6 in trial 2 preferred natural pray to larger extent than the other families in those trials. This confirms that the genetic influence of sea lice consumption can be strong (Imsland et al., 2016). Given the differences found in the consumption of natural *C. elongatus* between the families it may be speculated that these fish are more disposed to seek out natural food sources. If this behaviour has, a genetic basis it may further enhanced through selection and targeted breeding programs.

The effect of lumpfish on *C. elongatus* incidence on Atlantic salmon: large-scale observations

Large-scale trial at Lerøy Aurora, Troms, Norway

Imsland et al. (2018) performed a large-scale trial at a commercial Atlantic salmon sea farm at 69.80°N, 19.41°E (Lerøy Aurora, Troms county, Norway) from 6 October 2015 to 17 May 2016. The experiment was conducted in eight large sea cages (130 m circumference, 37688 m^3 volume) holding 0+ smolts of Atlantic salmon (n=193304 ± 2089 fish pen^{-1}) with an initial mean (±SEM) body-weight of 198 ± 20 g. Lumpfish were stocked at 4, 6 and 8% density in duplicate sea cages. During the trial period *C. elongatus* were counted on 240 salmon every two weeks during the trial period.

Levels of *C. elongatus* rose in all groups during the autumn (Fig. 5). Significantly, lower levels of *C. elongatus* was seen in the lumpfish groups from late February to early April (Student-Newman-Keuls post hoc test, $P < 0.05$, Fig. 5). In April, the *C. elongatus* levels decreased in all experimental groups and final levels in May were similar to the initial ones in October the year before.

Large-scale observations at Nordlaks, Nordland, Norway

A large-scale observation was performed at a commercial Atlantic salmon sea farm at 68.40°N, 15.11°E (Nordlaks, Nordland county, Norway) from 1 July 2017 to 2 February

2018. The observation was conducted in 12 large sea cages (160 m circumference, 58900 m^3 volume) holding 0+ smolts of Atlantic salmon. Two nearby locations, Finnkjerka and Mollgavlen, in the same seawater basin (10 km between them) were monitored. At location Finnkjerka there were six sea pens holding on average 198250 ± 3200 salmon smolts in each pen with an initial mean (±SEM) bodyweight of 75 ± 9 g in October 2016. In July 2017 around 12000 lumpfish pen^{-1} with mean weight of 32 ± 3 g were added to all the sea pens at this location. In the nearby location of Mollgavlen there were six sea pens holding on average 164724 ± 8632 salmon smolts in each pen with an initial mean (±SEM) bodyweight of 76 ± 12 g in October 2016.

Every second week during the observation period thirty salmon from each sea pen were sedated, individually weighted and any lice present were recorded. After counting was complete, any lice remaining in the container were also recorded. Lice were registered in 4 categories: 1) *Lepeophtheirus salmonis*; Adult female; 2) *L. salmonis*: Pre-adult; 3) *L. salmonis*: Chalimus; 4) *Caligus elongatus*

Overall less *C. elongatus* were found on the salmon with lumpfish present (Finnkjerka location) compared with the location with no lumpfish (Fig. 6). This effect was most evident during the winter and spring but was also observed during summer as *C. elongatus* increased at Mollgavlen (without lumpfish) location from July whereas this was not seen at the nearby location with lumpfish in the sea pens (Finnkjerka). Overall, there were more sea lice challenges at the Mollgavlen location, and this resulted in approximately 600 g lower final slaughtering weight of the salmon at this production site.

Discussion: large-scale observations

The relatively high numbers of *C. elongatus* throughout both large-scale studies were indicative of all production sites, as these lice are known transfer easily between fish (Heuch et al. 2007). Despite the presence of lumpfish, there were sufficiently high numbers of lice elsewhere on the site to allow for continual re-colonisation into the cages stocked with lumpfish. Nevertheless, overall the mean number of *C. elongatus* was lower in groups with lumpfish present at both salmon farms. The added positive effect of lumpfish at the Nordlaks production sites was around 600 g higher slaughter weight (3.82 kg vs. 3.18 kg) at the location with lumpfish present and this is almost surely linked to less problems with sea lice (both *L. salmonis* and *C. elongatus*) at this location.

Summary

Lumpfish efficacy for C. elongatus removal

In order to summarize the relationship between the use of lumpfish and the occurrence of *C. elongatus* on Atlantic salmon we have compiled current knowledge from the published literature, reports and from interviewing fish health personnel in the Atlantic salmon farming industry in Table 1. Available data clearly indicates that lumpfish grazes on *C. elongatus* and that it is possible to enhance this grazing with the assistance of live-feed conditioning prior to sea-pen transfer and with selective breeding. Grazing is observed in various size classes (25 g to 550 g, Table 1), at temperatures ranging between 4 to 13°C and at in all seasons (Table 1). Majority of published data is from Northern Norway, but there are also indications from the Faroe Islands, Scotland and Iceland that clearly indicate that the lumpfish grazes on *C. elongatus*. In the Faroe Islands an investigation into 5511 lumpfish stomach (Eliasen et al. 2018) showed that *L. salmonis* was found in 13.5% of those (743 individuals) and of those around 80% had also *C. elongatus* in their stomach (K. Eliasen, Fiskaaling, Faroe Islands, pers. comm.). The consensus in the salmon farming industry in Faroe Islands is that lumpfish is effective in reducing the numbers of *C. elongatus*, but that the infestation pattern is so different from that of *L. salmonis* that lumpfish is not systematically used as a biological delouser for *C. elongatus* (K. Eliasen, Fiskaaling, Faroe Islands, pers. comm.). In Scotland the *C. elongatus* numbers can be seasonally important, but efficacy of cleaner fish with *C. elongatus* can be difficult to assess in the summer as *C. elongatus* continue to re-infect from a range of wild fish species. Even after bath treatments re-infestation of *C. elongatus* can be rapid (J. Treasurer, FAI Aquaculture, Scotland, pers. comm.). In the Westfjords area of Iceland *C. elongatus* infestations are presently considered a more severe problem than the *L. salmonis* and the numbers of *C. elongatus* on each salmon can be high (> 10) in late autumn (October-November) (Eva D. Jóhannesdóttir, Arctic Sea Farm Ltd., pers. comm., Hjörtur Methúsalemsson, Arnarlax Ltd., pers. comm.). In this area large scale trials have clearly shown that lumpfish is very effective in lowering numbers of *C. elongatus*.

Lumpfish and C. elongatus: Survey from the salmon farming industry

To investigate in more details the possible effect of lumpfish on *C. elongatus* on Atlantic salmon we conducted a survey by interviewing fish health personnel and biological controllers working in the salmon farming industry in Norway (N=18), Faroe Islands (N=5) and Iceland (N=2) (https://www.fhf.no/prosjekter/prosjektbasen/901539/). In Norway we interviewed personnel working in companies Northern Norway (i.e. from Production Areas (PA) 9-13, see Fig. 1 in Overton et al. 2018). The survey findings showed that almost all participants agreed that lumpfish grazed on *C. elongatus* (Fig. 7A), but that the extent of the grazing is unclear. On the Faroes Islands all participants agreed that lumpfish grazed to large extent on *C. elongatus*, whereas in Northern Norway the views were split between *large extent* and *some extent* (Fig. 7A). When asked further whether the grazing of lumpfish lead to reduction of *C. elongatus* on the Atlantic salmon the survey showed different views on the extent of *C. elongatus* reduction on salmon (Fig. 7B). The majority in all three countries think that the grazing reduces *C. elongatus* on salmon to large or some extent. In all three countries it was commended that the lumpfish influenced the numbers of *C. elongatus* if the number of *C. elongatus* on salmon is moderate or low.

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Conflict of Interest: The authors declare that they have no conflict of interest.

Ethical Statement: The experiment described has been approved by the local responsible laboratory animal science specialist under the surveillance of the Norwegian Animal Research Authority (NARA) and registered by the Authority.

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Figure legends

Fig. 1 Total average number of *C. elongatus* per fish recorded for each duplicate treatment during each of the sampling dates in the trial of Imsland et al. (2014a). Values are presented as means ± S.D. Mean values which do not share a letter were found to be significantly different by ANOVA and by Tukey`s multiple range test ($P < 0.05$). The average number refers to the total number of fish sampled from both cages at each sampling time

Fig. 2 Total average number of *C. elongatus* per Atlantic salmon recorded for each duplicate treatment during each of the sampling dates of the sea pen study in Imsland et al. (2019). Values are presented as means ± S.D. Mean values which do not share a letter were found to be significantly different by ANOVA and by SNK post hoc test ($P < 0.05$). The average number refers to the total number of fish sampled from both cages (N=60) at each group each sampling time

Fig. 3 Mean percentage values *C. elongatus* found in nine lumpfish families sampled at each sampling time point. Data from Imsland et al. (2016)

Fig. 4 Percentage values *C. elongatus* found in stomach of lumpfish of the ten lumpfish families sampled at each sampling time point. Values presented as means ± S.D. Data from Imsland et al. (unpublished data)

Fig. 5 Occurrence of *C. elongatus* per salmon (n=60 in each group at each sampling point) in large scale sea cages at Lerøy Aurora, northern Norway, with 0 (control), 4, 6 and 8% density of lumpfish recorded for each duplicate treatment during each of the sampling (bi-weekly) dates

Fig. 6 Sea lice development at two production sites of Nordlaks in northern Norway 2017-18. Arrows indicate mechanical and chemotherapeutical delouse operations during the observation period

Fig. 7 Results from interview survey of fish health personnel and biological controllers working in the salmon farming industry in Norway (N=18), Faroe Islands (N=4) and Iceland (N=2)

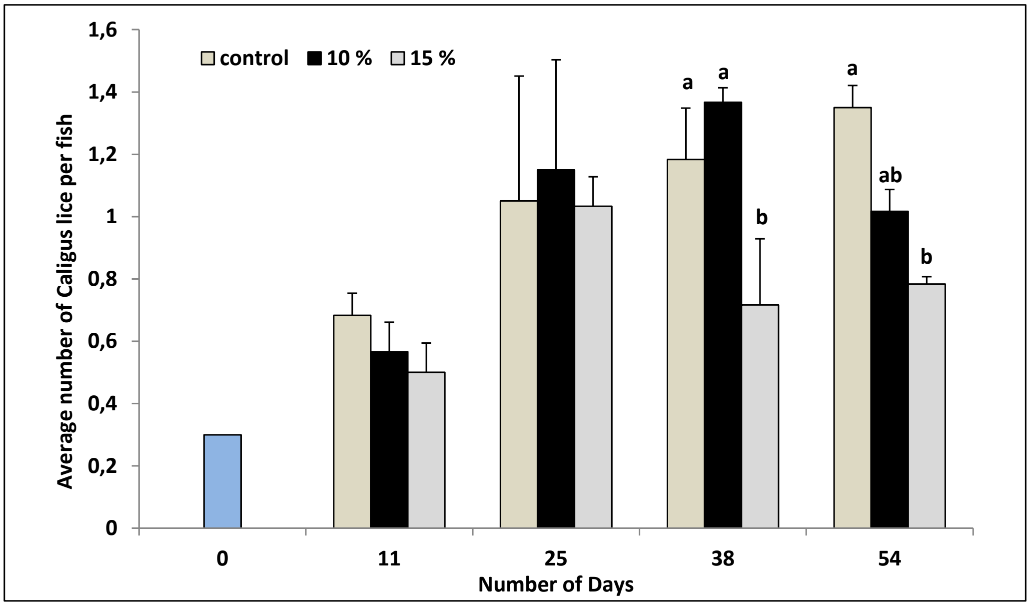

Fig. 1 Imsland et al.

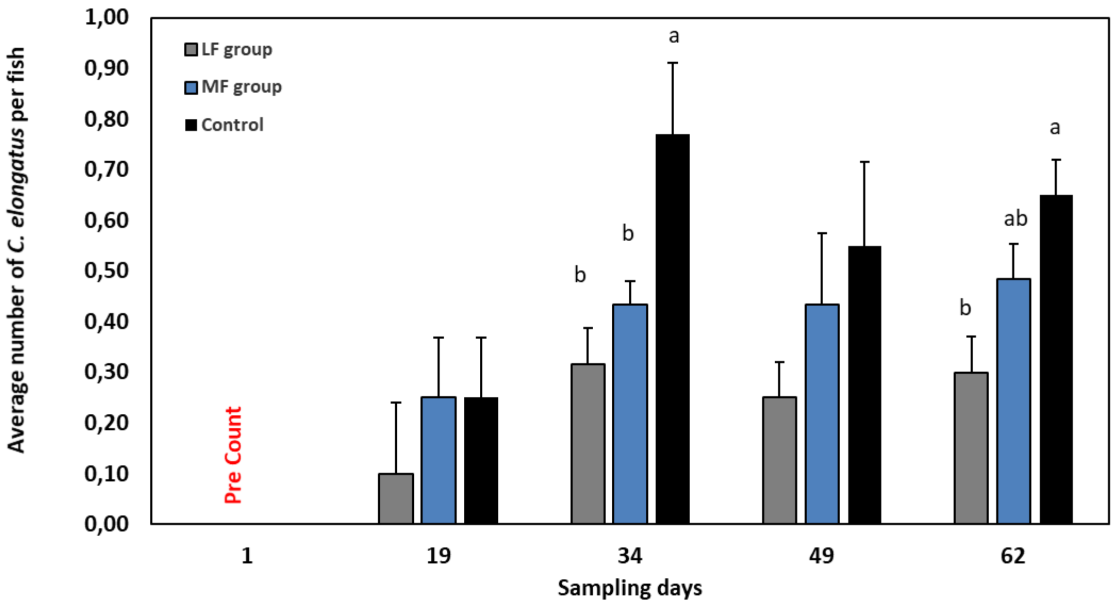

Fig. 2 Imsland et al.

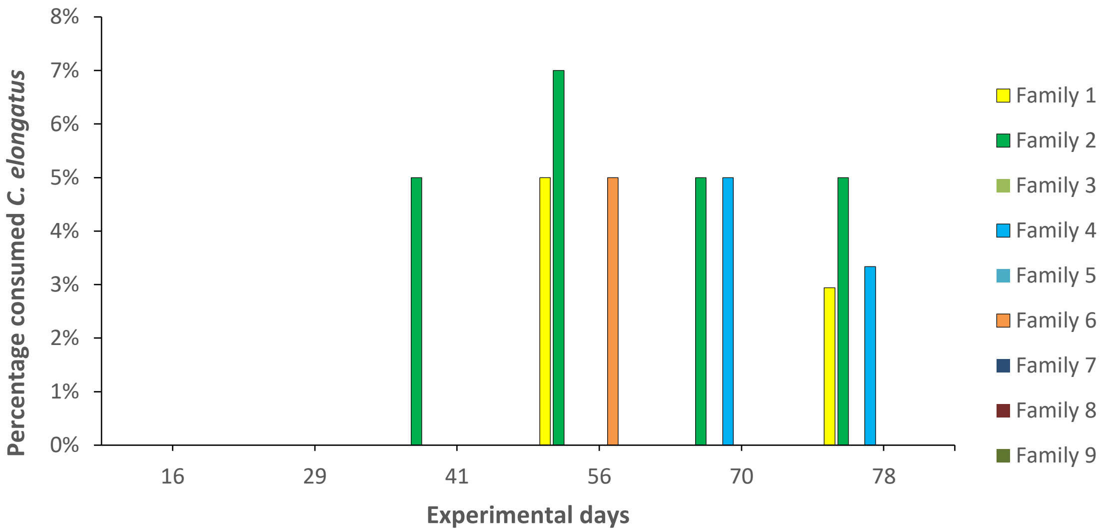

Fig. 3 Imsland et al.

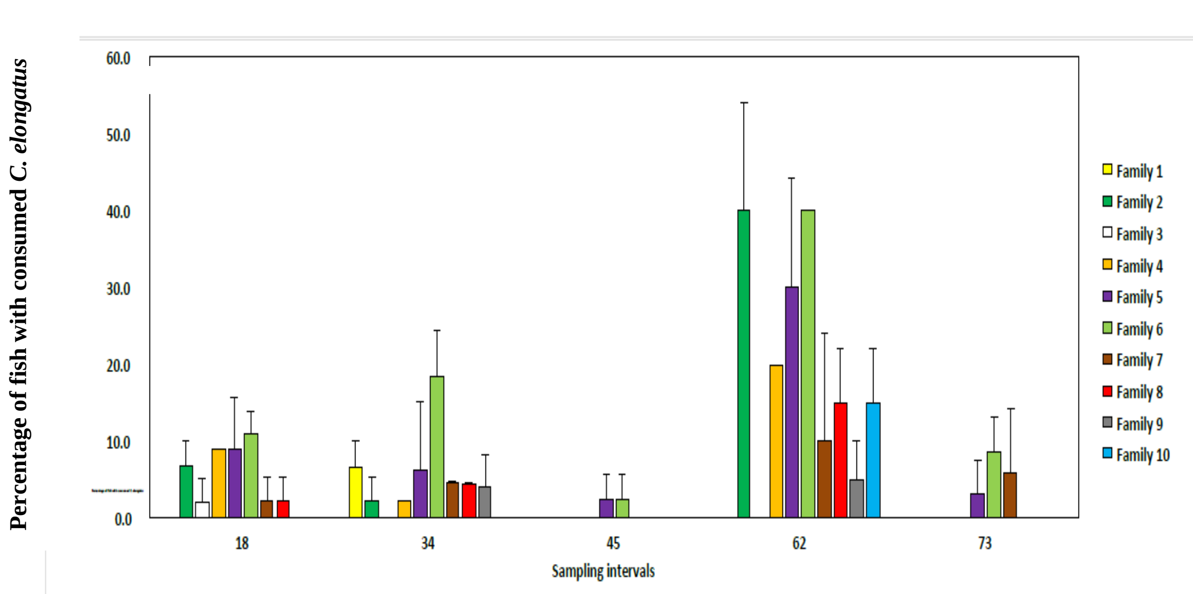

Fig. 4 Imsland et al.

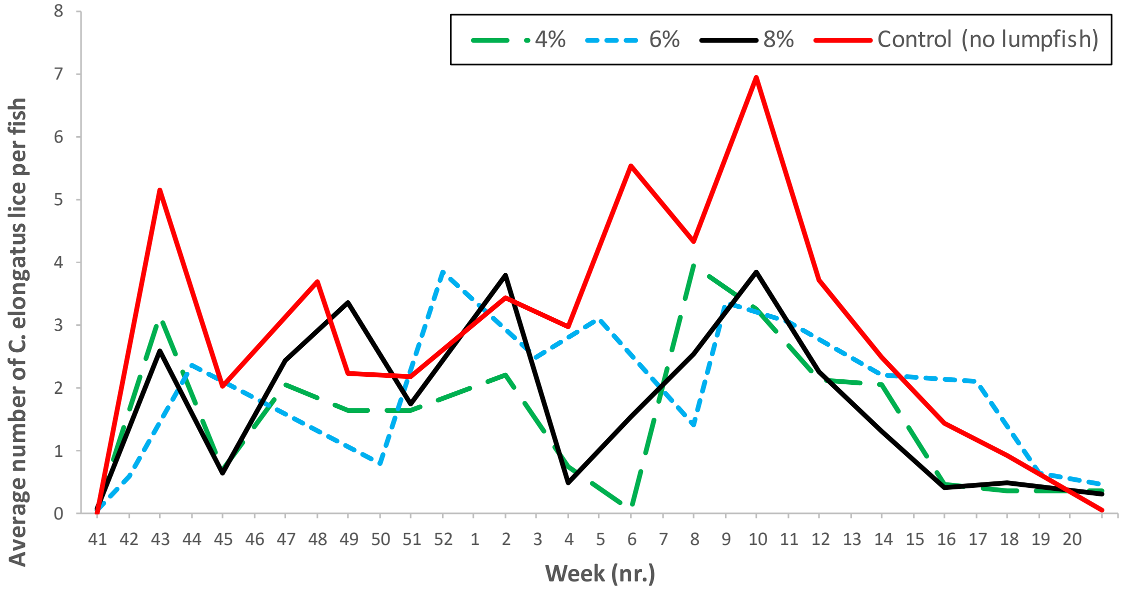

Fig. 5 Imsland et al.

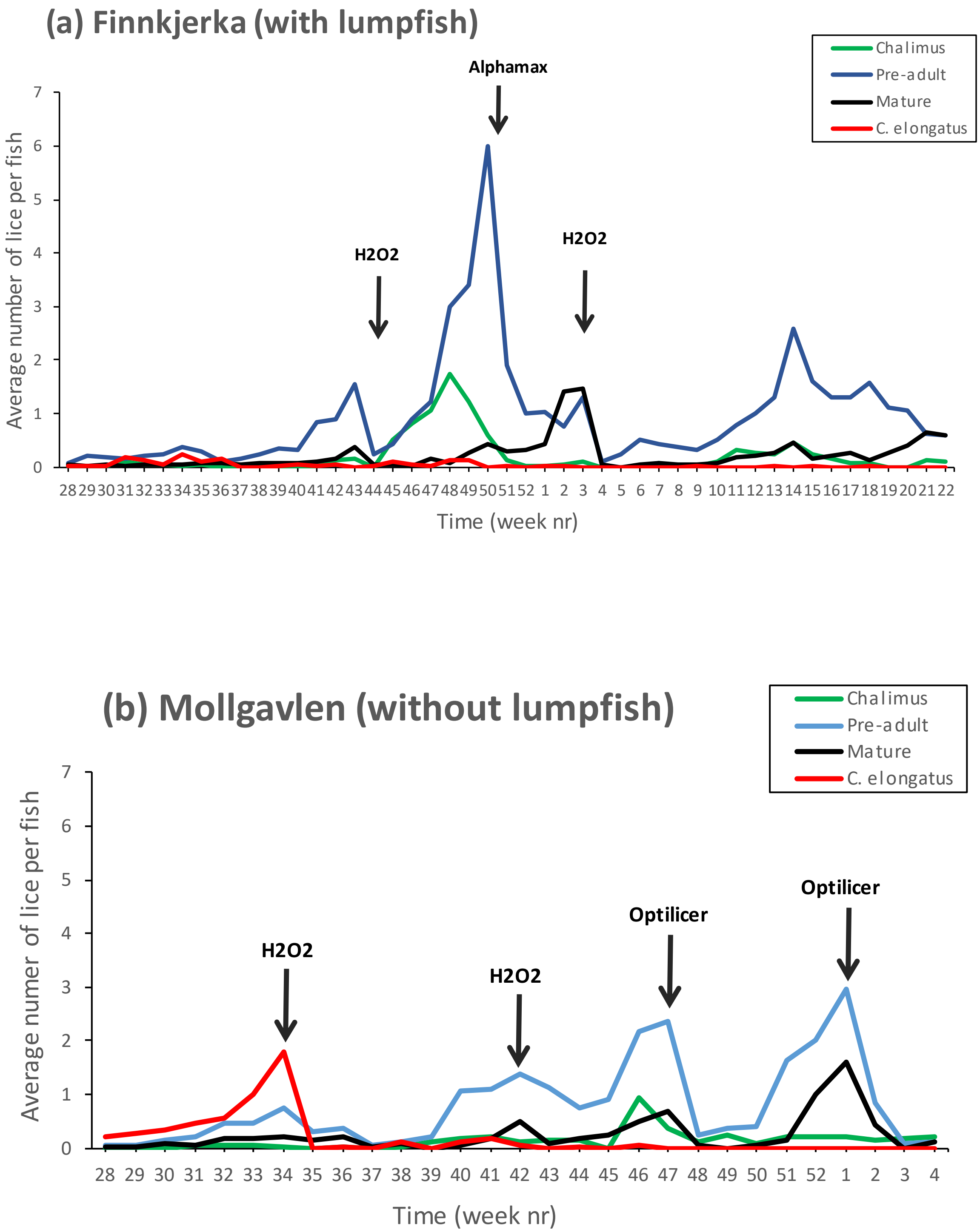

Fig. 6 Imsland et al.

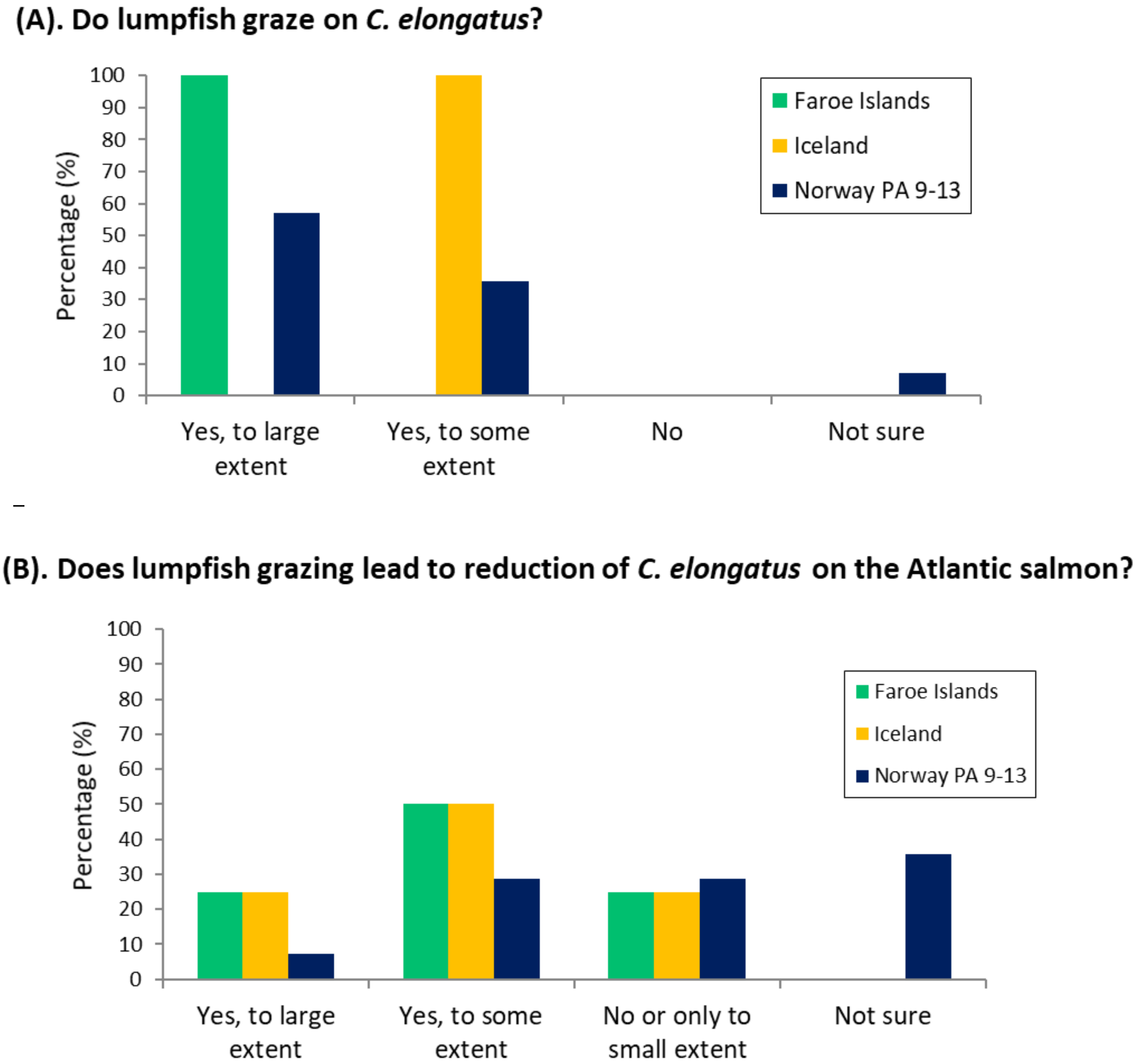

Fig. 7 Imsland et al.

Table 1. A summary of the current literature (peer-reviewed journal articles and scientific reports) and observations (including pers. comm.) on experiments with lumpfish and its effect on *C. elongatus* infestations on farmed Atlantic salmon. Data included: experimental period and temperature, experimental unit, experimental site/country, stocking density of lumpfish, effect investigated and if was effect found.

Citation	**Experimental period and temperature**	**Experimental unit (number and size)**	**Experimental site/country**	**Size and density of lumpfish**	**Effect investigated**	**Effect on *C. elongatus* found?**
Imsland et al. (2014a)	June – August, 9.0-12.1°C	4 small sea cages 5x5x5 m (125 m^3)	Nordland county, Norway	53-182 g 10% and 15%	Different density of lumpfish	Yes, increased effect at 15% density
Imsland et al. (2019)	May – July, 7.2-13.3°C	4 small sea cages 5x5x5 m (125 m^3)	Nordland county, Norway	114-180 g 10%	Habitation of lumpfish	Yes, and habitation of lumpfish increased the effect
Imsland et al. (2016)	May – August, 7.1-13.2°C	9 small sea cages, 5x5x5 m (125 m^3)	Nordland county, Norway	169-549 g 10%	Different families, parental effect	Yes, and varied between families
Imsland et al. (unpublished data)	Sept. – December, 10.5-6.8°C	10 small sea cages, 5x5x5 m (125 m^3)	Nordland county, Norway	30-123 g, 12%	Different families	Yes, and varied between families
Imsland et al. (unpublished data)	July – January, 12.2-5.5°C	12 large sea cages (160 m circumference, 58900 m^3 volume)	Nordlaks AS, Nordland county, Norway	32-157 g, 6%	Large scale evaluation of sea lice grazing in lumpfish	Yes
Imsland et al. (2018)	October – May,	8 large sea cages (130 m circumference, 37688 m^3 volume)	Lerøy Aurora AS, Troms county, Norway	25-115 g, 4, 6 and 8%	Different densities of lumpfish in large scale sea cages	Yes, similar at all densities

	8.3°C in October 3.6°C in March 6.8°C in May					
Eliasen et al. (2018), Kirsten Eliasen, Fiskaaling, Faroe Islands, pers. comm.)	Year round, 6-11°C	Large sea cages from 9 farming sites	Faroe Islands	13-545 g, Density not given	Cleaning efficacy of lumpfish in relation to size and season	Yes, around 80% of those that graze on *L. salmonis* graze on *C. elongatus*
Eva Dögg Jóhannesdóttir, Arctic Fish Ltd. (pers. comm.)	June-December, 10.1-3.2°C	7 sea pens (160 m circumference)	Iceland, Dýrafjörður	20-255 g, 8-10%	Comparison of sea lice at sites with and without lumpfish	Yes, significantly lower *C. elongatus* with lumpfish present
Hjörtur Methúsalemsson, Arnarlax Ltd. (pers. comm.)	Sept.-September (one year) 1.9°C (February) 11.1°C (early Sept).	12 sea pens (160 m circumference)	Iceland, Arnarfjörður	32-340 g 8-10%	Comparison of sea lice at sites with and without lumpfish	Yes, significantly lower *C. elongatus* with lumpfish present