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Short communication

Epidemiological description of the sea lice (*Caligus rogercresseyi*) situation in southern Chile in August 2007

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ABSTRACT

Salmon sea lice represent one of the most important threats to salmon farming throughout the world. Results of private monitoring efforts have shown an increase in the number of positive cages and cage-level abundance of sea lice in southern Chile since 2004. As a consequence, the Chilean Fisheries Service implemented an Official Surveillance Program in the main salmon production area of southern Chile to assess the situation of sea lice in fish farms. Results showed that the prevalence of sea lice in the fish farms was 53.4%, ranging from 3.5% in Puerto Aysén to 100% in the Seno de Reloncaví zone. The average sea lice abundance was 11.8 per fish (Geometrical mean (GM) = 8.61, 95% CI (2.1–6.9)). The highest levels were found in Seno de Reloncaví (GM = 24.99, 95% CI (15.9–39.2)), Hornopirén (GM = 14.7, 95% CI (10.4–20.8)) and Chiloé norte (GM = 9.75, 95% CI (1–1.9)), and the lowest loads were observed in Puerto Aysén (GM = 1.35, 95%CI (1–1.9)) and Puerto Cisnes (GM = 1.67, 95%CI (1.1–2.6)).

Salmo salar and *Oncorhynchus mykiss* had the highest abundance levels (GM = 6.93, 95% CI (5.7–8.5), and (GM = 5.55, 95% CI (3.6–8.5), respectively). *O. kisutch* showed lower levels (GM = 1.34, 95% CI (1–1.7)), apparently being more resistant to infestation.

Sea lice in farmed salmon are widely distributed in different zones of southern Chile, and are becoming a serious threat to this industry. Prevalence and abundance levels were found to be generally high, decreasing in southern zones.

1. Introduction

Chilean salmon industry began in the early 1980s, and until 2005 Chile was the fastest-growing salmon producer in the world, with production peaking in 2006. Today, salmon farms are concentrated in the south of the country where the rugged coastline offer sheltered sites with ideal water temperatures and salinity for salmon production (Asche et al., 2009).

Since the early 1970s salmon sea lice (*Lepeophtheirus* spp. and *Caligus* spp.) have been a threat for the worldwide salmon farming industry, becoming the most significant and widespread pathogenic marine parasite infestation affecting cultured salmon (Revie et al., 2002). The pathogenic effects of sea lice infestation include mild skin damage represented by epithelium loss, bleeding, tissue necrosis and loss of physical and microbial protective function. Besides, the parasite can decrease the appetite, growth and food-conversion efficiency of the host fish and this may cause an impaired immune competence. Moreover, fish under this stress and with these injuries are more

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susceptible to secondary infections and other diseases; this may lead to stress-induced mortality (Costello, 2006). Sea lice infestation thus creates a significant economic impact in countries such as Norway, Scotland, Canada, Ireland and Chile, where salmon farming is an important component of the annual national agricultural output and a major source of employment (Costello, 2006; Revie et al., 2007).

Sea lice infestations became a problem soon after the Chilean salmon industry began and the predominant species is *Caligus rogercresseyi* (Boxshall and Bravo, 2000). As salmonids were free of metazoan parasites when the salmon species were introduced to Chile, it has been suggested that the origin of *Caligus* infestation was native fish fauna including *Eleginops maclovinus* and *Odonthestes regia* (Carvajal et al., 1998; González and Carvajal, 1994). The life cycle of *C. rogercresseyi* includes eight stages: two nauplius, one copepodid, four chalimus and one adult. Being chalimus and adult the parasitic stages. Adults can be classified as indistinguishable adults (either male or female) or female with eggs. Female with eggs are considered as the most relevant stage since it represents the potential growth of the infestation through the egg production (González and Carvajal, 2003). The timing of these different stages is directly dependant on water temperature, the cycle being shorter in summer (18 days) and longer in winter (45 days). The minimum development temperature threshold was found to be of 4.2 °C (González and Carvajal, 2003).

The Salmon Technical Institute (INTESAL) conducted a private sea lice monitoring program in southern Chile since 1999, gathering information from fish farms belonging to its associated industries. Results of this program for 1999–2002 reported a mean count of adult sea lice of 3.38 parasites (SD 6.36) per fish (Zagmutt-Vergara et al., 2005). Between 2004 and 2007 an increase in the number of positive cages and parasite counts was described. In 2004, the average counts of sea lice, considering both adults and juveniles stages, were 5, 10 and 3 parasites for rainbow trout, Atlantic salmon and coho salmon, respectively. Later on, at the beginning of 2007, the average parasite counts were 20, 34 and 29 for the same fish species (Rozas and Ascencio, 2007). In response to this situation, the Chilean National Fisheries Service (Sernapesca) decided to implement an official surveillance program (OSP) to assess the real situation of sea lice in seawater and estuarine fish farms in southern Chile. This new program included the use of "rest areas", where all salmon production is stopped in a coordinated way among different companies, to reduce the parasite density in the area. This measure has reportedly produced good results in other fish producing countries. The aim of the current study is to assess the epidemiological situation of sea lice in southern Chile based on the information collected through the first activities of the OSP.

2. Material and methods

2.1. Surveillance program and data gathered

The first activities of the OSP for sea lice were performed in August 2007, consisting of random sampling of ten fish from all cages in each fish farm. The total numbers of indistinguishable adults (male and female), female adults with eggs and juvenile stages were recorded. Qualified personnel working at the fish farms were responsible for counting sea lice and reporting to Sernapesca. The information gathered was grouped into ten productive-ecological macro zones (Fig. 1), as defined by the official authorities and reported by INTESAL (Casas-Cordero et al., 2004).

2.2. Database and analysis

A database was constructed using MS Excel® spreadsheets and statistical analysis was performed using Infostat® statistical package. Prevalence at farm and cage levels was calculated to describe the epidemiological sea lice situation in southern Chile. For farm-level prevalence a fish farm was considered positive when the average parasite count per fish was higher than five. For cage-level prevalence, a cage was considered positive when the average parasite count in fish exceeded five. The average count of five parasites per fish was used to define a case at both farm and cage level, since represents the threshold to start the treatment in a cage as defined by the Chilean sanitary authority (Rozas et al., 2007). It must be noted that the term prevalence is used through this study referred to the case definition, meaning that a farm with less than five parasites is not considered a case and therefore will be not counted in the prevalence calculations. The sea lice count represent a classical right skewed distribution, usually observed in parasite count studies (Dash et al., 1988; Dobson et al., 2009), were classical averages and standard deviations values are biased by the extreme values of the data. To properly describe these populations the following procedure was followed. First a 0.5 value was added to the parasite count to address the presence of zeroes (Dash et al., 1988), the most common result (mode) in this sea lice count study. Afterwards data was log transformed to address the highly skewed distribution. Based on the +0.5 log data, geometric means (GM), geometric standard deviation and 95% confidence intervals (95% CI) are presented. Also, classical average sea lice abundance was presented when necessary to complement the information regarding disease occurrence. Comparisons between zones and species were done using the Kruskal–Wallis test and the Tukey–Krammer multiple comparisons test between groups (Zar, 1999; Thrusfield, 2005) as a way to compare this non-parametrical data.

3. Results

The OSP in 2007 surveyed 323 fish farms (5681 fish cages). After data cleaning the valid entries resulted in a database of 292 fish farms and 4704 fish cages (Table 1). Ninety percent of the fish farms bred only one salmon species the predominant being Atlantic salmon (59% of fish farms).

The sea lice prevalence among the fish farms was 53.4%. Lowest levels were found in the south of the study area and the highest in the north, ranging from 3.5% in Puerto Aysén to 100% in the Seno de Reloncaví zones (Table 1). Cage-level prevalence was 47.8%, and the same situation was observed, with highest prevalence in the north of the

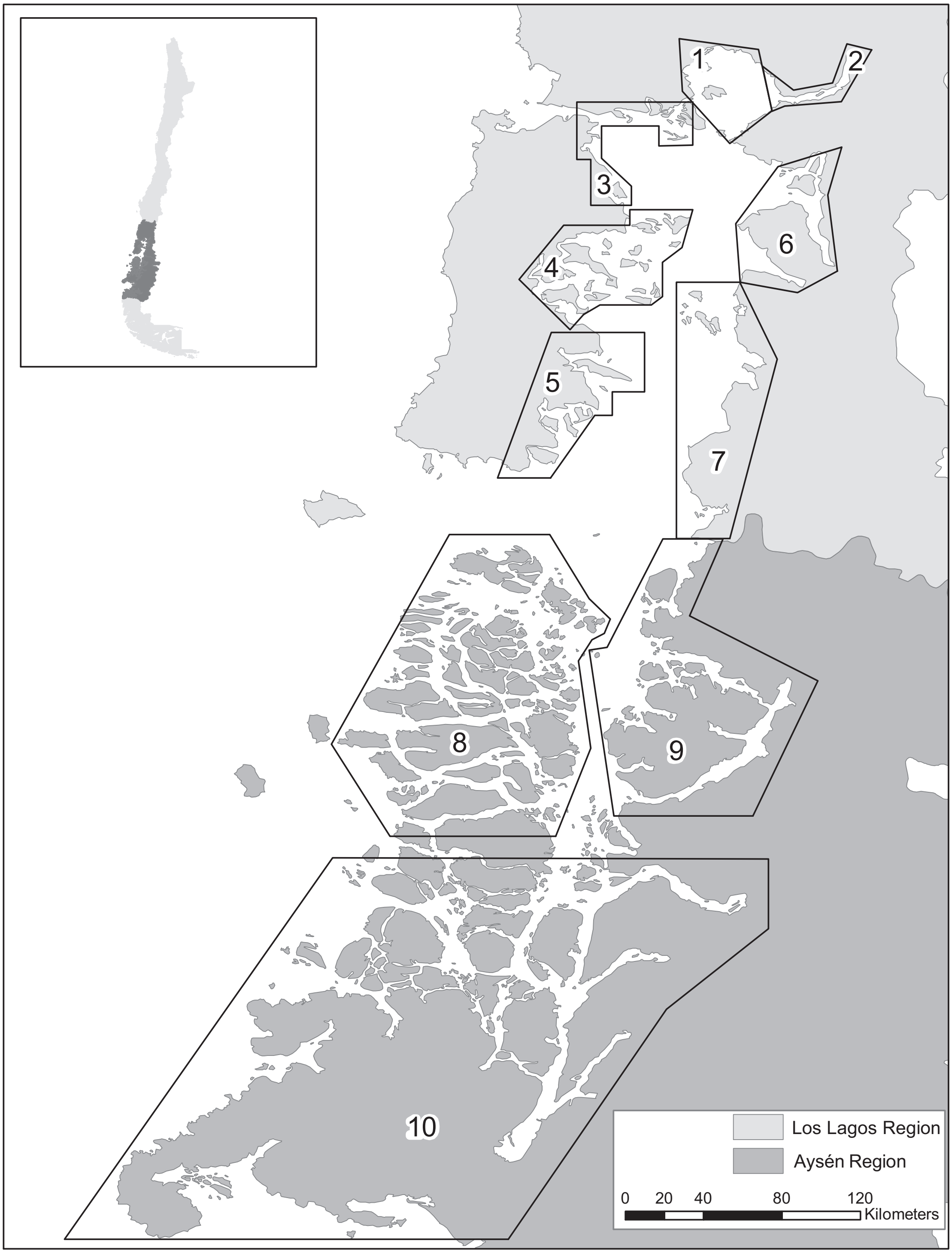

Fig. 1. Production-ecological zones in the primary salmonids-producing area in southern Chile, as of 2007: (1) Seno de Reloncaví, (2) Estuario de Reloncaví, (3) Chiloé norte, (4) Chiloé centro, (5) Chiloé sur, (6) Hornpirén, (7) Chaitén, (8) Melinka, (9) Puerto Cisnes and (10) Puerto Aysén.

study area, ranging from 5.6% to 89.1% in Puerto Aysén and Seno de Reloncaví zones, respectively.

The average sea lice count was 11.8 parasites per fish (GM = 8.61, 95%CI (2.1–6.9)). For the different development stages the mean count was 4.1, 3.6 and 4.1 for juvenile, female with eggs and indistinguishable adult stage, respectively (Table 1). Differences in average abundance levels of *C. rogercresseyi* between zones were statistically significant ($P < 0.01$). The highest average sea lice loads were found in the north of the study area, e.g. Seno de Reloncaví

Table 1
Number of salmonids fish farms, cages, prevalence at farm and cage levels, abundance levels of different sea lice development stages, and multiple comparison tests for sea lice average (*Caligus rogercresseyi*), in different geographical zones of Southern Chile, August 2007.

Zone	Main fish *Sps.*	Farms *N*	Cages *N*	Prevalence		Average counts			Multiple comparisons test**
				Farm	Cage	Juvenile	Female	Adult	
(1) Seno Reloncaví	*S. salar*	15	276	100.0	89.1	12.3	9.3	13.2	e
(2) Estuario Reloncaví	*O. mykiss*	26	393	50.0	34.4	3.2	3.2	3.8	b
(3) Chiloé norte	*S. salar*	23	351	69.6	59.5	6.0	6.8	5.8	cd
(4) Chiloé centro	*S. salar*	67	1070	68.7	64.6	5.9	4.5	5.3	cd
(5) Chiloé sur	*S. salar*	41	812	46.3	41.4	3.4	2.3	2.6	bc
(6) Hornopirén	*S. salar*	20	379	95.0	79.7	5.8	6.7	6.5	cde
(7) Chaitén	*S. salar*	10	103	80.0	61.2	4.9	4.1	6.6	de
(8) Melinka	*S. salar*	34	508	41.2	38.8	1.6	2.1	2.0	ab
(9) Puerto Cisnes	*S. salar*	27	417	18.5	11.0	0.7	1.1	1.2	a
(10) Puerto Aysén	*	29	395	3.4	5.6	0.5	0.5	0.5	a

Juvenile: average count of juvenile stages; Female: average count of female with eggs stage; Adult: Average count of adult, excluding female with eggs stage.
* Same number of cages for *S. salar, O. kisutch* and *O. mykiss*.
** Different letters indicate significant differences ($P \leq 0.05$).

(GM = 24.99, 95%CI (15.9–39.2)), Hornopirén (GM = 14.7, 95%CI (10.4–20.8)) and Chiloé norte (GM = 9.75, 95%CI (5.6–16.9)). In contrast, the lowest levels were found in the southern zones like Puerto Aysén (GM = 1.35, 95%CI (1–1.9)) and Puerto Cisnes (GM = 1.67, 95%CI (1.1–2.6)) (Table 1). The average level for the female with eggs stage was 3.7 parasites per fish, and this ranged from 0.5 in Puerto Aysén to 9.2 in Seno de Reloncaví zones. There were significant differences in sea lice abundance between species cultured in southern Chile (P < 0.01). *S. salar* had the highest levels (GM = 6.93, 95%CI (5.7–8.5)), followed closely by *O. mykiss (GM = 5.55, 95%CI (3.6–8.5))*. The lowest parasite loads were for *O. kisutch* (GM = 1.34, 95%CI (1–1.7)).

4. Discussion

Aquaculture is the fastest growing food-producing sector in the world, providing many products for human consumption. Diseases are the major constraint to aquaculture, and sea lice infestation is the most important pathogenic marine parasite infestation affecting farmed salmon systems (Revie et al., 2002; Subasinghe, 2005).

The OSP implemented in Chile gathered information from only 50% of active fish farms in 2007. This lack of participation was probably due to the outbreak of Infectious Salmon Anaemia Virus (ISAv) that started in late July 2007 (OIE, 2010). Actually, the high levels of prevalence and abundance of sea lice may have played a role in the ISAv epidemic due to the pathogenic effects and impaired inmunocompetence caused by this parasite (Costello, 2006), increasing the fish susceptibility to ISAv infection. Furthermore, sea lice may have played a role in the virus spread, since it has been demonstrated that sea lice can be vector of ISAv (Nylund et al., 1994). The random sampling of ten fish from each fish-cage, as used during the OSP is reported in the scientific literature as sufficient to give a good level of precision to the results, considering the sea lice's clustering that occurs within cages (Revie et al., 2007).

Results indicate that the sea lice infestation in farmed salmon was widely distributed through different zones in southern Chile. In general there was a high prevalence at both the fish farm and the cage levels. It was also observed that farm prevalence was higher in northern zones (between 41°28′ and 43°32′ S) and decreased in southern zones (between 43°45′ and 47°02′ S). These variations could be related to environmental factors like water temperature and water salinity, or due to management factors such as farm and fish density or treatments applied, among others (Revie et al., 2002; Zagmutt-Vergara et al., 2005). These factors also were identified as risk factors for sea lice in Chile, analysing data from OSP (Yatabe et al., 2011).

The prevalence figures coupled with the high average parasite count of 11.8 (GM = 8.6) parasites per fish reflect a high-intensity sea lice infection. The average levels of the female with eggs stage had wide variability in southern Chile, showing the same pattern than the prevalence, with higher loads in the north and decreasing to the south. The Hornopirén, Chiloé Norte and Seno de Reloncaví zones had a mean abundance higher than 6.5 adult females with eggs (Table 1); these continue their egg production, thereby increasing the load of larval stages in the environment. Hence, this could lead to high sea lice levels for the spring and summer months when the water temperature increases and the parasite life cycles are shorter (Heuch et al., 2005). Future data analyses from the OSP would be necessary to evaluate if winter adult female with eggs loads can predict spring and summer infestation levels. When these parasite loads are compared with the treatment thresholds in other countries, the seriousness of the sea lice problem in Chile is highlighted. For instance, in Norway the legal limit to treat fishes is a mean per cage of 0.5 adult females or five mobile lice for autumn and winter, and ten mobile lice or two adult female for spring and summer. In Ireland the limit ranges from 0.3 to 2 adult females per fish. In British Columbia the limit is three mobile lice (Sea Lice Management, 2005; SLMS, 2008; Heuch et al., 2005).

Previous studies had reported differences in the susceptibility (reflected as average parasite abundance) for sea lice infestation in different salmonids species. Traditionally coho salmon has been described as the most susceptible species and Atlantic salmon as the most resistant (Carvajal et al., 1998; González et al., 2000) although lately it has been indicated that in the last years coho salmon have presented higher infestation levels than rainbow trout (Rozas and Ascencio, 2007). Other studies even found differences between Atlantic salmon families in their susceptibility to sea lice *L. salmonis*, but no difference for *C. elongatus* (Glover et al., 2004; Glover et al., 2005). In this study it was found that rainbow trout and Atlantic salmon were the most susceptible species, and coho salmon was the most resistant. The increase in sea lice abundance in Atlantic salmon has also been observed in studies previously conducted by the private sector (Rozas et al., 2007).

The main mean of control authorized in Chile is the use of emamectin benzoate. Although initially very effective, nowadays the effect of this treatment has decreased against sea lice. Therefore Chilean authorities have implemented a strategic period for coordinated treatment with piretroids to reduce infestation. At the same time it is important to consider broader pharmacological options for dealing with sea lice, and these must be safe for food and to the environment. The identification of environmental and management risk factors will also give further options to complement pharmacological treatment and create the most effective program for the prevention and control of sea lice.

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