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Sea lice counts on Pacific salmon caught in the Central North Pacific Ocean and Bering Sea aboard the R/V *Wakatake maru* using gillnets and long line gear in July 2005

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Abstract

Sea lice were identified from a total of 88 Pacific salmon caught in gillnets and 105 Pacific salmon from long line catches. All sea lice were *Lepeophtheirus salmonis*. Accurate counts of stages of sea lice would be obtained only from salmon caught on long lines. The prevalence of all stages for salmon caught on long lines ranged from 100% for pink salmon to 25% for sockeye salmon. The intensity of sea lice on salmon caught on long lines ranged from 17.6 for pink salmon to 3.0 for sockeye salmon. Non-mobile stages represented only 6% of all sea lice. Adult female sea lice were almost three times more abundant that adult males and 60% of all females were gravid.

Introduction

Accurate estimates of the species and stages of sea lice on Pacific salmon are needed to understand the processes that affect the natural productivity of sea lice. An understanding of the production dynamics of sea lice is a necessary contribution to the understanding of the dynamics of sea lice produced on cultured salmon. Sea lice are a common parasite of Pacific salmon (*Oncorhynchus* spp.). Despite the reported common occurrence of the sea lie *Lepeophtheirus salmonis* (Kabata 1973) and *Caligus clemensi* (Kabata 1972) there are very few studies that identify the prevalence and intensity of all stages of these sea lice on the various species of Pacific salmon that rear in marine ecosystems. Accurate reports of sea lice abundance require that the individual hosts are captured in a manner that does not abrade sea lice off the skin or facilitate the exchange of sea lice from one individual host to another. There are two studies in the North Pacific that captured Pacific salmon in such a manner that ensured that sea lice counts were accurate for a variety of species of Pacific salmon in a common ecosystem. A recent study by Beamish et al. (2005) used troll gear to catch adult Pacific salmon and land them individually in a manner that all sea lice could be counted and identified. A study by Nagasawa (2001) identified the prevalence and intensity of adult female *L. salmonis* on samples of Pacific salmon captured using surface long line gear fished in the central North Pacific Ocean and Bering Sea in the summer from 1991 to 1997. In order to compare the results of our study in the coastal waters of British Columbia (Beamish et al. 2005), we repeated the study of Nagasawa (2001) by sampling all stages of sea lice in the same area sampled by Nagasawa (2001), using similar gear and the same vessel (R/V *Wakatake maru*).

Methods

Pacific salmon were captured using gillnets and long line gear according to the procedures described in Fukuwaka et al. (2005). Fishing locations (Fig. 1) and methods were similar to those

used for the studies of Nagasawa (2001). A total of 25 stations were sampled from the R/V *Wakatake maru* between June 8 and July 20, 2005.

The gillnet was used at 8 stations in the central North Pacific Ocean and 10 stations in the central Bering Sea. The gillnet was set for 12 hours at each station, starting at 16:00 (Local Mean Time, GMT +12) and ending at 04:00 the following morning (Fukuwaka et al. 2005). The gillnet configuration consisted of a variable-mesh research gillnet (3 tans (one tan is 50 m long) each of 48, 55, 63, 72, 82, 93, 106, 121, 138 and 157 mm mesh size) combined with panels of a commercial-mesh gillnet (19 tans (one tan is 50 m long) of 115 mm mesh size) (Fukuwaka et al. 2005). The long line was fished at 25 stations in both the central North Pacific Ocean and in the central Bering Sea. The long line was comprised of 30 hachi (overall length 3.32 km; 1 hachi is 110.68 m long with 49 hooks) (Fukuwaka et al. 2005). The long line was baited with salted Japanese anchovy (*Engraulis japonicus*) and set for approximately one hour at 30 minutes before and after sunset (Fukuwaka et al. 2005).

Salmon captured on the long line that were dead or not in suitable condition for a concurrent tagging study were examined for sea lice. Live salmon captured on the long line were removed and placed in a recovery tank. Those deemed not to be tagged were examined for sea lice. Salmon caught by the commercial gillnet were also examined for sea lice. All fish were measured (fork length) to the nearest 1 mm. Fish examined for sea lice were placed individually in a solid tray to ensure that sea lice falling off the fish would not be lost. All surfaces of the fish were examined for sea lice.

Magnification was used to confirm that all sea lice had been counted. The species and stages of all sea lice were identified at sea for each fish and preserved in 70% ethanol. There samples were returned to the Pacific Biological Station, Nanaimo, British Columbia where an expert in sea lice taxonomy identified all samples. The identifications reported here were made at the Pacific Biological Station. In some cases it was necessary to resolve differences in counts made in the field and in the laboratory as not all sea lice stages counted at sea found their way intact to the laboratory. The terms prevalence, (the percentage of fish with sea lice); intensity, (the average number of sea lice on infected fish); and abundance, (the average number of sea lice on all fish sampled) were used according to Margolis et al. (1982).

Results

Fish were captured from 17 gillnet and 22 long line fishing locations in the North Pacific Ocean and central Bering Sea (Fig. 1). A total of 88 fish were sampled from gillnets and 105 fish from long line catches (Table 1). The average length of each species is shown in Table 2.

All sea lice were *L. salmonis*. Most sea lice were in mobile stage (Table 3). Chalimus and copepodid stages were observed on pink salmon and chinook salmon, but these non-mobile stages represented only about 10% of all stages. Approximately 81% of all mobile stages on fish from gillnets were females and 40% of these were gravid females (Table 3).

Samples from long line catches had a combined prevalence of sea lice of 78.6 % and an intensity of 7.7 (Table 4). The abundance for the total sample was 6.9 (Table 5). Pink salmon were the most numerous in the sample and the prevalence was 100%. Pink salmon had the largest intensity of 17.6 with 89.5% in the mobile stage. Of these, 52.6% were adult females with about one half (52.9%) being gravid females. The prevalence was smaller for coho and chum salmon as was the intensity (Table 5).

The total number of fish sampled from long lines in this study was much smaller that the combined sample examined by Nagasawa (2001). The prevalence observed in this study was larger for all species, as was the intensity (Table 6). The abundances of adult female sea lice in this study were larger that reported by Nagasawa (2001) for all species except for steelhead and coho salmon (Table 6). The overall abundances were equal for coho salmon.

Discussion

Fish collected from long lines and gillnets commonly had sea lice, confirming the popular statements that sea lice in general, and *L. salmonis* in particular, is a common parasite of Pacific salmon. Only *L. salmonis* was observed. *Caligus clemensi* is common on juvenile and adult Pacific salmon in the coastal waters of British Columbia (Beamish et al. 2005) but was not observed in our samples. The low percentage of non-mobile stages was also different from the observations in the coastal study of Beamish et al. (2005).

It is known (Nagasawa 1985), and to be expected that the counts of sea lice from fish captured in gillnets will not be accurate. However, there is some useful information from the observations of sea lice on gillnet-captured Pacific salmon. For example, non-mobile stages are attached to the fish and the percentages of these stages were similar to the percentages observed on long line captured samples.

Nagasawa (2001) did not report the percentages of non-mobile stages, pre-adult stages and adult male stages. In the long line samples, these stages represented approximately 11%, 10%, and 19%, respectively. Adult female *L. salmonis* dominated (55%) the abundance of all sea lice stages. Adult female stages were also three times more abundant than adult male stages. This is consistent with reports that indicate that female *L. salmonis* may receive sperm from a male and store the sperm (Anstensrud 1990; Hull et al. 1998). As the male may inseminate the females only once, males would be expected to have a shorter life span than female sea lice. The much smaller percentage of mature males may be an indication of this shorter life span. It is interesting that the lifespan of female *L. salmonis* remains to be determined. This is an important determination that is needed to understand the relative importance of sea lice transported from the coastal areas, back into the ocean. About one half (53%) of the adult female sea lice were gravid females. This represented an abundance of 2.7 gravid female sea lice for all the species of Pacific salmon sampled from long lines in the centre of the Pacific Ocean and Bering Sea.

It would be expected that our estimates of total abundance might be larger than reported by Nagasawa (2001) as we counted all stages of sea lice. Comparisons with the results of Nagasawa (2001), however should be considered preliminary as our sample size was small compared to Nagasawa (2001) and we have only one year of data. Our largest sample was for pink salmon and it was pink salmon in the Nagasawa (2001) and this study that had the largest prevalence and intensity of sea lice.

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Table 1. Number of fish examined for sea lice captured by gillnet and long line at each station of the *Wakatake maru* cruise.

Station	Number of fish (Gillnet)	Number of fish (Long line)
1	-	-
2	-	-
3	2	2
4	1	12
5	-	6
6	5	2
7	8	1
8	5	-
9	4	2
10	4	1
11	-	3
12	-	3
13	-	6
14	-	2
15	-	-
16	-	4
17	-	8
18	6	5
19	6	8
20	7	4
21	6	8
22	6	2
23	4	10
24	6	8
25	6	5
26	6	-
27	6	3
Total	88	105

Table 2. Average length of Pacific salmon examined for seal lice, standard deviation is shown in brackets.

	Gillnet sample		Long line sample	
Species	Number	Average length (mm)	Number	Average length (mm)
Pink salmon	62	479 (±27)	45	474 (±30)
Sockeye salmon	9	489 (±95)	4	552 (±90)
Chum salmon	10	442 (±85)	30	493 (±48)
Coho salmon	5	560 (±22)	20	519 (±37)
Chinook salmon	1	626	3	496 (±116)
Steelhead trout	1		3	593 (±49)
Total	88		105	

Table 3. Sea lice (*L. salmonis*) observed on Pacific salmon from long line and gillnet surveys on the R/V *Wakatake maru*, July 2005.

Species	Gear	Number caught	Prevalence	Intensity	% mobile	% chalimus	% copepodid
Pink salmon	Long line	45	100%	17.6	89.5	8.5	2.0
	Gillnet	62	85%	6.4	92.9	4.1	3.0
Sockeye salmon	Long line	4	25%	3.0	0	100	0
	Gillnet	9	11%	2.0	100	0	0
Chum salmon	Long line	30	77%	4.7	98.1	1.9	0
	Gillnet	10	20%	1.5	0	100	0
Coho salmon	Long line	20	70%	3.4	91.2	8.3	0
	Gillnet	5	40%	3.5	100	0	0
Chinook salmon	Long line	3	100%	13.7	75.6	0	24.4
	Gillnet	1	100%	7.0	85.7	14.3	0
Steelhead trout	Long line	3	100%	3.7	54.5	45.5	22.2
	Gillnet	1	100%	8.0	100	0	0
Total	Long line	105					
	Gillnet	88					
Average	Long line		78.6	7.5	68.1	27.4	8.1
	Gillnet		59.3	4.7	79.7	19.7	0.5

Table 4. Sea lice (*L. salmonis*) numbers and stages on Pacific salmon sampled from gillnets.

Species	Number of fish	Number infected fish	Prevalence	Total lice	Range	Abundance	Intensity	Number chalimus	Number mobile	Number pre-adult	Number adult male	Number adult female	Number gravid female[1]
Pink salmon	62	53	85	335	1-19	5.4	6.4	22[2]	313	17	37	259	150
Sockeye salmon	9	1	11	2	-	0.2	2.0	0	2	1	1	0	0
Chum salmon	10	2	20	3	1-2	0.3	1.5	3	0	0	0	0	0
Coho salmon	5	2	40	7	2-5	1.4	3.5	0	7	0	0	7	7
Chinook salmon	1	1	100	7	-	7.0	7.0	1	6	0	1	5	2
Steelhead trout	1	1	100	8	-	8.0	8.0	0	8	0	2	6	4
Total	88	60	59	362		3.7	4.7	26	336	18	41	277	163

[1]Also included in counts of adult female, [2]includes 10 copepodids.

Table 5. Sea lice (*L. salmonis*) numbers and stages on Pacific salmon sampled by long line.

Species	Number of fish	Number infected fish	Prevalence	Total lice	Range	Abundance	Intensity	Number chalimus	Number mobile	Number pre-adult	Number adult male	Number adult female	Number gravid female[1]
Pink salmon	45	45	100	793	3-36	17.6	17.6	83[2]	710	95	173	442	271
Sockeye salmon	3	1	25	4	-	0.8	3.0	4	0	0	0	0	0
Chum salmon	30	23	77	107	1-31	3.6	4.7	2	105	8	24	73	42
Coho salmon	20	14	70	48	1-11	2.4	3.4	4	44	5	9	30	16
Chinook salmon	3	3	100	41	2-17	13.7	13.7	10[3]	31	0	1	30	16
Steelhead trout	3	3	100	11	1-4	3.7	3.7	5[4]	6	1	1	4	3
Total	105	89	79	957		6.9	7.7	108	896	109	208	579	348

[1]Also included in counts of adult female, [2]includes 16 copepodids, [3]includes 10 copepodids, [4]includes 2 copepodids.

Table 6. Comparison of the sea lice counts on fish captured on long lines in this study and in the study of Nagasawa (2001).

	Long line		Prevalence %		Intensity		Average abundance of adult females	
Species	Nagasawa 2001	This study	Nagasawa 2001	This study	Nagasawa 2001	This study, all stages	Nagasawa 2001	This study
Pink salmon	1664	45	94	100	5.9	17.6	5.5	8.9
Sockeye salmon	528	4	8	25	1.0	3.0	0.1	0
Chum salmon	4807	30	36	77	2.1	4.7	0.8	2.3
Coho salmon	495	20	64	70	2.4	3.4	1.5	1.5
Chinook salmon	108	3	81	100	5.3	13.7	4.3	10.0
Steelhead trout	90	3	92	100	6.1	3.7	5.6	1.0
Total	7692	105						
Average			62.5	78.6	3.8	7.7	2.9	3.9

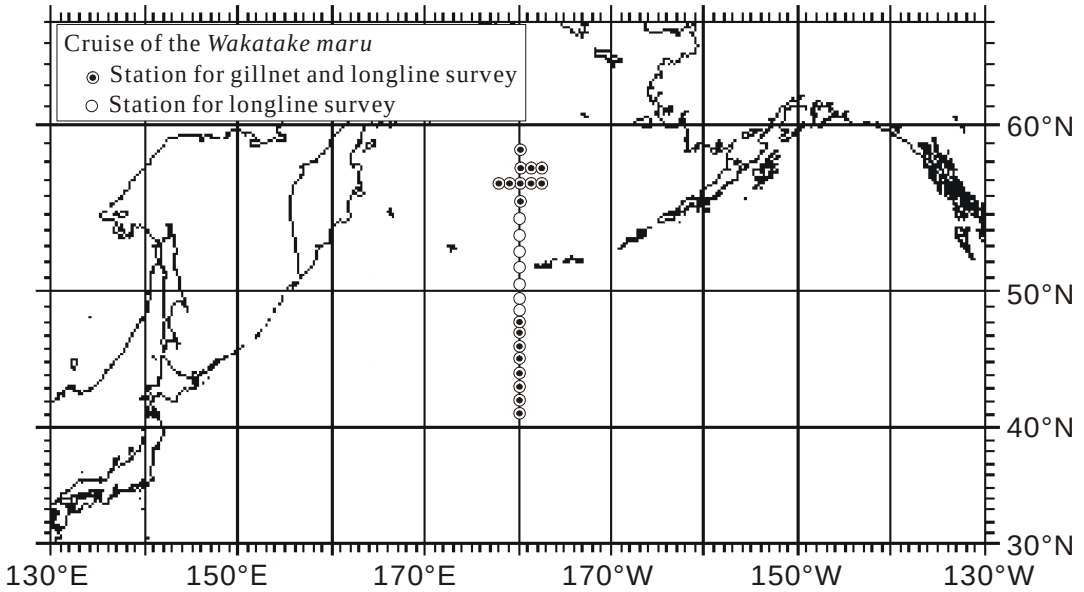

Fig. 1. Gillnet and long line fishing stations of the summer 2005 research cruise of the R/V *Wakatake maru* (Fukuwaka et al. 2005).