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Sea lice infection of juvenile salmon in the marine waters of the northern region of southeastern Alaska, May-August 2003

by

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Abstract

Juvenile Pacific salmon (*Oncorhynchus* spp.) were sampled for sea lice infection in northern region of southeastern Alaska in 2003. Juvenile salmon (fish in their first summer at sea) were sampled in littoral waters from seawater netpens and in neritic waters from strait and coastal habitats. Immature and adult salmon captured concurrently in neritic waters were also examined for sea lice. Differences in infection by sea lice were observed between species of juvenile salmon, between habitats, and temporally. Prevalence, intensity, and abundance of sea lice on juvenile salmon over all sampling periods and habitats were lowest for pink salmon (*O. gorbuscha*), and highest for coho salmon (*O. kisutch*). Both juvenile pink and chum (*O. keta*) salmon had low prevalence of sea lice, 2.9% and 4.2% respectively. Prevalence of infection was 8.4% on sockeye salmon (*O. nerka*) juveniles, and 53.2% on coho salmon juveniles. Prevalence and intensity of infection on adult fish was consistently higher than on juveniles of the same species; prevalence ranged from 33% on adult chum salmon to 100% on adult coho salmon examined. No evidence of infection was seen on juvenile chum salmon sampled from seawater netpens in littoral areas, after as many as 93 days rearing prior to release in May and early June. In late June, when juvenile salmon were first encountered in neritic waters, no evidence of infection was observed on juvenile pink and chum salmon, and infection of juvenile sockeye and coho salmon was 1.9% and 11.1%, respectively. Prevalence increased for juveniles of all four of these species from June to July, then declined from July to August, except for coho salmon. Prevalence of infection for juvenile salmon in July was higher in the inside strait habitat than in the coastal habitat in the Gulf of Alaska. Juvenile coho salmon were much more susceptible to infection in neritic waters than juveniles from other species. The timing of infection of juvenile pink and chum salmon and the wide disparity between the prevalence of sea lice on juveniles and adults of these species are consistent with the hypothesis that sea lice infection of salmon also occurs in oceanic waters.

Introduction

Sea lice (*Lepeophtheirus salmonis* and *Caligus* spp.) are parasitic copepods which infect salmonids in both the Pacific and Atlantic oceans (MacKinnon 1997). In wild populations, sea lice generally cause only minor host tissue damage (Wooten et al. 1982; Nagasawa et al. 1987). However, sea lice have occasionally been associated with severe damage and disease of wild adult salmon (White 1940; Johnson et al.1996). Sea lice, especially *L. salmonis,* are also a serious pathogen of farmed Atlantic salmon (*Salmo salar*) , causing reduced growth and mortality at high rates of infestation (MacKinnon 1997; Johnson 1998). Young smolts of farmed Atlantic salmon are considered particularly susceptible to pathogenic infection (Stone et al. 2002). Sea lice infection in wild Atlantic salmon, Arctic char (*Salvelinus alpinus*), and sea trout (*Salmo trutta)* is a subject of increasing concern because infection rates may be increasing along regular migratory routes where salmon farming is practiced (Bjorn et al. 2001; Bjorn and Finstad 2002). Recently high rates of sea lice infection were observed for juvenile Pacific salmon (*Oncorhynchus* spp.) in areas adjacent to commercial salmon farms in British Columbia (Gardner and Peterson 2003). These observations and concerns about transmission from salmon farms to wild fish have underscored the need for better information on background levels, especially on juvenile Pacific salmon in nearshore marine waters during their early marine life history (Trudel et al. 2002; Trudel et al. 2003). In this paper, we report on the incidence of sea lice on juvenile Pacific salmon during their first months at sea in nearshore waters of southeastern Alaska, and contrast the prevalence of infection with adult Pacific salmon captured synoptically.

Methods

Juvenile Pacific salmon were sampled for sea lice infestation in the northern region of southeastern Alaska in 2003 (Figure 1). The habitats sampled included 1) seawater netpens in littoral habitat near Juneau; and 2) neritic waters within the Alexander Archipelago in Chatham Strait and Icy Strait (strait habitat), and off Icy Point in the Gulf of Alaska (coastal habitat).

Juvenile chum salmon were cultured in seawater netpens at three sites by a private non-profit aquaculture corporation, Douglas Island Pink and Chum, Inc. (DIPAC). Juvenile chum salmon were placed into the netpens in early March, and held for 63-93 days. Prior to release, samples of fish were netted out of the pens, anaesthetized, measured, and examined for sea lice.

Neritic waters were sampled with trawls deployed from the National Oceanic and Atmospheric Administration (NOAA) ship *John N. Cobb*. Sampling stations were at least 1.5 km from shore. Sampling extended from June through August (Table 1). Strait habitat was sampled during five cruises from early June to late August; sampling in late August was limited by vessel mechanical problems. Sampling of coastal habitats was restricted to late June and late July. Two trawl types were fished from the vessel. Most sampling was done with the rope trawl normally fished for the Southeast Coastal Monitoring Program (Orsi et al. 2002). This trawl is a Nordic 264 rope trawl modified to fish the surface water directly astern of the ship. The rope trawl was 184 m long and had a mouth opening of 24-m deep by 30-m wide. Each rope trawl haul was fished for 20 min at 1.5 m/sec (3 knots), covering approximately 1.9 km (1.0 nautical miles) across a station. A two-boat surface trawl or townet, 3-m deep by 10-m wide, was also fished in the strait habitat in June. The townet was pulled between the *John N. Cobb* and a 7-m outboard-powered vessel. Each townet haul was 10 min at 1.0 m/sec (2 knots).

Juvenile salmon sampled by the trawls were anaesthetized, identified to species, enumerated, measured, labeled, individually bagged, and frozen. Large catches were subsampled due to processing time constraints. Inspection for sea lice was typically done at sea; each fish was measured and both sides inspected for the presence of lice. However, fish from one townet haul in June were not inspected for lice at sea; instead, the frozen samples were inspected later in the laboratory. A small number of adult salmon (pink salmon, *O. gorbuscha*, chum salmon, *O. keta*, and coho salmon, *O. kisutch*) and immature (one- or two-ocean) chinook salmon, *O. tshawystcha*, were also captured in the trawl hauls. All of these fish were also measured and inspected for sea lice.

Sea lice observed were preliminarily identified as *L. salmonis*. Samples of lice of various sizes were taken and preserved in alcohol for validation. All sea lice observed were counted. Size of lice (cephalothorax width) ranged from 0.5 mm to almost 5 mm. This size range includes chalimus larva, preadults, and adult *L. salmonis* (Johnson and Albright 1991). Prevalence, intensity, and abundance of sea lice infections were calculated according to Margolis et al. (1982). Prevalence is the percentage of infected fish, mean intensity is the mean number of parasites per infected fish, and abundance is the mean number of parasites per fish.

Results

Juvenile chum salmon sampled from DIPAC netpens increased in average size from 35 to 38 mm at the time of entry to seawater in early March to 61-65 mm by mid-May, and 69-81 mm by late May and early June (Table 2). No sea lice were observed in over 4,000 juvenile chum salmon sampled from the net pens at time of release.

A total of 74 trawl hauls were made, capturing 4,634 juvenile salmon. Of these, 89% were juvenile pink or chum salmon (Table 3). No juvenile salmon were captured in neritic waters in early June, indicating that juvenile salmon were still primarily in more littoral habitats at that time. In late June, juvenile salmon were captured in strait habitat, but not in the two trawl hauls in coastal habitat (Table 1).

Of the juvenile salmon captured in the trawls, 3,278 were examined for sea lice. Prevalence, intensity, and abundance of sea lice over all sampling periods and habitats were lowest for pink salmon, and highest for coho salmon (Table 3). Both juvenile pink and chum salmon had low prevalence of sea lice, 2.9% and 4.2%, respectively. Prevalence was 8.4% on sockeye salmon juveniles, and 53.2% on coho salmon juveniles. Chinook salmon juveniles were excluded from these comparisons, because the sample size (two) was too small to be considered representative.

Small numbers of immature chinook salmon and adult pink, chum, and coho salmon were also captured and examined for sea lice (Table 3). For each species, prevalence and intensity was higher on the older fish than on the juveniles. Prevalence was 100% on adult coho salmon, but the sample size was only three fish. Pink salmon adults also had high prevalence, 71%, and the highest intensity observed, 4.1 lice per infected fish. Prevalence on chum salmon adults and immature chinook salmon was lower, 33% and 25% respectively.

Juvenile salmon had higher prevalence of sea lice in strait habitat than in coastal habitat in July, the time period when fish were caught in both habitats (Table 4). Lice were observed on all four species of juvenile salmon captured in strait habitat, with prevalence of 4.6% for pink salmon, 10.4% for chum salmon, 26.9% for sockeye salmon, and 52.7% for coho salmon. In contrast, on samples from coastal habitat, no sea lice were observed on pink, chum, and coho salmon juveniles, and sockeye salmon juveniles had a prevalence of only 4.5% (Table 4).

Prevalence of sea lice on juvenile salmon in the strait habitat varied temporally. Generally low prevalence was observed in late June, when fish were first captured in the neritic habitat. At this time, no lice were observed on pink and chum salmon, and sockeye and coho salmon had lice prevalences of 1.9% and 11.1%, respectively (Table 5). For all four species, prevalence increased from late June to late July, with the greatest increases observed for sockeye salmon (to 26.9%) and coho salmon (to 52.7%). From late July to early August, lice prevalence stayed about the same for pink salmon, 4.6% and 4.4%, respectively. Lice prevalence declined from 10.4% to 1.9% for chum salmon, and from 26.9% to 0 for sockeye. Lice prevalence continued to increase for coho salmon in early August, to 57.1%, and in late August, to 78.9% (Table 5). In late August, only 2 pink, 0 chum, and 1 sockeye salmon juveniles were captured, with no lice observed; these sample sizes were too small to reflect trends in prevalence.

Pink salmon were the only species of adult salmon caught in June, July, and August. Sample size was small, with 13, 12, and 6 fish caught each month. Prevalence was stable for these small samples, at 69%, 75%, and 67%, respectively.

Average size of juvenile salmon, both infected and uninfected, increased with time for all four species (Table 6). Differences in size between infected and uninfected fish were not consistent among species. For pink, chum, and sockeye salmon, both infected and uninfected fish were captured only in late July and early August. In both time periods, the average size of pink salmon was larger for infected fish than for uninfected fish, whereas the average size of chum and sockeye salmon was larger for uninfected than infected fish. For coho salmon, average size of infected fish was larger than uninfected fish for three of the time periods (Table 6), but in late June, the only infected coho salmon was the smallest juvenile coho captured.

Discussion

We observed both temporal and spatial differences in infection by sea lice of juvenile salmon in their first summer at sea in the northern region of southeastern Alaska. No evidence of infection was seen in juvenile chum salmon reared in seawater netpens in littoral areas for as many as 93 days prior to release in May and early June. In late June, when juvenile salmon were first encountered in neritic waters, no evidence of infection was observed on juvenile pink and chum salmon, and infection of juvenile sockeye and coho salmon was relatively low. Prevalence increased for juveniles of all four of these species from June to July. Prevalence for juveniles in July was higher in the strait habitat within the archipelago than in the coastal habitat in the Gulf of Alaska.

Juvenile salmon were less infected than adults of the same species, consistent with the observations of Trudel et al. (2003). For adult pink salmon, prevalence was high (>66%), and changed little throughout the summer. Adult pink salmon typically migrate from the Gulf of Alaska into the straits of southeastern Alaska beginning in June; thus, this prevalence probably reflects infection rates on the high seas.

The low initial infection of juvenile pink and chum salmon suggests that the juvenile fish are being infected by larval lice released by ovigerous females lice on returning adult salmon, rather than from lice on resident fish (e.g, chinook salmon overwintering in southeastern Alaska). Pink and chum salmon had been in the marine environment for 60 to 120 d by time of sampling in June, sufficient time for copepod development to visible stages given a source of infection, but no lice were observed on these juveniles. Adult pink and chum salmon return through Icy Strait in June and July in the tens of millions. The higher infestation rates in July in the strait habitat than in coastal habitat may reflect the concentration of copepod-bearing adult salmon as they funnel through these relatively narrow passages from the Gulf of Alaska.

Trudel et al. (2003) found that patterns of sea lice infection for pink and chum salmon juveniles and adults salmon are consistent with the hypothesis that sea lice transmission also occurs in oceanic waters. The wide disparity we observed between prevalence on juvenile pink salmon and adults also supports that hypothesis. The fact that sea lice prevalence either did not increase or declined on juvenile pink, chum, and sockeye salmon from July to August indicates that the prevalence in July was not biased low simply because larvae had not developed to observable size on the high seas, and that continued infection must occur later in the fishes' life history to reach the adult level of prevalence.

Coho salmon juveniles were much more susceptible to infection in neritic waters than juveniles of other species. Coho salmon juveniles had a higher prevalence and intensity of infection than the other species, both overall and all time periods. Prevalence increased for juvenile coho salmon throughout the summer; prevalence peaked in July for the other species of juvenile salmon. These high rates of infection were surprising, as coho salmon juveniles were more resistant to infection by *L. salmonis* under experimental challenge than chinook or Atlantic salmon (Johnson and Albright 1992). Coho salmon juveniles are larger than those of other species; their larger size may increase the probability of encounter with the infectious copepodid stage of the parasite. However, increasing size of other species over the period of sampling did not result in continued increase in infection, and coho salmon juveniles were more infected than larger immature chinook salmon that had been at sea at least a year longer. Another possible explanation is that coho salmon juveniles forage extensively at interface of waters having different salinity, where infectious copepodid larvae have been shown to concentrate (Heuch 1995). Juvenile coho salmon have been shown to be more surface oriented than chinook salmon (Orsi and Wertheimer 1995); sharp salinity gradients are characteristic of surface waters in summer in southeastern Alaska (Orsi et al. 2002).

Higher prevalence on juvenile coho salmon relative to other juvenile salmon also could be an artifact of trawl sampling. Some sea lice may have been dislodged by the net when fish were captured, and small fish, due to their higher surface to volume ratio, may be more susceptible to abrasion and scaling (Nagasawa 1987; Trudel et al. 2003). Some dislodgement of sea lice certainly occurred in our sampling; we observed loose adult lice adhering to the sides of the container into which the trawl had been emptied, indicating that the rates we did observe were biased low. The type of gear used to sample the fish can have a substantial impact on the observed rate of infection by sea lice (Nagasawa 1985). However, several observations validate the species, temporal, and spatial differences in infection we observed. First, low infestation rates were observed in May and June for all gear types used to sample juvenile salmon. Juvenile chum salmon were sampled from netpens with fine mesh dipnets that cause minimal abrasion and scaling. Also, in late June both a townet and a rope trawl were used to sample juvenile salmon. Because the townet is fished at a slower speed and for a shorter duration, it causes less scaling to the fish. However, prevalence of sea lice was low for both trawl types. Second, no consistent difference was seen in prevalence of sea lice relative to temporal differences in size of juvenile salmon. Prevalence of sea lice on pink, chum, and sockeye salmon did increase with size from June to July, but stabilized or declined from July to August at the same time fish size continued to increase. In contrast, prevalence of sea lice on coho salmon juveniles continued to increase temporally with size. Third, prevalence of sea lice was substantially higher for juvenile coho salmon, which ranged in size from 141 to 268 mm, than for immature chinook salmon, which ranged in size from 265 to 545 mm. Finally, the prevalence of sea lice for juvenile pink salmon (3%) and coho salmon (53%) in our trawl samples was very different than those observed in trawl samples by Trudel et al. (2003). These researchers reported overall prevalence of 10% for juvenile pink salmon and 13% for juvenile coho salmon. These results support the conclusions of Trudel et al. (2003) of substantial spatial and temporal variation in infection of juvenile salmon by sea lice.

Direct comparisons between studies of sea lice infection on salmon are complicated not only by possible bias from different sampling gears, but also differences in the stages of sea lice counted. For example, Nagasawa (2001) counted only adult female copepods on salmon captured in oceanic waters, and Johnson et al. (1996) counted copepodid, chalimus, preadult, and adult stages of sea lice on adult sockeye salmon captured in a coastal inlet. For juvenile salmon, Trudel (2002) examined juvenile salmon for chalimus, preadult, and adult stages, as we did in this study, and Trudel et al. (2003) counted preadult and adult stages.

Despite such problems, there are obvious large spatial and temporal differences in sea lice infection among the species of juvenile salmon sampled. Considerably more data are needed to describe these differences, to determine the interannual variation, and to understand the conditions that can result in high and potentially pathogenic infection.

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Table 1. Sampling times and number of trawl hauls fished to sample juvenile salmon in neritic waters in strait and coastal habitats in the northern region of southeastern Alaska, 2003.

			Trawl Hauls	
Sampling Period	Dates Fished	Habitat	Rope Trawl	Tow Net
Early June	June 12-15	Strait	9	6
Late June	June 23-30	Strait	15	4
	June 22	Coastal	2	0
Late July	July 24-30	Strait	17	0
	July 23	Coastal	4	0
Early August	August 8-11	Strait	13	0
Late August	August 21	Strait	4	0
TOTAL			64	10

Table 2. Prevalence of sea lice (5 observed with lice) on juvenile chum salmon reared for 63 to 93 days in seawater netpens in littoral waters in the northern region of southeastern Alaska.

Location	Median Entry Date	Mean Size at Entry (mm)	Release Date	Mean Size at Release (mm)	Number Examined for Lice	Prevalence (% Observed With Lice)
Amalga	March 8	35	May 12	62	899	0
Harbor	March 8	35	May 30	73	900	0
Macauley	March 10	38	May 13	61	600	0
Hatchery	March 10	37	June 2	69	600	0
Thane	March 6	36	May 13	65	595	0
	March 6	35	June 2	81	600	0

Table 3. Number of fish captured, number of fish examined for sea lice, prevalence of sea lice (% fish observed with lice), abundance of lice (lice per fish examined), intensity of infection (lice per infected fish), and range of number of lice per fish on juvenile, immature, and adult Pacific salmon in neritic waters in the northern region of southeastern Alaska, June-August 2003. Juvenile salmon are in their first summer at sea; immature chinook salmon are fish which are in at least their second summer at sea, but will not mature in 2003; adult salmon are fish maturing in 2003.

Species	Captured	Examined	Prevalence (%)	Abundance	Intensity	Range
Juveniles						
Pink	2399	1407	2.9	0.03	1.1	0-2
Chum	1723	1321	4.2	0.05	1.3	0-4
Sockeye	369	367	8.4	0.13	1.5	0-4
Coho	141	141	53.2	1.35	2.6	0-11
Chinook	2	2	0	0	---	0
Immature						
Chinook	28	28	25.0	0.29	1.1	0-2
Adults						
Pink	31	31	71.0	2.87	4.1	0-12
Chum	15	15	33.3	0.53	1.6	0-4
Coho	3	3	100.0	3.67	3.7	1-5

Table 4. Number of juvenile salmon captured, number examined for sea lice, and prevalence of sea lice (% fish observed with lice) from trawl samples in two neritic habitats in the northern region of southeastern Alaska, late July, 2003.

Species	Habitat	Captured	Examined	Prevalence
Pink salmon	Strait	820	717	4.6
	Coastal	450	328	0
Chum Salmon	Strait	527	500	10.4
	Coastal	232	232	0
Sockeye Salmon	Strait	93	93	26.9
	Coastal	44	44	4.5
Coho Salmon	Strait	74	74	52.7
	Coastal	4	4	0

Table 5. Number of fish examined (n) and prevalence (%) of sea lice on juvenile Pacific salmon by time period, June-August 2003, for juvenile salmon collected in strait habitat.

	Late June		Late July		Early August		Late August	
Species	n	%	n	%	n	%	n	%
Pink salmon	179	0	717	4.6	181	4.4	2	0
Chum salmon	432	0	500	10.4	157	1.9	0	--
Sockeye salmon	215	1.9	93	26.9	14	0	1	0
Coho salmon	9	11.1	74	52.7	35	57.1	19	78.9

Table 6. Sample size (n), average size in mm (Avg), and SE (in parentheses) for infected and uninfected juvenile salmon captured in strait habitat in the northern region of southeastern Alaska in 2003, by time period.

	Late June		Late July		Early August		Late August	
Species	n	Avg (SE)	n	Avg (SE)	n	Avg (SE)	n	Avg (SE)
Pink salmon								
Infected	0	--	33	124 (1.8)	8	145 (6.8)	0	--
Uninfected	179	98 (1.0)	684	122 (0.4)	173	133 (1.1)	2	179 (13.5)
Chum salmon								
Infected	0	--	52	122 (1.6)	3	137 (4.6)	0	--
Uninfected	432	115 (0.5)	448	124 (0.7)	154	138 (1.3)	0	--
Sockeye salmon								
Infected	4	106 (10.5)	25	121 (2.0)	0	--	0	--
Uninfected	211	118 (1.1)	68	127 (2.1)	14	145 (5.5)	1	253
Coho salmon								
Infected	1	141	39	202 (3.5)	20	219 (6.0)	15	237 (6.3)
Uninfected	8	178 (6.2)	35	200 (3.1)	15	211 (5.1)	4	223 (9.9)

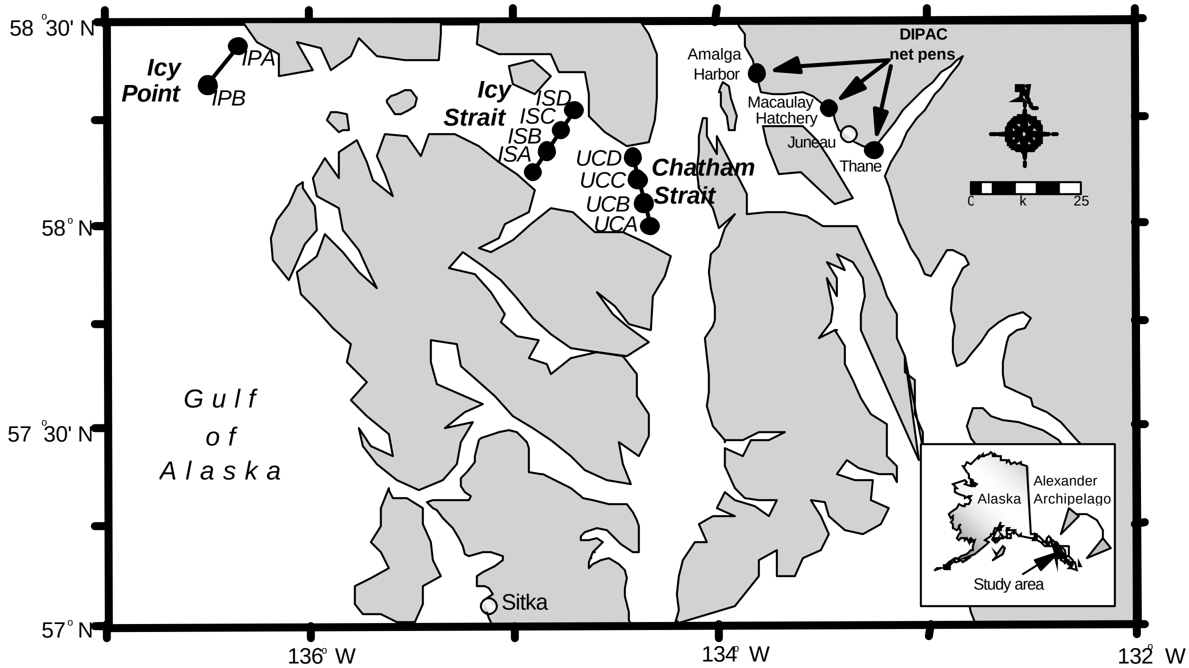

Figure 1. Locations in the northern region of southeastern Alaska sampled for sea lice infection on juvenile salmon. Sampling sites in neritic waters were classified as coastal habitat (IPA, IPB) and strait habitat (UCA, UCB, UCC, UCD, ISA, ISB, ISC, ISD).