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ANNUAL CHANGES IN THE POPULATION SIZE OF THE SALMON LOUSE *LEPEOPHTHEIRUS SALMONIS* (COPEPODA: CALIGIDAE) ON OFFSHORE PACIFIC SALMON (*ONCORHYNCHUS* SPP.) AND RELATIONSHIP TO HOST ABUNDANCE

by

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ABSTRACT

Pacific salmon (*Oncorhynchus* spp.) caught in the central North Pacific Ocean and Bering Sea were examined for the salmon louse, *Lepeophtheirus salmonis*, in the summers of 1991-1994. The total population of *L. salmonis* on all salmonids fluctuated between years, which resulted largely from marked annual changes in abundance of pink salmon (*O. gorbuscha*), a preferred host for *L. salmonis*. Chum salmon (*O. keta*) were stably abundant in the years and supported annually a high population of *L. salmonis*. Chum salmon are considered to be "stable" hosts that can support the copepod population at a high level, but pink salmon to be "unstable" hosts that can only maintain a fluctuating copepod population.

INTRODUCTION

The salmon louse, *Lepeophtheirus salmonis* (Kroyer, 1837), is an important pathogen of farmed salmonids, causing serious problems in countries of northern hemisphere, such as Norway (Brandal and Egidus, 1979), Scotland (Wooten et al., 1982), Ireland (Tully, 1989), Canada (Kent, 1991), and Japan (Nagasawa and Sakamoto, 1993). This species has recently been studied extensively, and such efforts have resulted in much information on its biology and control (see Boxshall and Defaye, 1993). These situations also prompted to study *L. salmonis* on wild salmonids from coastal seas (Nagasawa, 1985; Tully and Whelan, 1993; Tully et al., 1993a, 1993b; Berland 1993), but only scant information is available on its occurrence on salmonids from offshore waters in the ocean (e.g., Templeman, 1967; Boxshall, 1974; Wooten et al., 1982). In offshore waters of the North Pacific Ocean, Nagasawa and his colleagues (Nagasawa, 1987; Nagasawa and Takami, 1993; Nagasawa et al., 1993) first conducted a large-scale survey on the infection of *L. salmonis* on 6 species of Pacific salmon (genus *Oncorhynchus*) and found that pink (*O. gorbuscha*) and chum salmon (*O. keta*), especially pink salmon, are the most important hosts for *L. salmonis*.

No information is yet available on annual fluctuations in *L. salmonis* population on salmonids from offshore oceanic waters. This is partially due to difficulty in conducting salmon research in offshore waters. The Japanese Fisheries Agency has sent the R/V *Wakatake maru* every summer since 1991 to the central North Pacific Ocean and Bering Sea (Fig. 1) for assessing the abundance of Pacific salmon and for studying their biological chracteristics. During her research cruises, Pacific salmon caught were routinaly examined for the infection of *L. salmonis*. Results obtained in 1991 were earlier reported by Nagasawa et al. (1993). The purposes of this paper are to document annual changes in the population size of *L. salmonis* on offshore Pacific salmon in the summers of 1991-1994 and to evaluate their possible causes which are related to host abundance.

MATERIALS AND METHODS

Salmonids were collected with longlines at 21 predetermined sampling stations from 38°30'N to 58°30'N along a transect of 179°30'W from mid-June to mid-July in 1991-1994 (Fig. 1). The R/V *Wakatake maru* operated fishing every evening at each station and then moved to the next northerly station every morning. Although some additional fishings were made both in the Bering Sea in 1991-1994 and south of the Aleutian Islands in 1991, data from those surveys were not analyzed herein and only data from the fishings along the transect of 179°30'W are used in this paper.

Longlines were set approximately 30 min. before sunset and allowed to fish for 60 min. Thirty hachi (unit of longline; one hachi contains 120 m longline and 49 hooks) were used for each operation. Bait was salted Japanese anchovy (*Engraulis japonicus*). A total of 630 hachi was used during each cruise. The longline is known to be preferred gear to precisely assess the infection level of *L. salmonis* on salmonids (Nagasawa, 1985).

Soon after the longlines were hauled aboard, salmonids were removed from hooks, identified and examined for adult female *L. salmonis*. The fork length and body weight of each fish were measured and sex and gonad weight also recorded. One or two scales were removed from the lateral side of each fish for subsequent age determination.

To assess their annual abundances and fluctuation, total numbers of each and all species of Pacific salmon caught were used. These numbers were thought to represent relative salmonid abundances, because the 4-year surveys were conducted at the same sampling locations (21 stations from 38°30'-58°30'N at 179°30'W) by employing the same fishing effort (630 hachi of longlines) during the same season (mid-June to mid-July). Moreover, based on such salmonid catch data, annual total number of *L. salmonis* occurring on each species of Pacific salmon was calculated as abundance of infection × total number of each salmonid caught each year. Finally, total annual population of *L. salmonis* on all salmonids was calculated as combining the total copepod number on each salmonid.

The three terms, prevalence, mean intensity and abundance, follow the definitions of Margolis et al. (1982): prevalence is the percentage of infected fish, mean intensity the mean number of parasites per infected fish, and abundance the mean number of parasites per fish examined. The term infection level is also used to embrace the concepts of prevalence, mean intensity and abundance of infection.

RESULTS AND DISCUSSION

Salmonid species and their abundances in 1991-1994

The following 6 species of Pacific salmon were collected: sockeye salmon(*O. nerka*), chum salmon, pink salmon, coho salmon (*O. kisutch*), chinook salmon (*O. tshawytscha*), and steelhead trout (*O. mykiss*).

Abundance of pink salmon most markedly fluctuated every year (Fig. 2). It was high in the odd-number years but was low in the even-number years. This trend was pronounced in 1991 and 1992 (461 fish for 1991 vs 7 for 1992). Unlike pink salmon, annual abundances of other salmonids were relatively stable (Fig. 2). Chum salmon were the most abundant, followed by coho and chinook salmon and steelhead trout.

Abundance of all salmonid species combined fluctuated between years (Fig. 2). Its trend was similar to that of pink salmon, indicating that total salmonid abundance was strongly affected by abundance of pink salmon.

Infection levels of L. salmonis *on salmonids in 1991-1994*

Highest levels of *L. salmonis* infection were recorded for pink and chinook salmon and steelhead trout (Table 1). These salmonids were followed by coho and chum salmon. The infection level on sockeye salmon was quite low. These results were the same as those previously reported by Nagasawa (1987) and Nagasawa et al. (1993).

There was no marked changes in infection level of *L. salmonis* on each salmonid species between years (Table 1). As has been suggested by Nagasawa (1987) and Nagasawa et al. (1993), these stable different levels of *L. salmonis* infection among salmonid species are considered to be determined by host-related factors, such as differences in host's ocean distribution, duration of ocean residence, swimming speed, swimming layer, and susceptibility to infection.

Population size of L. salmonis *on salmonids in 1991-1994*

Annual changes in population size of *L. salmonis* occurring on each and all species of Pacific salmon are shown in Fig. 3. Total annual population of *L. salmonis* on all salmonids fluctuated markedly between years, but its fluctuation was synchronized largely with annual changes in abundance of both pink salmon and copepods on these salmon. In the years, such as in 1991, when pink salmon were abundant, total annual copepod population was very high, because copepod population on pink salmon was high. However, in the years, such as in 1992, when pink salmon were rare, total annual copepod population remained at a low lev-el. Although total annual copepod population did not decline in 1994 despite low abundance of pink salmon, it was caused by the fact that abundantly caught chum salmon enhanced the copepod populationn for that year. Based on these results, pink salmon are preferred hosts for *L. salmonis* (Nagasawa, 1987; Nagasawa et al., 1992), but their annual importance as hosts for supporting the copepod population is thought to unstable and change between years.

The significance as hosts of chum salmon was different from that of pink salmon. Because annual abundance of chum salmon was stably high, they could constantly support a high population of *L. salmonis* despite of its low infection level on them.

In conclusion, stably abundant chum salmon are considered to be "stable" hosts that can support the *L. salmonis* population at a high level, but pink salmon, whose abundance annually fluctuates greatly, to be "unstable" hosts that can only maintain a fluctuating copepod population.

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Table 1. Occurrence of *Lepeophtheirus salmonis* on six species of Pacific salmon collected along a transect of 179°30'W in June-July from 1991-1994.

Salmonid species	Year	Percent prevalence (infected/examined)	No. of copepods found	Intensity Mean (range)	Abundance
Pink salmon	1991	92.4(426/461)	2,203	5.17(1-21)	4.78
	1992	100 (7/7)	33	4.71(1-7)	4.71
	1993	94.8(147/155)	879	5.98(1-18)	5.67
	1994	93.8(60/64)	278	4.63(1-17)	4.34
	Total	93.2(640/987)	3,393	5.30(1-21)	4.94
Sockeye salmon	1991	2.3(1/44)	1	1.00(1)	0.02
	1992	3.0(1/33)	1	1.00(1)	0.03
	1993	2.6(1/38)	1	1.00(1)	0.03
	1994	10.3(14/135)	15	1.07(1-2)	0.11
	Total	6.8(17/250)	18	1.06(1-2)	0.07
Chum salmon	1991	42.5(233/548)	497	2.13(1-14)	0.91
	1992	39.0(201/515)	418	2.08(1-10)	0.81
	1993	25.5(171/671)	365	2.13(1-13)	0.54
	1994	34.4(261/758)	607	2.33(1-17)	0.80
	Total	34.8(866/2,492)	1,887	2.18(1-17)	0.76
Coho salmon	1991	60.1(110/183)	250	2.27(1-7)	1.37
	1992	62.5(15/24)	26	1.73(1-6)	1.08
	1993	72.2(26/36)	65	2.50(1-6)	1.81
	1994	58.3(21/36)	67	3.19(1-10)	1.86
	Total	61.6(172/279)	408	2.37(1-10)	1.46
Chinook salmon	1991	70.8(17/24)	56	3.29(1-7)	2.33
	1992	56.3(9/16)	49	5.44(1-11)	3.06
	1993	90.9(10/11)	37	3.70(1-6)	3.36
	1994	75.0(9/12)	87	9.67(4-16)	7.25
	Total	71.4(45/63)	229	5.09(1-16)	3.63
Steelhead trout	1991	86.7(13/15)	54	4.15(1-10)	3.60
	1992	100 (8/8)	55	6.88(1-13)	6.88
	1993	100 (6/6)	29	4.83(1-9)	4.83
	1994	100 (14/14)	120	8.57(2-23)	8.57
	Total	95.3(41/43)	258	6.29(1-23)	6.00

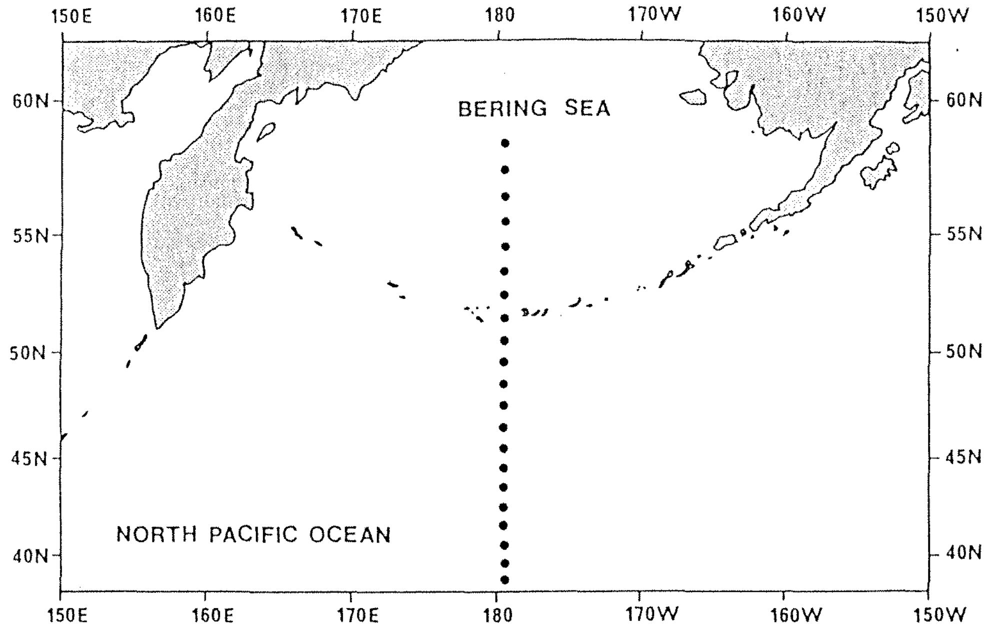

Fig. 1. Locations where Pacific salmon were collected for *Lepeophtheirus salmonis* along a transect of 179°30'W during the cruises of the R/V *Wakatake maru* in June-July from 1991-1994.

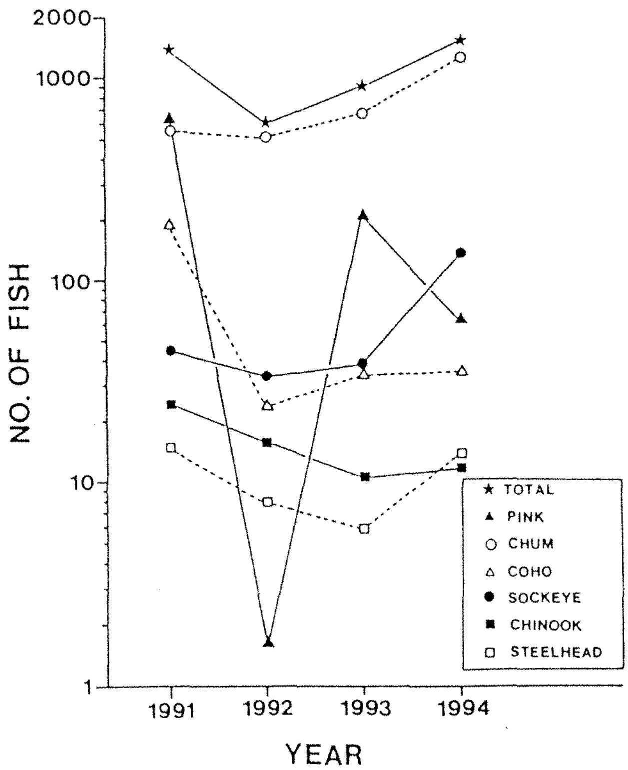

Fig. 2. Annual changes in abundance of six species of Pacific salmon along 179°30'W in June-July from 1991-1994.

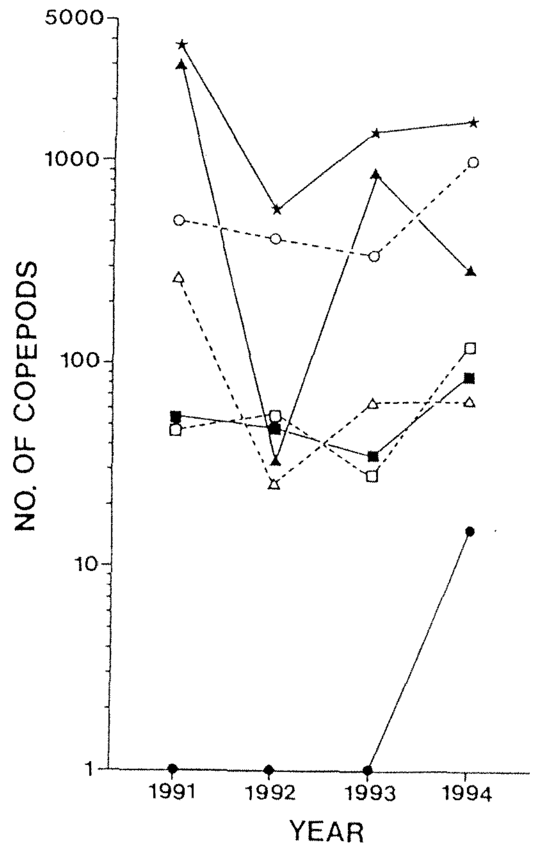

Fig. 3. Annual changes in population of *Lepeophtheirus salmonis* on six species of Pacific salmon along 179°30'W in June-July from 1991-1994. Symbols are as in Fig. 2.