

Prevalence of Visceral Adhesions in Sockeye Salmon, *Oncorhynchus nerka*, in the Central North Pacific Ocean

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A shipboard survey was undertaken to determine the prevalence of visceral adhesions in sockeye salmon, *Oncorhynchus nerka*, in the central North Pacific Ocean in the spring and early summer of 1981-1983. Of 3,935 sockeye from 49 locations examined, 206 (5.2%) were affected. Although no adhesions were observed in fish less than 30 cm in fork length, prevalence increased in medium-sized fish. Visceral adhesions were most common among fish between 35 and 49 cm. In fish above 50 cm, however, the proportion of affected fish decreased with increasing fish size. No adhesions occurred in fish of 65 cm and larger.

A close relationship between prevalence and fish age was noted. Prevalence increased steadily with increasing freshwater age (0-winter, 0%; 1-winter, 4.1%; 2-winter, 6.3%; 3-winter, 11.0%). As to ocean age, prevalence was highest (6.9%) in fish which had spent two winters at sea, but was at a low level in fish of each of other ages (1-winter, 1.4%; 3-winter, 1.2%; 4-winter, 0%).

The percentage of affected fish was higher in males (7.9%) than in females (2.7%). This was stable among years and most fishing locations. Adhesions also occurred most often in immature fish (male, 9.4%; female, 4.2%). With developing fish maturation, prevalence decreased and reached null in both sexes when fish were mature.

Prevalence varied latitudinally, declining from south to north in general. This was reflected by latitudinal changes in the size and maturity compositions of fish. In the areas between 42° and 47°N, most catches consisted of immature medium-sized fish, in which adhesions were often observed. In the areas between 48° and 51°N, however, fish were large and maturing, and adhesions were rarely found in them.

Introduction

Sockeye salmon, *Oncorhynchus nerka* (WALBAUM), are widely distributed in the northern North Pacific Ocean and adjacent seas. They are major objects of coastal and high-seas fisheries and have been heavily exploited. While a volume of information has been accumulated on many aspects of their biology (see FOERSTER, 1968), little is known concerning diseases during their ocean life.

FRENCH (1965) first reported the occurrence of visceral adhesions in Pacific salmon captured on the high seas. He found visceral adhesions most often in sockeye salmon and rarely in chum salmon, *Oncorhynchus keta* (WALBAUM). MARGOLIS (1970)

also mentioned that visceral adhesions occurred in high-seas sockeye salmon.

Visceral adhesions are associated with the infections of a dracunculoid nematode, *Philonema oncorhynchi* KUITUNEN-EKBAUM. This is a parasite of the body cavity of salmonids in the North Pacific region of both American and Asian sides (e.g., KUITUNEN-EKBAUM, 1933; BANGHAM and ADAMS, 1954; AKHMEROV, 1955; MARGOLIS, 1963; KONOVALOV, 1971). Although it is commonly found in high-seas sockeye salmon (MARGOLIS, 1963), it is actually a freshwater parasite using a copepod, *Cyclops bicuspidatus*, as its intermediate host (PLATZER and ADAMS, 1967; KO and ADAMS, 1969). Young sockeye salmon get infected by feeding on *C. bicuspidatus* during their lake residence. The nematode larvae develop slowly in the tissues during the sockeye's ocean life and move from the tissues to the body cavity prior to the host's homeward

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migration. Visceral adhesions are induced by the host reaction associated with this movement. PLATZER and ADAMS (1967) reported that sockeye salmon infected with *P. oncorhynchi* developed visceral adhesions in the laboratory. MARGOLIS (1970, 1982) briefly reviewed the life cycle of *P. oncorhynchi* and visceral adhesions in sockeye salmon.

Under the cooperative program of the International North Pacific Fisheries Commission, Japan, Canada and the United States have conducted research to clarify the distribution, abundance, and continent of origin of Pacific salmon in the North Pacific Ocean and Bering Sea. The RV *Hokushin maru* of the Hokkaido Fisheries Experimental Station has been engaged in such salmon research every year as a member of Japanese research vessels. When I was on board the *Hokushin maru* in the spring and early summer of 1981-1983, I examined the occurrence of sockeye salmon with visceral adhesions in the gillnet catches. This paper deals with the prevalence of visceral adhesions in high-seas sockeye salmon from the central North Pacific Ocean in relation to the size, age, sex and maturity of fish and the fishing location.

Materials and Methods

Sockeye salmon were sampled at 49 locations in the central North Pacific Ocean during the cruises of the RV *Hokushin maru* in July 1981, May and June 1982, and May and June 1983. The fishing locations were distributed over a wide area south of the central Aleutian Islands (Fig. 1). Fish were captured by gillnets, which consisted of two types: non-selective research gillnets which were composed of 10 different mesh sizes from 48 to 157 mm to eliminate the mesh selectivity (TAKAGI, 1975) and commercial gillnets (mesh sizes 112 and 116 mm).

Fish were measured (fork length) and weighed. They were opened, sexed and examined for the presence of visceral adhesions. Gonad weights were recorded and scale samples were also collected for subsequent age determination.

Ages of fish were recorded according to the European formula (KOO, 1962): the numeral preceding a dot (freshwater age) represents the number of winters spent in fresh water after hatching, and the numeral following a dot (ocean age) shows the number of winters spent in the sea. Based on

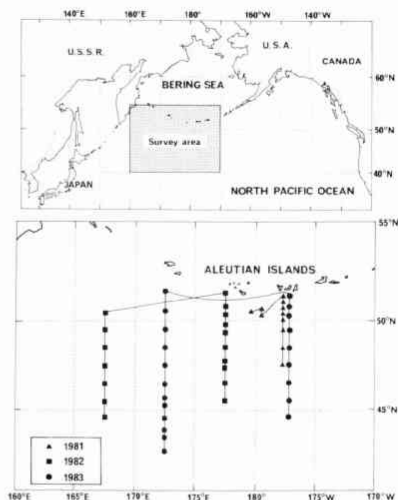


Fig. 1. Cruise tracks of the RV *Hokushin maru* and fishing locations of sockeye salmon examined for visceral adhesions in 1981-1983.

gonad weight data, the maturity of fish was assigned to one of the following four stages: immature, maturing I, maturing II and maturing III. Maturing fish were those fish destined to spawn in the year of catch and immatures were those fish which would have remained in the sea one or more winters if they had not been caught. The differentiation of immature and maturing fish was made using the gonad weight criteria established by TAKAGI (1961) and OSAKO (1973), and new criteria were used for the separation of the three maturing stages. The new criteria were developed by the staff of the Far Seas Fisheries Research Laboratory, Shimizu, Japan.

Results

The gross appearance of visceral adhesions in sockeye salmon was the same as that described by FRENCH (1965). Visceral organs and gonads were tightly bound and compacted to a mass. They were surrounded by a thick connective tissue sheath, which adhered to the peritoneum of the body wall (Fig. 2). There were no external differences between fish with adhesions and normal fish.

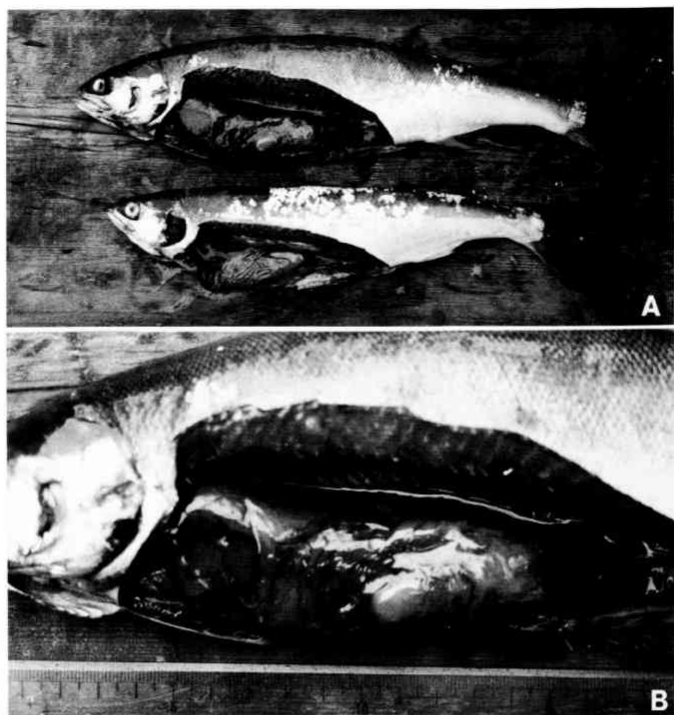


Fig. 2. Visceral adhesions in sockeye salmon. A: Fish with visceral adhesions (top) and normal fish (bottom). B: Visceral organs and gonads are enveloped by a thick connective tissue sheath.

During the period 1981 to 1983, a total of 3,935 sockeye salmon captured in the central North Pacific Ocean were examined and 206 (5.2%) of these were affected with visceral adhesions. The proportion of affected fish was relatively stable among the three years, ranging from 4.0 to 6.9% (Table 1). Diseased fish were distributed throughout the sampling area, as indicated by the fact that visceral adhesions were found at 41 of 49 (83.7%) fishing locations.

There were marked differences in prevalence between sexes of fish (Table 1). Males were more often affected than females. Prevalence in males was also higher than that in females at 35 of 41 (85.4%) locations.

Table 1. Prevalence of visceral adhesions in sockeye salmon in the central North Pacific Ocean, 1981-1983

Year	Male	Female	Total
1981	58/883 (6.6)*	26/817 (3.2)	84/1700 (4.9)
1982	32/545 (5.9)	11/541 (2.0)	43/1086 (4.0)
1983	69/764 (9.0)	10/385 (2.6)	79/1149 (6.9)
Total	159/2192 (7.3)	47/1743 (2.7)	206/3935 (5.2)

* Number with visceral adhesions/number examined (percent).

Table 2. Prevalence of visceral adhesions in sockeye salmon by age in the central North Pacific Ocean, 1981–1983

Age group	1981	1982	1983	Total
0.1**	—	0/1 (0)*	—	0/1 (0)
1.1	1/29 (3.4)	0/17 (0)	0/17 (0)	1/63 (1.6)
2.1	1/10 (10.0)	0/26 (0)	0/25 (0)	1/61 (1.6)
3.1	—	0/2 (0)	0/7 (0)	0/9 (0)
X.1***	0/4 (0)	0/1 (0)	0/6 (0)	0/11 (0)
0.2	0/2 (0)	0/3 (0)	0/1 (0)	0/6 (0)
1.2	45/967 (4.7)	11/182 (6.0)	23/322 (7.1)	79/1471 (5.4)
2.2	21/422 (5.0)	22/194 (11.3)	34/273 (12.5)	77/889 (8.7)
3.2	0/8 (0)	1/7 (14.3)	7/39 (17.9)	8/54 (14.8)
X.2	9/92 (9.8)	1/15 (6.7)	2/28 (7.1)	12/135 (8.9)
0.3	—	0/12 (0)	0/6 (0)	0/18 (0)
1.3	0/33 (0)	2/279 (0.7)	2/195 (1.0)	4/507 (0.8)
2.3	0/32 (0)	3/215 (1.4)	2/121 (1.7)	5/368 (1.4)
3.3	0/2 (0)	2/20 (10.0)	0/6 (0)	2/28 (7.1)
X.3	0/2 (0)	0/28 (0)	1/31 (3.2)	1/61 (1.6)
0.4	—	—	0/1 (0)	0/1 (0)
1.4	—	0/8 (0)	0/9 (0)	0/17 (0)
2.4	—	0/2 (0)	0/2 (0)	0/4 (0)
X.4	—	—	0/1 (0)	0/1 (0)
X.X	6/87 (6.9)	1/71 (1.4)	6/51 (11.8)	13/209 (6.2)
—****	1/10 (10.0)	0/3 (0)	2/8 (25.0)	3/21 (14.3)

* Number with visceral adhesions/number examined (percent).

** Freshwater age precedes a dot, and ocean age follows a dot.

*** Undetermined age is expressed by X.

**** Scales for age determination were not collected.

No adhesions were detected in fish less than 30 cm in fork length. There was a marked increase in the prevalence in medium-sized fish. Visceral adhesions were most common among fish between the lengths of 35 and 49 cm. In fish above 50 cm, however, the percentage of afflicted fish decreased with increasing size of fish. No fish of 65 cm and larger had visceral adhesions (Fig. 3).

Fifteen age groups were recognized during this study. Of these, age 3.2 fish were most frequently affected. Prevalence in this group was highest in 1982 and 1983, although in 1981 no adhesions were found possibly because of the small sample size. The second highest prevalence was observed in age 2.2 fish. Fish of ages 1.2 and 3.3 had also relatively high prevalences (Table 2).

The proportion of affected fish increased sharply with increasing length of stay in fresh water (Fig. 4). Visceral adhesions did not occur in age 0. fish. Prevalences in fish of ages 1. and 2. were 4.1 and 6.3%, respectively, and the rate reached a high of

11.0% in age 3. fish.

On the other hand, the percentage of afflicted fish increased markedly from 1.4% in age .1 fish to 6.9% in age .2 fish. However, prevalence decreased to 1.2% in age .3 fish and adhesions were absent in age .4 fish (Fig. 4).

The occurrence of visceral adhesions was closely related to fish maturity (Fig. 5). Visceral adhesions occurred most frequently in immature fish of both sexes, except for females in 1981. The overall percentages of immature affected males and females during 1981 and 1983 were 9.4 and 4.2%, respectively. In maturing fish, however, there was a sharp decrease in prevalence, which declined with proceeding maturation of fish. In maturing-I fish, the combined prevalence in each sex among the years was 6.7% in males and 1.8% in females. Only three of 502 (0.6%) maturing-II fish had visceral adhesions and no adhesions were observed in 147 maturing-III fish.

Although the proportion of affected fish was high

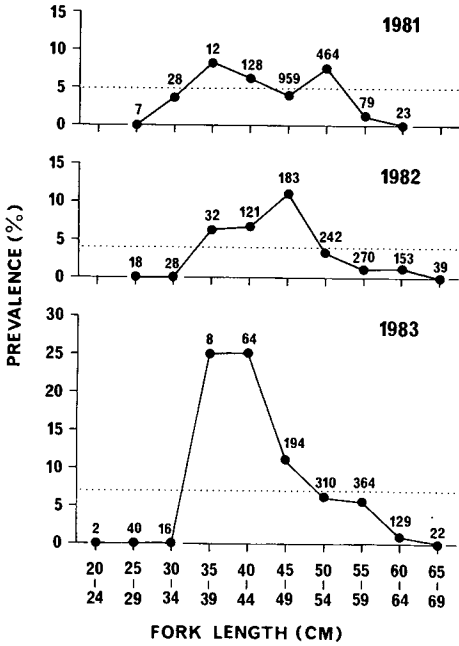


Fig. 3. Prevalence of visceral adhesions in relation to size of sockeye salmon in the central North Pacific Ocean, 1981-1983. Numerals refer to the number of fish. The dotted horizontal line indicates a prevalence level of each year.

between 50° and 51°N along 177°30'W in 1983, prevalence generally decreased from south to north (Fig. 6). This was reflected by latitudinal changes in the size and maturity compositions of fish. Except for 177°30'W in 1981, small- and medium-sized fish predominated between 42° and 47°N. The majority of these fish were immature or maturing I. However, the percentage of large and maturing-II or -III fish increased northward to 51°N (Figs. 7 and 8). Since visceral adhesions occurred most often in immature medium-sized fish, higher prevalences in the southern regions were due to the restricted distribution of such fish in those areas.

Discussion

During the period 1981 to 1983, the prevalence of visceral adhesions in central North Pacific sockeye salmon was relatively stable, ranging from 4.0 to 6.9%. FRENCH (1965) reported that the percentage of affected sockeye captured on the high seas ranged from 0 to 25% between 1957 and 1964 and it increased markedly from 0-2% in 1957-1962 to 9-25% in 1963-1964. He mentioned that the frequency of occurrence of afflicted fish in 1963-1964

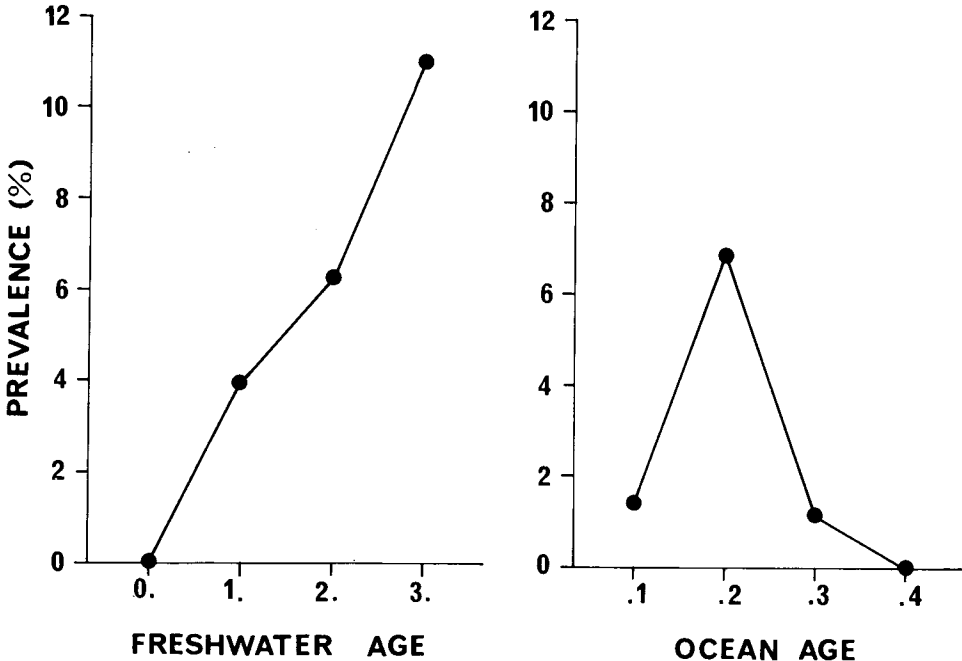


Fig. 4. Prevalence of visceral adhesions in relation to freshwater age (left) and ocean age (right) of sockeye salmon in the central North Pacific Ocean, 1981-1983. Data were taken from Table 2.

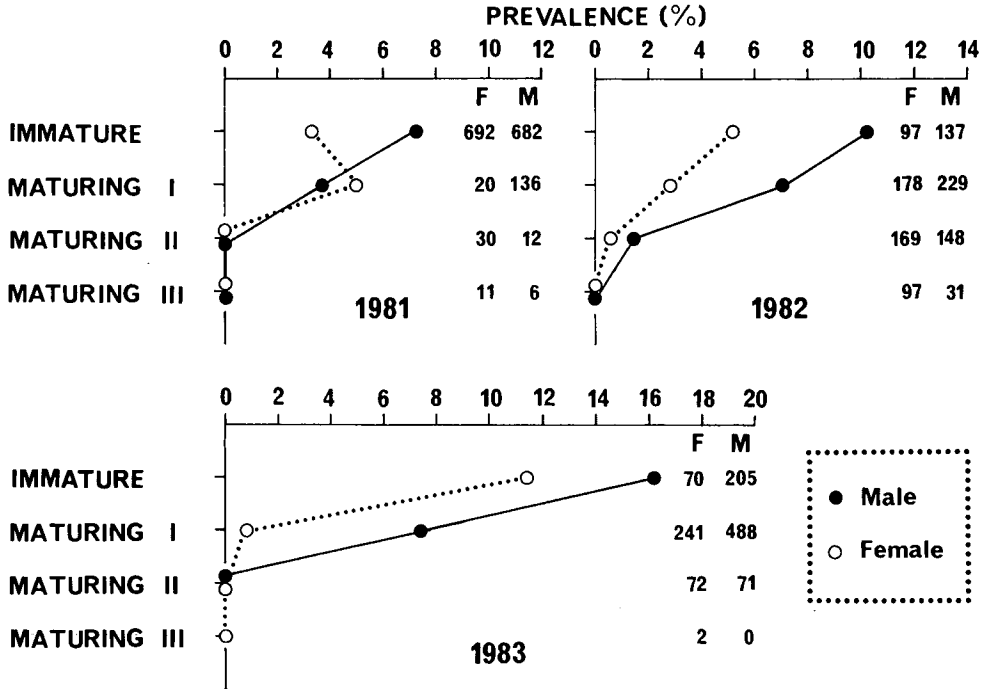


Fig. 5. Prevalence of visceral adhesions in relation to maturity of sockeye salmon in the central North Pacific Ocean, 1981-1983. Numerals refer to the number of fish of each sex (F, female; M, male).

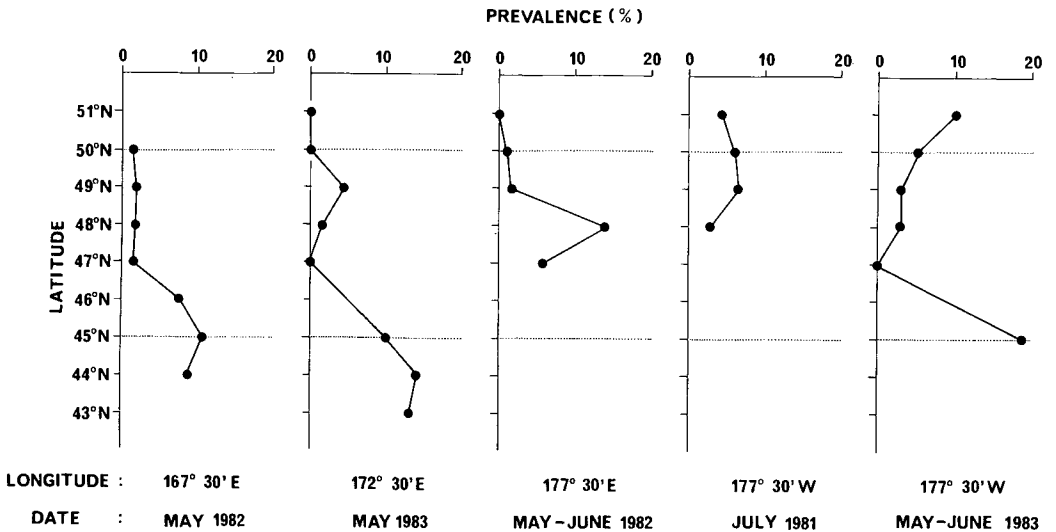


Fig. 6. Latitudinal changes in the prevalence of visceral adhesions in sockeye salmon in the central North Pacific Ocean, 1981-1983. Sample sizes are given in Fig. 7. Samples under 10 were excluded.

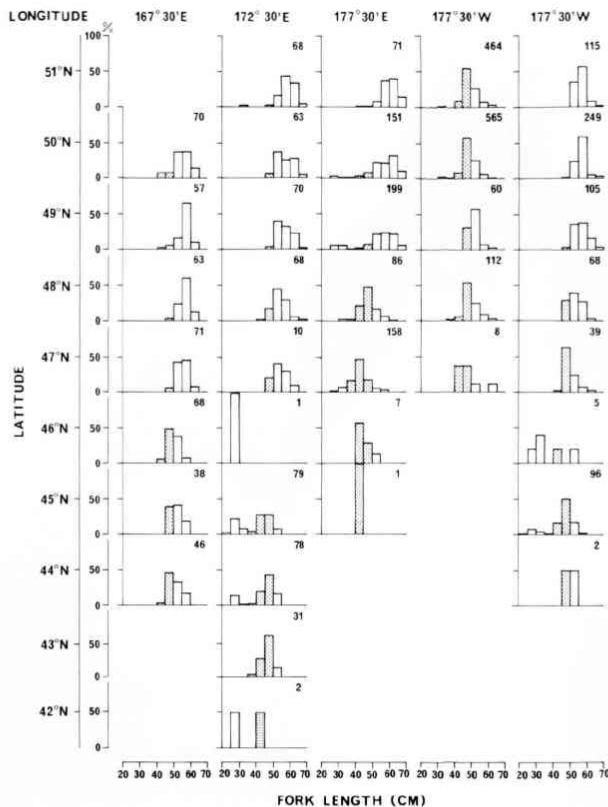


Fig. 7. Latitudinal changes in the size frequency distribution of sockeye salmon in the central North Pacific Ocean. Numerals refer to the number of fish. Stippled areas indicate fish between 35 and 49 cm long.

represented a true increase. This suggests that prevalence fluctuates year by year. The present study, however, revealed that prevalence was closely related to the size, age, sex and maturity of fish. Thus, biological data of samples are needed for an accurate comparison of prevalence levels. In addition, maturity of fish changes with season and size (age) and maturity compositions vary from place to place. Date and location of capture should be considered when prevalence data are compared.

The proportion of affected fish increased with

increasing freshwater life of fish. This is probably because the longer young sockeye salmon stay in the lake, the more heavily they become infected with *Philonema oncorhynchi* through ingestion of its intermediate hosts. As visceral adhesions result from the host reaction associated with the migration of the parasite, the higher prevalence in fish of longer freshwater stay indicates that heavy infections of *P. oncorhynchi* raise marked host reaction.

The occurrence of visceral adhesions was sex-related, with male sockeye having a higher pre-

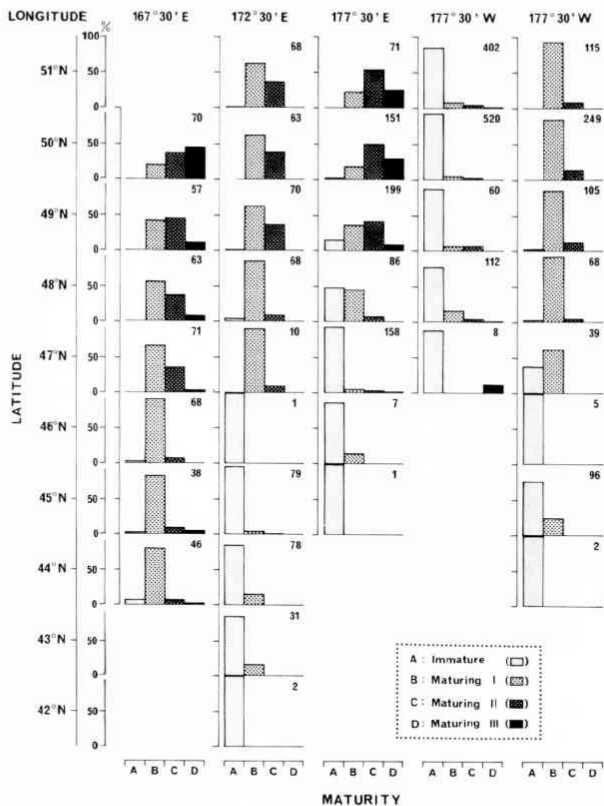


Fig. 8. Latitudinal changes in the maturity composition of sockeye salmon in the central North Pacific Ocean. Numerals refer to the number of fish.

valence than females. Similar observations were made by FRENCH (1965). Since the intake of intermediate hosts of *P. oncorhynchi* seems to be equal between both sexes of fish, there must be no differences in parasite burdens between them. Thus, the disparity in prevalences between sexes suggests that the host reaction to migrating *P. oncorhynchi* is related not only to the intensity of the infection but also to other factors such as host sex hormones. Furthermore, the timing of migration of *P. oncorhynchi* from the tissues to the body cavity may be different between sexes.

The prevalence of visceral adhesions decreased with growth, ocean age, and maturation of sockeye salmon. This phenomenon indicates that visceral adhesions disappear with these processes or affected fish die in the ocean. MARGOLIS (1970) suggested that since visceral adhesions were not found in mature fish, the condition is transitory. PLATZER and ADAMS (1967) made a similar suggestion. MARGOLIS also mentioned that there seems to be no mortality of affected fish. However, whether visceral adhesions cause ocean mortality of sockeye salmon is not known. FRENCH (1965)

mentioned that if salmon with adhesions die before reaching maturity, the adhesions could be a natural mortality factor. Recently, BELL and MARGOLIS (1976) reported that the survival of progeny of sockeye salmon was partially affected by the intensity of infection of female parent with *P. oncorhynchi*. The impact of visceral adhesions on sockeye populations remains still obscure, and further study is needed to clarify the effects of visceral adhesions on sockeye salmon.

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