REPORT ON PARASITE STUDIES OF SOCKEYE AND PINK SALMON COLLECTED IN 1955, WITH SPECIAL REFERENCE TO THE UTILIZATION OF PARASITES AS A MEANS OF DISTINGUISHING BETWEEN ASIATIC AND AMERICAN STOCKS OF SALMON ON THE HIGH SEAS - A PROGRESS REPORT ON WORK BEING CARRIED OUT AS PART OF F.R.B.'S COMMITMENTS TO INPFC

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1. Introduction

In October, 1954, at a meeting of INPFC, Canada agreed to undertake certain research projects on the problems raised by the Protocol. One of these projects involved a systematic study of the parasites of salmon to determine if there are qualitative or quantative differences in the parasite fauna of Asiatic and American stocks, which subsequently could be used to identify these stocks on the high seas.

This report deals with the results obtained from examination of all 1955 sockeye and pink samples available for parasitological studies. The samples of salmon were collected through the co-operation of American, Canadian and Japanese agencies. Most of the samples were frozen as soon as possible after capture and shipped to the Biological Station, Nanaimo, in the frozen state. A few sockeye smolt samples were preserved in formalin.

2. Distribution and number of salmon examined

One thousand, five hundred and nine salmon were examined, comprising 966 sockeyes and 543 pinks. The sockeye total included 476 downstream migrant smolts, 92 marine juveniles and 398 adults. The smolts were taken from 13 localities from Alaska to the Columbia River. All marine juveniles were taken at one locality in British Columbia. The adult sockeyes were taken on the high seas (mainly in the Western Pacific but also in eastern areas) and from 11 North American coastal regions, extending from Attu Island to Bristol Bay, Alaska, and south to the Columbia River. Some of the coastal samples were collected after the fish had re-entered fresh water on their spawning migration and consequently, external parasites of marine origin were lost, with acquisition, in some cases, of external parasites of freshwater origin.

The pink salmon consisted of 100 fry, 94 marine juveniles and 349 adults. The fry were taken from two localities, one each in British Columbia and Alaska. The marine juveniles represented two localities in British Columbia. The adults were captured, with few exceptions, in essentially the same areas as the adult sockeye.

Table I lists in detail the localities from which salmon were examined, the date of capture and the number of fish from each locality.

Figures 1 and 2 show the distribution of the adult samples of sockeyes and pinks, respectively, on charts of the North Pacific origin. Adjacent localities that are encircled were analyzed as one sample. It is seen that the region west of 173° E. longitude is represented by high-seas samples. East of 173° E. there is a large gap in the high seas sampling; sockeye samples are lacking between 173° E. and 165° W. and pinks between 170° E. and 145° W. The coastal samples were taken mainly east of approximately 162° W. (King Cove, Alaska Peninsula), except for one sample each of sockeyes and pinks taken at Attu, which lies at approximately 173° E. Thus, taking into consideration both high seas and coastal samples, there are approximately 22 degrees longitude of unsampled territory in what may well be a critical zone.

The selection of areas for sampling was largely governed by what readily could be made available and the size of sample was largely determined by the number of fish that could be handled effectively in the laboratory in the course of a year. Originally it was planned to examine 50 fish from each selected area but the number was later reduced to 25.

3. Methods of examination for parasites and of identification

The parts of the fish subjected to examination for parasites are as follows:

(1) skin and fins
(2) eyes
(3) gills
(4) muscle
(5) blood
(6) heart
(7) gall bladder
(8) coelomic cavity and surface of viscera and mesenteries
(9) air bladder
(10) alimentary tract

After thawing the fish, the skin and fins were scanned macroscopically, for copepods and monogenetic trematodes. The eyes and gills were then removed and examined microscopically. Blood smears from heart blood were made in an attempt to discover protozoa. However, after about 100 smears, this examination was abandoned because of the inability to obtain satisfactory smears from the thawed fish. Hearts of young fish were examined microscopically. Examination of the hearts of the adults were discontinued early in the work because of the apparent absence of metazoan parasites from this organ. Smears from the gall bladder were examined for protozoa in the early part of the investigation. The apparent absence of protozoa from this organ led to the cessation of its examination. The body cavity and surface of viscera were scrutinized for presence of helminths or protozoan cysts. The alimentary tract was examined in three sections: stomach, plyloric caeca region and posterior intestine. The conten of the digestive tract were examined for helminths only. The air bladder was slit open and examined microscopically. No parasites were found in adult salmon air bladders and this examination was terminated part way through the investigation. The muscle was flaked and observed macroscopically for helminths and protozoan cysts.

With smolts and marine juveniles, all examinations were made directly in petri dishes containing ordinary tap water, saline or isotonic baking soda solution. With the larger fish, the gills, eyes and alimentary tract (the last two organs after being opened) were washed and shaken in 500 to 1,000 cc. of isotonic baking soda solution. The solution was allowed to stand in a graduated glass cylinder until the parasites had settled. The super-natant fluid was then decanted and the sediment examined in petri dishes. All microscopic examinations were carried out with binocular steroscop microscopes using a magnification of from 10X to 40X.

Species separation in most cases was accomplished by examination with the stereoscopic microscope. Identifications were carried out under greater magnification, using a phase contrast microscope with magnifications up to 1200X.

All parasites were fixed in 10% formalin and subsequently transferred through water to 70% ethanol. Trematodes, cestodes and acanthocephalans were stained in carmine and mounted in Canada balsam on glass slides. In some instances, it was necessary to cut microtome sections of termatodes and cestodes for accurate identification. Such sections were stained with haematoxylin and eosin. Nematodes and copepods were cleared in lacto-phenol and examined in temporary mounts in this solution. Protozoa were examined in temporary water mounts on glass slides. With experience came the ability to recognize and identify most species by examination with the low power of the stereoscopic microscope and eliminated to a large extent the necessity of preparing slides for examination with the phase contrast microscope.

The number of each species of parasite encountered and the organs infected in each fish were recorded on punch cards which permitted ready analysis of the data.

4. Parasites encountered

More than 50 parasite species were met with in this survey. The exact number is held in doubt because of the occurrence, on the one hand, of more than one species of certain genera along with specifically unidentifiable specimens of the same genera,and because of the occurrence of larval stages which possibly belong to more than one species of the same genus. As is usually the case in surveys of the present type, specimens were encountered which could not be identified either because of their poor condition or because they were immature, and hence did not present sufficient morphological characters for specific or even generic determination.

Forty-five species were identified, at least generically, of which 2 were monogenetic trematodes, 14 were digenetic trematodes, 9 were cestodes, 6 were acanthocephalans, 9 were nematodes, 4 were copepods and 1 was a protozoan. Forty-two species were parasitic in sockeye, of which 16 were acquired in fresh water, 24 were acquired in the sea and the origin of 2 species is unknown. Of the known freshwater-acquired species in sockeyes, 3 were found to persist throughout the life of the fish. A fourth species, found in sockeye adults, was undoubtedly acquired in fresh water, although it was not found in any of the sockeye smolts examined. Pinks harboured 27 species, of which 1 was probably acquired in fresh water, 25 were acquired in the sea and 1 is of unknown origin.

Tables II to VI give the incidence and intensity, by area, of most of the species encountered in sockeye smolts, sockeye juveniles, sockeye adults, pink juveniles and pink adults, respectively. The incidence is recorded as the percentage of infected individual salmon in the sample examined and the intensity is given as the average number of worms per infected fish. The latter value is the number in parentheses. Pink fry were free of parasites.

A briefly annotated list of all the parasites follows:

TREMATODA (MONOGENEA)

Gyrodactylodies strelkowi: A small trematode parasitizing the gills of sockeyes and pinks in marine waters. It is lost immediately upon return of the salmon to fresh water. It was found in varying abundance in both eastern and western waters.

Tetraonchus alaskensis: A freshwater species, parasitic on the gills of sockeye smolts. It was found only once at Lake Aleknagik, Alaska.

TREMATODA (DIGENEA)

Bucephaloides sp.: A gasterostome, not yet specifically identified, of marine origin, found in the intestines of pinks only. It was confined almost entirely to eastern waters.

Bacciger sp.: An uncommon marine parasite of the intestines of sockeys and pinks. Only immature specimens were taken from sockeyes at Egegik, Bristol Bay and 2 mature individuals were recovered from a pink captured in Pavlov or Volcano Bay, Alaska Peninsula. This species closely resembles Bacciger harengulae but may be a distinct and as yet undescribed species.

Podocotyle shawi: A fiarly large trematode, apparently of marine origin, found only in sockeyes from the Columbia River where it occurred in about 50% of the fish examined.

Diplostomulum sp.: A larval fluke, of freshwater origin, found in the eyes of sockeyes. It probably matures in piscivorous birds. Although having a freshwater life cycle, the parasite apparently remains in sockeyes throughout the life of the fish, since it has been found in sockeyes while still at sea but on their spawning migration. Infection of fish by this parasite is by direct penetration by the infective larvae (cercariae) and therefore, spawning sockeyes are susceptible to reinfection upon entering fresh water. The parasite was found in adult sockeyes in eastern and western areas, with an apparent greater abundance in certain Alaskan localities. In smolts, it occurred irregularly and with varying abundance from the Columbia River to Alaska.

Tetracotyle sp.: A larval fluke belonging to the same group as Diplostomulum and with the same type of life history. It was found encysted usually in the pericardium, but also in visceral mesenteries of sockeye smolts. Its distribution was sporadic from the Fraser River to Alaska.

Hemiurus levinseni: A stomach fluke of marine sockeyes and pinks. In sockeyes it was almost entirely restricted to western areas. In pinks it was widely distributed with a generally lower incidence in Alaskan waters.

Parahemiurus sp.: This species, also of marine origin, appears to be P. achnoviae. It was recovered mainly from the stomachs of pinks in which it was restricted to coastal samples from northern British Columbia to Puget Sound. It was found once in a Fraser River sockeye.

Brachyphallus crenatus: Another stomach fluke of marine sockeyes and pinks which was found in almost all samples, with greatest abundance at Kodiak Island and other Alaska areas. There was a general trend in the coastal areas, particularly in sockeyes, for the incidence and intensity to decrease progressively from Alaska southward. At the Fraser River the parasite was absent.

Tubulovesicula lindbergi: A marine stomach fluke found in pinks and sockeyes only in eastern waters. It was more abundant in pinks, where it exhibited a progressive increase in incidence from Alaska to Puget Sound.

Lecithaster gibbosus: An intestinal fluke with a marine life cycle, found in pinks and sockeyes. It appeared to be more abundant in eastern than western samples with the greatest intensity in coastal samples.

Genolinea oncorhynchi: Only two specimens of this marine stomach fluke were recovered from a juvenile pink salmon from northern British Columbia. It has been described recently as a new species.

Derogenes varicus: A stomach fluke of marine sockeyes and pinks. In pinks it was absent from western areas and present in many of the eastern areas.

Aponurus: Another stomach trematode of marine sockeyes. It was not encountered in pinks. In sockeyes, it was found occasionally in eastern and western areas. The specimens apparently belong to an undescribed species.

Syncoelium katuwo: This trematode was found on the gills of marine pinks in many localities from the Okhotsk Sea to Puget Sound. It was found once on a sockeye from 48° N., 177° W. The small sample of sockeyes from this area does not appear in the analyses because of the poor condition of the fish. The viscera were in an advanced state of decomposition so as to render very doubtful the validity of the results of their examination.

CESTODA

Diphyllobothrium spp.: At least 2 species, both larval forms, of this genus were discovered. The commonest form was encysted on the serosa of the stomach or pyloric caeca of sockeyes mainly. It was also found once in a juvenile marine pink from Alert Bay, British Columbia, and in an adult pink from the Gulf of Alaska. The parasite in sockeyes was commonly found in smolts and marine adults. The life cycle takes place in fresh water with the definitive host being a bird or mammal and the first intermediate host a copepod. The larvae are acquired in fresh water and retained through the life of the salmon. On Kodiak Island the final host is the black bear and here the parasite has been named D. ursi. It is unknown if all Diphyllobothrium larvae from cysts on the stomach or pyloric caeca of salmon belong to this species. Diphyllobothrium larvae in stomach or pyloric caeca cysts were found in varying abundance in smolts from the Columbia River to Alaska. They were most abundant on Kodiak Island. In adult sockeyes they were found in many localities from the Okhotsk Sea to the Columbia River, but absent from some areas. Again, the maximum abundance was at Kodiak Island. Although there was no distinction in degree of infection between eastern and western stocks of sockeyes, there were pronounced local differences.

Another larval form of Diphyllobothrium, in the flesh of marine sockeyes and pinks, was encountered rarely. It is unknown whether this is a marine or freshwater-acquired parasite. It was encountered in a sockeye and in a pink from the Gulf of Alaska and in a pink from southeast Alaska.

Triaenophorus crassus: This larval cestode was common in the flesh of sockeye smolts from Lake Aleknagik, Alaska. Its first intermediate host is a copepod and the final host probably the pike.

Eubothrium salvelini: Found in the pyloric caeca of a few sockeye smolts in Babine Lake, British Columbia and Brooks River, Alaska.

Eubothrium (?)oncorhynchi: Immature specimens of Eubothrium, that may be E. oncorhynchi, were frequently seen in the pyloric caeca and intestines of marine pinks from eastern waters and rare in pinks from western waters. The species was recovered from one sockeye in Bristol Bay and from one sockeye near King Cove, Alaska Peninsula.

Eubothrium sp.: Immature specimens, that may be E. salvelini, were occasionally recovered from the intestines or pyloric caeca of smolts taken in British Columbia and Washington State.

Diplocotyle sp.: This species is probably D. olriki and was found in the intestines of adult sockeyes and pinks only at Attu Island. It was commoner in pinks.

Phyllobothrium caudatum: A post-larval cestode which was common in the intestines of all samples of marine adult sockeyes and pinks. The level of infection was considerably higher in pinks. The natural definitive host is probably an elasmobranch.

Nybelini surmenicola: A post-larval cestode, with a marine life cycle, occasionally found in cysts in the stomach wall of sockeyes and pinks. In sockeyes, it was noted twice at Kodiak and once at the Skeena River. In pinks, it was discovered at King Cove, Alaska Peninsula, Central British Columbia and Puget Sound. The definitive host is an elasmobranch.

Proteocephalus spp.: Larval or post-larval stages of this freshwater cestode genus were found in the intestines or pyloric caeca of smolts from many localities from the Columbia River to Alaska. Adults of P. salmonicida were taken from smolts collected at Wenatchee Lake on the Columbia River and which had been kept at a hatchery for about 3 months. An unidentified adult was taken from a smolt in Redfish Lake, Idaho (Columbia River system). Larval forms were also taken from several early-marine-stage sockeyes from British Columbia. The abundance of this genus in sockeye smolts and its absence from adults attests to its inability to survive for any length of time after the sockeyes enter the sea. The larval or post-larval individuals cannot be specifically identified.

ACANTHOCEPHALA

Bolbosoma sp.: A post-larval acanthocephalan of marine origin, found commonly in the intestines of pinks and sockeyes. In pinks, the incidence is considerably higher in western than eastern areas and, in the eastern areas, there is a progressive decrease in incidence from Alaska to Puget Sound. In the Fraser River and Puget Sound samples, the parasite was absent. The definitive host is a marine mammal.

Corynosoma strumosum: One post-larval specimen of this species was found in a visceral cyst in a pink from Kodiak Island. The definitive hosts are pinnipeds.

Corynosoma villosum: Two post-larval specimens were taken from visceral cysts in a pink from near King Cove, Alaska Peninsula. The definitive hosts are pinnipeds.

Corynosoma spp.: Post-larval specimens were collected in small numbers from visceral cysts in sockeyes and pinks from several scattered localities. The definitive hosts are pinnipeds. Specific identity of these post-larvae was not possible because the proboscis was retracted.

Nipporhynchus sp.: The condition of the specimens did not permit specific identification. An uncommon parasite, they were located in the intestines or stomachs of several marine pinks and sockeyes taken from 3 localities.

Echinorhynchus gadi: A marine species found in the intestines of sockeyes and pinks, more frequently in the latter. In both species of salmon the parasite was most abundant in far western areas.

Neoechinorhynchus rutili: An intestinal parasite of sockeye smolts. It was very abundant in Cultus Lake, British Columbia and also occurred in small numbers in several localities from Washington State to Alaska.

NEMATODA

Anisakis sp. (spp.): Larval nematodes of this genus were found in almost all adult sockeyes examined and in a very large proportion of the adult pinks. The nematodes were found encysted in the muscles, in the mesenteries, on the surface of the viscera and on the peritoneum. They were considerably more abundant in sockeyes than pinks. This is attributed largely to the longer time spent at sea by sockeyes. Anisakis larvae, once acquired, are permanent parasites, i.e., they are cumulative. Larval Anisakis do not present sufficient morphological characters for specific identification. The definitive host(s) of these larvae would be marine mammals and/or piscivorous birds.

Terranova (or Porrocaecum) sp.: These larval nematodes are very closely related to Anisakis and were found sparingly in the deep muscles of several sockeyes and pinks from several Alaskan areas. They are probably the larvae of Terranova (formerly Porrocaecum) decipiens, an extremely common stomach worm of pinnipeds.

Contracaecum spp.: Nematodes of this genus were common in marine pinks and sockeyes from all areas sampled. One specimen, possibly the larval stage of C. spiculigerum, was taken from the body cavity of a sockeye smolt from Lake Aleknagik, Alaska. The specimens from marine pinks and sockeyes include adults, sub-adults and larval stages and probably represent more than one species. In adult pinks, the incidence of Contracaecum was considerably higher in eastern than western areas.

Ascarophis skrjabini: A marine nematode found in the stomachs and intestines of pinks from several eastern and western areas. Only one specimen was taken from a sockeye in the Sea of Okhotsk.

Dacnitis truttae: Found in the intestines of 2 sockeyes from the Sea of Okhotsk and in 1 sockeye from western high seas. This parasite is basically a freshwater species indicating that the sockeye had retained it since the smolt stage.

(?)Rhabdachona sp.: Specimens, in poor condition, were recovered from the intestines of 4 sockeye smolts from Baker River, Washington. The identification is tentative.

Capillaria sp.: Three sockeye smolts from Kodiak yielded a total of 4 females of this genus from the intestines. The lack of males prevents positive species identification.

Philonema oncorhynchi: A very common nematode in the body cavity of adult sockeyes, it was also noted in some sockeye smolts, particularly at Babine Lake (Skeena River), British Columbia. This parasite apparently has a freshwater life cycle. The apparent lesser abundance in seaward migrant smolts is possibly due to the inability, by the methods employed, to detect or recognize early stages in its development.

Nematode larva: A tiny nematode larva, located in the mesenteries and particularly in the wall of the swim bladder, was very abundant in sockeye smolts from many localities in North America, but was entirely absent from several areas. These latter areas are identical with areas of extremely low incidence of Philonema in adult sockeyes, suggesting that these larvae possibly are young stages of Philonema. Furthermore, areas in which smolt samples showed 100% incidence with larvae also displayed close to 100% incidence of Philonema in adults. It is also remarkable that the intensity of infection with nematode larvae in smolts closely parallelled the intensity of adult infection with Philonema. However, there is no morphological or life history evidence to connect the nematode larvae with Philonema.

COPEPODA

Salmincola falculata: This freshwater copepod was found attached to the gills or external surfaces of several sockeye smolts from 2 localities in British Columbia and also on the gills of several returning sockeye spawners from Babine Lake, British Columbia and Kodiak Island. The parasite is lost upon entry of the smolt into salt water.

Ergasilus (2 species): Specimens of one species were abundant on the gills of Karluk (Kodiak Island) sockeye smolts and a second species was common on the gills of Okanagan River smolts. Both species are possibly new to science. A macerated specimen was taken from a smolt at Lake Aleknagik, Alaska. Migration into the sea frees the smolts of these copepods.

Lepeoptheirus salmonis: An external skin parasite of marine sockeyes and pinks, appearing to be more abundant on pinks than sockeyes. This copepod is lost shortly after the salmon return to fresh water.

MOLLUSCA

Mussel glochidia: These larval molluscs were found on the gills of a small number of sockeye smolts from Lakelse and Babine Lakes, British Columbia (Skeena River system). No attempt was made to identify the species.

PROTOZOA

Henneguya salminicola: Cysts containing many hundreds of spores of this myxosporidian were seen in the muscle of one sockeye from Copper River, Alaska and in 4 sockeyes from the Gulf of Alaska. It is unknown whether this parasite is acquired in marine or fresh water.

In addition to the above list of parasites, a miscellaneous group of approximately 15 species, generically unidentifiable, but which could be recognized as not belonging to any of the identified species, were also recovered. These were species of rare occurrence and are briefly discussed in the following paragraph.

Nine or ten identified trematodes are included in the miscellaneous collection. Three or four species, of which 2 resemble Genolinea and 1 resembles Bacciger, were recovered from marine juvenile pinks in British Columbia. Immature specimens of a member of the Lepocreadiidae were common in the intestines of sockeyes from King Cove, Alaska Peninsula, and one was also seen in a pink from Cook Inlet. Unidentified encysted and unencysted metacercariae of unknown affinities were frequently encountered in the intestinal washings of adult sockeyes from Lake Corries and Lake Nicholas, Attu Island. A specimen, possibly belonging to Genarchopsis, was observed in the stomach of a sockeye from Cook Inlet. Two trematodes of the family Allocreadiidae (possibly Podocotyle) were collected from the intestine of a sockeye from Larsen Bay, Kodiak Island. An immature fluke, apparently identical with Distoma meischeri (a trematode of unknown systematic affinities) was found on the gills of a sockeye from the Sea of Okhotsk. Another immature digenetic trematode of unknown systematic position was located on the gills of a sockeye from the Skeena River. Unidentified cestodes are represented by larvae of 3 or 4 species. In the intestines of several marine juvenile sockeyes and pinks from Alert Bay, British Columbia, were found organisms that resemble young Pseudophyllidean plerocercoid larvae. The presence of these larvae are probably the result of accidental infection by ingestion of infected zooplankton.

Inverted larval cestode scoleces bearing a single row of large hooks were represented by two individuals. One, with 8 hooks, was found in the intestinal washings of a sockeye smolt from Baker River, Washington, and the other, with 12 hooks, was recovered from the gill washings of an adult sockeye from the far western Pacific. The affinities of these larvae are unknown. Unidentified nematodes are represented by several specimens taken from the stomach and intestines of 4 sockeye smolts from Redfish Lake Creek, Idaho. Unidentified copepods are represented by at least 2 species. Two specimens of one species were noted on the gills of a pink from the Gulf of Alaska and specimens of the family Caligidae were noted on the gills of several adult sockeyes from Bristol Bay, the Sea of Okhotsk, the Fraser River and the Skeena River. Two specimens of Caligidae were also taken from the gills of a pink in Puget Sound.

5. Prospects of using parasites to distinguish between Asiatic and North American salmon

Investigating the possibilities of distinguishing Asiatic from North American salmon stocks by means of parasite differences is in effect a search for a natural tag. The ideal type of parasite to fulfill the role of a natural tag is one that is acquired in fresh water, retained throughout the marine life of the salmon and brought back to fresh water in the spawning fish. Although 4 species were found in sockeyes that appear to have this type of life history, unfortunately their distribution was either too sporadic or too common on both eastern and western sides of the Pacific to be of value in distinguishing Asiatic from American populations of salmon. However, as discussed in the next section, these parasites, as well as others, seem to have possibilities in separating "local" stocks.

Because of the absence of suitable parasites of freshwater origin, attention was focused on the geographical distribution of the marine-acquired parasites. If a line or zone could be found, to the east of which stocks of high seas and coastal salmon had certain parasite characteristics which differed from those of salmon taken to the west of a such line or zone, then it seems reasonable to assume that such parasite characteristics would serve to distinguish between salmon stocks originating from the two continents.

The analysis of the 1955 data suggests that certain parasites may be used to distinguish between eastern and western salmon stocks. With full realization of the limited information at hand, we nevertheless are presenting the evidence to demonstrate the possibilities of the parasite method of approach to the problem of distinguishing stocks of salmon. Some of the limitations are the lack of adequate samples from the high seas, the complete lack of coastal samples from Asia, the comparatively small number of fish examined, the fact that only one year's data are available, the lack of samples from all seasons of the year and the absence of knowledge of the longevity of the marine-acquired parasites.

In sockeye, 4 parasites have been found and in pinks 8 parasites have been found that show differences to a greater or lesser degree, between eastern and western stocks. These are discussed individually.

Sockeye Salmon

(1) The trematode Hemiurus levinseni was present, in 21% to 56% of the 5 samples taken from Attu Island to the Sea of Okhotsk, with an average of 2 to 4 worms per infected fish. Of the 12 areas from the Alaska Peninsula to the Columbia River, the parasite was found but once in each of 3 localities. This parasite thus indicates a much greater abundance in western waters. The distribution of this parasite is shown in Table IV and graphically in Figure 3. In all figures the incidence of occurrence (in percentage of the sample infected) is plotted by area in the form of histograms.

(2) The trematode Tubulovesicula lindbergi was present in small numbers in 8 of 12 samples from eastern waters and entirely absent from 5 samples from Attu to the Sea of Okhotsk. The presence of this parasite seems to indicate stocks of eastern origin. Table IV and Figure 3 show the distribution and abundance of this fluke.

(3) The trematode Lecithaster gibbosus was much more abundant in the samples from Attu eastward than in the samples to the west of Attu, as shown in Table IV and Figure 3. In 3 of the 4 western samples the incidence was less than 10%, with 1 parasite per infected fish and, in the Sea of Okhotsk, it was 40%, with 3 parasites per infected fish. Of the 13 areas from Attu to the east, the parasite was present in 12, with an incidence of 25% to 100% and an average intensity of 8 to 198 individuals per infected fish. In the sample from Copper River, Alaska, in which Lecithaster was absent, the viscera had undergone considerable decomposition, apparently before freezing. What few parasite species were found in these sockeyes also displayed evidence of considerable degeneration. It seems likely that delicate parasites, such as Lecithaster, were decomposed beyond recognition as flukes. The value of this sample is thus very doubtful. Also in the Columbia River sample, the stomachs and part of the pyloric caeca and intestine had been cut before the fish were available for parasite studies, with the possibility that parasites had been lost from the digestive tract. In examining the distribution of Lecithaster in eastern areas it is noted that in the coastal areas, except for the Columbia River and Copper River samples, the incidence is from 68% to 100%. In 2 offshore areas, the incidence was 35% and 50%, which is similar to the 40% incidence observed in the Sea of Okhotsk. However, the average intensity in the eastern offshore areas was 59 and 9 parasites per infected fish compared to 3 in the Sea of Okhotsk. The possibility that the apparent east-west differences in Lecithaster abundance are actually a reflection of offshore-onshore differences in parasitism cannot be overlooked.

(4) Echinorhynchus gadi, an acanthocephalan, was very common in the Sea of Okhotsk and the most westerly of the Pacific high-seas samples. In the central Japanese commercial fishing area and at Attu this species was observed but once. It was absent from the most easterly area fished by the Japanese fleet in 1955 and from 10 of the 12 areas east of the Alaskan Peninsula. It was a rare parasite in the adjacent areas of southeast Alaska and the Skeena River, B.C. The value of this parasite in distinguishing eastern and western sockeye stocks is not clear, but it was extremely characteristic of far western samples. Table IV and Figure 3 give details of distribution and abundance of this worm.

Pinks

(1) The acanthocephalan Bolbosoma occurred in 72% to 92% of the pinks from the 5 areas from Attu to the Sea of Okhotsk, with an average of 5 to 21 worms per infected fish. From the Alaska Peninsula eastward and southward, the incidence decreased progressively from 52% to complete absence at the Fraser River and in Puget Sound. The average number of worms per infected fish in the eastern areas was from 1 to 3. It is thus apparent that Bolbosoma was considerably more abundant in the areas from Attu to the west than in the eastern areas. Table VI and Figure 4 show the distribution, incidence and intensity (in the table only) of Bolbosoma in pinks.

(2) The nematode Contracaecum showed a distribution completely the reverse to that of Bolbosoma. In all areas from Attu to the east the incidence lay between 72% and 100%. West of Attu the incidence decreased progressively from 48% to 8% in the Sea of Okhotsk. Abundance of Contracaecum was associated with eastern stocks. The trends in distribution are shown in Table VI and Figure 4.

(3) Echinorhynchus gadi displayed a high abundance in the three most westerly areas, where it occurred in 56% to 92% of the samples, with an average intensity of 3 to 5 worms in the infected group. From Attu east, the parasite was absent in 7 of 10 areas but the incidence was less than 20%, except in Southeast Alaska where it was 32%. The average intensity in the eastern areas was 1 to 3 worms in the infected groups. The absence of Echinorhynchus from the area between 168° E.- 170° E. does not fall in line with the use of this parasite as a means of distinguishing eastern and western stocks of pinks. However, the high incidence in the 3 most westerly areas seems to be of significance. Table VI and Figure 4 show the distribution of Echinorhynchus.

(4) The trematode Bucephaloides appears to be essentially a parasite of eastern stocks of pinks, as shown in Table VI and Figure 4. It was found only in 2 fish of the 5 samples from Attu to the Sea of Okhotsk. Of the 9 samples from the Alaska Peninsula eastward, 8 areas, including the offshore area of the Gulf of Alaska, were positive for Bucephaloides. In 7 of the areas it was present in more than 10% of the sample (12% to 52%), but in the Fraser River sample it occurred only in 4%.

(5) Tubulovesicula lindbergi, a trematode, also appears to be characteristic of eastern stocks. It was not found in the samples from Attu to the Sea of Okhotsk, but was recovered from 8 of the 9 areas, including the offshore sample in the Gulf of Alaska, in per cent incidence varying from 4 to 92. There was a progressive increase eastward and south from the Alaska Peninsula. The distribution is shown in Table VI and Figure 5.

(6) The trematode Lecithaster gibbosus was also much more abundant in eastern than western samples. From Attu eastward, 92% to 100% of the samples were infected, except in the Gulf of Alaska where only 40% were infected. The average number of worms per fish in the coastal areas varied from 42 to more than 1,000, whereas that in the Gulf of Alaska was only 5. Of the 4 areas west of Attu, the parasite was present in only 2, with incidences of 28% and 36% and average intensities of 1 and 6 worms per

infected fish. The similarity in abundance of Lecithaster in the Gulf of Alaska and the 2 western offshore areas, and the immense difference between the Gulf of Alaska and eastern coastal samples suggest that the observed east-west differences are in reality a reflection of onshore-offshore differences. Further data is required to clarify the picture. Table VI and Figure 5 show the distribution of Lecithaster.

(7) The trematode Derogenes varicus was absent from the 5 samples from Attu westward and was found in 6 of the 9 eastern samples. The incidence, as shown in Table VI and Figure 5, varied from 8% to 21%. Since the parasite was absent from the one offshore eastern area from which pinks were available, Derogenes may also reflect onshore-offshore differences rather than an east-west difference.

(8) The cestode Eubothrium was very abundant in eastern areas and found only in small numbers in 2 of the 4 areas west of Attu. However, the Gulf of Alaska offshore sample displayed an abundance of Eubothrium only slightly higher than that in the 2 western areas. Again Eubothrium may be reflecting offshore-onshore differences rather than east-west differences.

Of the parasites that were selected as possibly possessing value in distinction of salmon stocks, some indicated that Attu salmon are similar to samples to the west, whereas others indicated that Attu fish were similar to eastern samples. It is possible that this picture is evidence that the separation of eastern and western stocks is in the neighbourhood of 175°E. On the other hand, it may be that Attu salmon should be considered in an analysis of Bering Sea catches, rather than with those south of the Aleutians. There is insufficient data at the present time to permit any definite conclusions.

Since all of the parasites discussed are acquired by salmon through an intermediate host, the prevalence of a given parasite will depend on the abundance of the intermediate hosts and the selection of these organisms as food items by the salmon. Also, the abundance of those parasites in salmon which are still in a larval stage will depend on the abundance of the final host in the areas inhabited by salmon. Thus the incidence and intensity of infection with Bolbosoma, which uses a cetacean or pinniped as a definitive host, will depend on the abundance of the proper species (1 or more) of the latter group of animals. Because of the dependence on the presence of certain other animals (plankton or otherwise) for the acquisition of parasites by salmon, any ecological factors which affect the distribution of these animals will affect the abundance of the parasites which they transmit to salmon. Since oceanographic conditions are not uniform throughout the North Pacific area, it is not surprising to find differences in abundance of salmon parasites in different areas.

6. Separation of "local" stocks by parasites

There are a number of species of parasites that apparently may be useful in separating "local" stocks although they did not present data of value in distinguishing Asiatic from North American stocks generally. It also seems possible that some populations of seaward migrant sockeyes in a large river can be identified with the spawning localities from which they came.

The latter possibility will be discussed first. Examination of Table I shows that from the Fraser River system smolts from 2 localities were examined, from the Columbia River system smolts from 3 localities were examined and from the Skeena River system smolts from 3 localities were examined. From Table II the following parasite differences between smolts from the same river system are apparent. In Cultus Lake (Fraser River) nearly every smolt harboured Neoechinorhynchus rutili and nematode larvae, parasites which were entirely absent from Chilco Lake (Fraser River). Lakelse Lake, Babine Lake and Bear Lake smolts from the Skeena system may be distinguished as follows. The Babine smolts had a much higher incidence of recognizable Philonema oncorhynchi and nematode larvae than the Lakelse smolts. Bear Lake smolts lacked recognizable P. oncorhynchi, but had a high incidence of nematode larvae. Also the incidence of Diphyllobothrium was twice that observed at Lakelse and Babine Lakes. In the Columbia River samples, Redfish Lake smolts can be distinguished by the high incidence of Diplostomulum and Proteocephalus, and the lack of Diphyllobothrium and Ergasilus. The Okanagan smolts had a high incidence of Diphyllobothrium and Ergasilus but lacked Displostomulum and had a low incidence of Proteocephalus. Wenatchee smolts lacked Diplostomulum and Ergasilus, but Diphyllobothrium and Proteocephalus were well represented in this sample.

The possibilities of identifying "local" stocks of adult salmon will now be considered. Table IV indicates that almost one-half of the Columbia River sockeye harboured the trematode Podocotyle shawi, which was not found elsewhere. If sockeyes taken on the high seas are found to be infected with this worm, one could postulate that such fish are of Columbia River origin. Similarly, Table IV shows for sockeyes and Table VI for pinks that the cestode Diplocotyle was taken only at Attu. This tapeworm may serve to identify Attu stocks of sockeyes and pinks. From Table IV it also appears that Bacciger may serve to distinguish Bristol Bay sockeye. However, all Bacciger specimens from sockeye were immature, probably indicating recent acquisition in coastal waters.

It was mentioned earlier that some parasites are retained from sockeye smolt through to spawner but would not serve to separate eastern and western stocks. They seem to have some value, however, in differentiating "local" stocks. For example, Diphyllobothrium occurred in 92% of the sample from Kodiak, with an average of 7 and 8 worms per fish. Individual fish had as many as 44 worms. This incidence was very much greater than in any of the neighbouring regions and the average number and individual number of worms per fish was higher than in any other sample. It should be possible to identify at least some Kodiak fish by the high intensity of Diphyllobothrium. In the Gulf of Alaska and Alaska Peninsula, offshore samples of sockeyes, the incidence and intensity of Diphyllobothrium was lower than at Kodiak but higher than in surrounding areas in Alaska. These fish are apparently a mixture of different spawning stocks, but none could be definitely identified as of Kodiak origin. On the other hand, many of the sockeyes lacking Diphyllobothrium are very likely not of the Kodiak stock, but could be a mixture of several of the Diphyllobothrium-negative coastal localities.

The Okhotsk Sea sample, which was taken from 5 localities on 5 different dates, showed apparently 2 distinct spawning populations on the basis of Diphyllobothrium and Philonema. Sockeyes from 3 localities taken between June 30 and July 20 appeared to be a homogeneous group, with Philonema incidence of 40% to 60% and Diphyllobothrium incidence of 40%. The samples from the other 2 localities, taken on July 30 and August 8, were 100% infected with Philonema and Diphyllobothrium. The differentiation of these 2 groups is based upon time of arrival in the fishery and not on the basis of locality. Knowledge of the parasite fauna of smolts from the Siberian area might permit identification of the spawning localities of these apparently different stocks of adult sockeyes.

The use of Philonema as a means of distinguishing "local" stocks of North American sockeyes is similar to the use of Diphyllobothrium. Table IV shows that there are areas free of the Parasite or of low incidence and areas of very high infection. For example, sockeyes from King Cove, Alaska were free of Philonema, whereas, those from Bristol Bay, Kodiak and Cook Inlet were almost 100% infected. In southern areas, e.g., Fraser River and Columbia River, the incidence was very low. In the offshore areas near the Alaska Peninsula and in the Gulf of Alaska, Philonema incidence was intermediate between the high and low areas, indicating a mixture of stocks.

A combination of Diphyllobothrium and Philonema may prove useful in separating "local" stocks of sockeyes. As an example, King Cove sockeyes did not harbour either of these parasites, Kodiak sockeyes showed a very high incidence of both species, and Cook Inlet sockeyes were almost all infected with Philonema but all, save one fish, lacked Diphyllobothrium. Other stocks showed various combinations of incidence and intensity of infection with these 2 parasites.

Many more samples are required before distinction of "local" stocks by Philonema and Diphyllobothrium can be used effectively.

One further parasite should be considered in discussing distinction of "local" stocks. Triaenophorus crassus larvae were encountered in the musculature of almost 40% of the sockeye smolts taken at Lake Aleknagik (Bristol Bay drainage), but were not evident in any other smolt samples. Because of the location of these larvae in smolts, it is most likely that they are retained throughout the life of the salmon and because of their limited distribution, which apparently is controlled by the distribution of pike, they may serve as an excellent tag of sockeyes from certain Alaskan areas. They were not seen in the 1955 Bristol Bay adult sockeye sample, but these fish were returning to spawn in areas known to be free of Triaenophorus.

7. Gradations in abundance of parasites from north to south in the coastal regions of North America

In both pink and sockeye adults it has been noted that in the coastal areas of North America there are several parasite species that either increase or decrease in abundance from north to south.

Tables IV and VI show that Brachyphallus crenatus, Phyllobothrium caudatum and Bolbosoma more or less progressively decrease in abundance from Alaska to the Columbia River or Puget Sound, in both pinks and sockeyes. Particularly evident in this respect is Bolbosoma in pinks. On the other hand, Table VI also illustrates that in pinks, Hemiurus levinseni, Tubulovesicula lindbergi and Eubotherium increase in abundance from north to south.

8. Comparison of parasitism in offshore and onshore populations of salmon

Although few offshore samples were available for comparison with onshore areas from the neighbouring continent, there is some evidence to suggest that certain parasite species are much more prevalent in coastal areas. For example, Brachyphallus crenatus and Lecithaster gibbosus in pinks and sockeyes appeared in greater numbers in coastal samples. Greater abundance of Eubotherium, Tubulovesicula lindbergi and Bucephaloides in pinks may also be related to conditions in coastal areas.

9. Comparison of parasitism in pinks and sockeyes

It has been noted earlier that 42 species of parasites were identified from sockeyes and 27 species from pinks. Twenty-four species were common to pinks and sockeyes, of which 22 were of marine origin, 1 of freshwater origin and 1 of unknown origin. The large difference in the number of species recorded from sockeyes and pinks is the result of acquisition by sockeyes of many more freshwater parasites, most of which, however, are lost after the sockeyes enter the sea. The longer period of freshwater residence experienced by sockeyes exposes them to a greater opportunity to become infected. Sockeyes normally spend 1 to 3 years in fresh water before migrating to sea, whereas, pinks usually move seaward almost immediately after emerging from the gravel and most of them, apparently, are free of parasites when they arrive in the ocean. One hundred downstream migrant fry that were examined did not yield any parasites.

Of the marine-acquired parasites, 2 trematodes were encountered in sockeyes but not in pinks and 2 trematodes in pinks but not sockeyes. Two species of the acanthocephalan genus Corynosoma were found in pinks. The specimens of this genus from sockeyes could not be identified to species but, for purposes of calculating the total number of species, they were considered as representing only 1 species. Aponurus, found in several localities and Podocotyle shawi, taken only at the Columbia River, are the 2 trematodes unique to sockeye. Bucephaloides, taken from adult pinks in most eastern localities and Genolinea oncorhynchi, a rare parasite from a juvenile pink, were not present in sockeyes. There were also several unindentifiable tramatode species in adult sockeyes that were not seen in pinks, and several unindentifiable trematodes in pink juveniles that were not collected from sockeyes.

In addition to the qualitative differences, comparison of Tables IV and VI show that there were also several notable differences in distribution and quantitative aspects of some species. Hemiurus levinseni, abundant only in western areas in sockeyes, is common in both eastern and western areas in pinks. Parahemiurus was found only once in a sockeye from the Fraser River, but in pinks it was encountered in all areas from the Skeena River southward. Brachyphallus crenatus and Lecithaster gibbosus, although displaying similar trends in distribution in pinks and sockeyes, were generally more abundant in pinks. In the King Cove area and at Kodiak Island, the average number of B. crenatus per sockeye was 77 and 253, respectively, and in pinks it was 316 and 1,498. Lecithaster gibbosus averages in the same two areas were 122 and 198 in sockeyes and 404 and 1,346 in pinks. Tubulovesicula lindbergi, confined to eastern areas, showed a much greater incidence in pinks, particularly in the southern coastal areas. Syncoelium katuw, a trematode of wide but scattered distribution in pinks, was found only once in a sockeye. Phyllobothrium caudatum, although occurring in a large percentage of both pinks and sockeyes, was found in much greater numbers in pinks. The maximum average number of worms per sockeye in any area was 32, whereas the maximum average number in pinks was 247. Eubothrium was a very common parasite of pinks, particularly in eastern areas but was extremely rare in sockeyes. Bolbosoma showed a rather uniform decrease in incidence from west to east in pinks, but showed no definite pattern in sockeyes. Anisakis levels of infection were higher in sockeyes in all areas. This is related to the longer marine residence of sockeyes, since Anisakis accumulates from year to year. Contracaecum showed a definite greater abundance in eastern areas in pinks, but not in sockeyes. Ascarophis skrjabini was widely distributed, but discontinuously, in pinks and was seen only once in a sockeye.

From the foregoing discussion, it is apparent that several species of helminths are more abundant in pinks than sockeyes. Some of these parasites (Brachyphallus, Lecithaster, Tubulovesicula, Bucephaloides and Eubothrium) have already been considered as possibly reflecting greater abundance in onshore than in offshore areas, which suggests that pinks in general do not migrate to high-seas areas to the same extent as sockeyes. This postulated longer residence in onshore areas would permit them to acquire more onshore species of parasites. It also appears that some of the pink-sockeye differences may be attributatble to differences in selection of feed.

The many differences in parasitism between pinks and sockeyes indicates that interpretation of data gathered from 1 species of salmon is not necessarily applicable to other species.

SUMMARY

1. The present report summarizes the results of the parasite studies on all pinks and sockeyes made available from 1955 collections.

2. The distribution and number of salmon examined are given in detail. Nine hundred and sixty-six sockeyes and 543 pinks were examined. The sockeyes consisted of 476 smolts, 92 marine juveniles and 398 adults. The pinks comprised 100 fry, 94 marine juveniles and 349 adults. Sockeye smolts were taken from 13 North American localities; pink fry from British Columbia and Alaska; pink and sockeye juveniles from British Columbia; and adult pinks and sockeyes from 18 high-seas or North American coastal areas. Samples from each area consisted mainly of 25 each of sockeyes and pinks.

3. The methods of examination for parasites, the organs examined and the method of collection and identification of the parasites are elucidated.

4. An annotated list of the parasites and tables showing the distribution, incidence and intensity of occurrence of most of the parasites are included. More than 50 species of parasites were found. Pink fry are apparently almost free of parasites.

5. Of the species encountered, 4 in sockeye and 8 in pinks, show indications, to a greater or lesser degree, of being more abundant in eastern or western areas and hence have possibilities of being used to distinguish Asiatic from North American stocks of salmon. Each parasite is discussed individually. The possibility that some of the observed differences are attributable to offshore-onshore differences rather than east-west differences is discussed.

6. Several species of parasites, some of which are of freshwater origin, may be useful in distinguishing "local" stocks, although they do not present overall differences between eastern and western stocks. These possibilities are discussed. There is also evidence to show that some populations of seaward migrant sockeyes in a large river can be parasitologically identified with the spawning locality from which they came.

7. It has been shown that several species of parasites exhibit a progressive increase or decrease in abundance from north to south in adult pink and sockeye samples from North American coastal areas.

8. Some evidence was presented to indicate that there are differences in parasitism between salmon taken in offshore areas and those in onshore areas. With the limited samples that were available, such differences may complicate analysis of the data in searching for east-west differences. In general, several species of trematodes appear to be more abundant in coastal samples.

9. Many differences in parasitism between pinks and sockeyes were pointed out. The greater variety of parasites in sockeyes is attributable to the longer freshwater residence of this salmon. The differences in marine-acquired parasites are of two types; (1) the presence of a parasite in one species and its absence in the other, and (2) very marked differences in distribution or abundance of some species. Possible explanations of this are presented.

10. Because of the limitations of the data, no definite conclusions on the parasitological distinction of stocks can be reached, although there are very good indications that the method is promising. Much more data are required before distinction of stocks by parasites can be used effectively.

TABLE I. AREA, NUMBER OF FISH, DATE OF CAPTURE, AND LIFE HISTORY STAGE OF SALMON SAMPLES STUDIED FOR PARASITES.

Locality		Date of capture	No. of fish examined		Life History Stage
		SOCKEYES			
Lake Aleknagik, Alaska	Drain into Bristol Bay	20-6-1955	26		Downstream migrant
Brooks R., Alaska		31-5-1955	50		" "
Karluk R., Kodiak Is; Alaska		28-6-1955	25		" "
Babine Lake, B.C.	Skeena River drainage	10-6-1955	50		" "
Lakelse Lake, B.C.		20-5-1955	50		" "
Bear Lake, B. C.		June 1955	25		" "
Port John, Central, B. C.		20-5-1955	50		" "
Cultus Lake, B. C.	Fraser River drainage	25-4-1955	50		" "
" " " "		30-5-1955	18		" "
Chilco Lake, B. C.		20-4-1955	50		" "
Baker R., Wash. - Skagit R. drainage to Puget Sound.		15-4 to 22-6-1955	34		" "
Redfish Lake, Idaho	Columbia River drainage	19-5-1955	23		" "
Okanagan R., Wash.		17-5-1955	5		" "
Wenatchee Lake, Wash.		10-5-1955	20		" "
TOTAL NO. DOWNSTREAM MIGRANTS			476		
51° 22' N, 154° 00' E	Okhotsk Sea	30-6-1955	5	25	Adult
53° 20' N, 153° 50' E		10-2-1955	5		"
52° 42' N, 154° 12' E		20-7-1955	5		"
52° 02' N, 154° 30' E		30-7-1955	5		"
52° 03' N, 154° 20' E		10-8-1955	5		"
51° 33' N, 159° 04' E	Western area of Japanese commer-cial fishery.	14-7-1955	15	25	"
50° 18' N, 158° 52' E		30-7-1955	10		"
48° 32' N, 167° 50' E	Central area of Japanese commer-cial fishery.	1-6-1955	15	25	"
49° 18' N, 167° 50' E		22-6-1955	10		"
48° 35' N, 168° 36' E	Eastern area of Japanese commer-cial fishery.	1-6-1955	10	25	"
48° 43' N, 170° 23' E		18-5-1955	7		"
48° 50' N, 173° 00' E		18-5-1955	8		"
Lake Corries	Attu, Aleutian Islands, Alaska.	28-7 to 13-8-1955	15	24	
Lake Nicholas		9-8-1955	3		"
Gravel Pit		1 to 6-8 1955	6		"

Locality		Date of capture	No. of fish examined		Life History Stage
Pavlov Bay	King Cove, Alaska Peninsula.	7-7-1955	8	25	Adult
Cold Bay		19-7-1955	15		"
between Popof and Unga Islands		3-8-1955	2		"
53° 20' N, 165° 27' W	Offshore from Alaska Peninsula.	2-8-1955	2	17	"
52° 14' N, 165° 21' W		1-8-1955	2		"
53° 12' N, 161° 49' W		30-7-1955	4		"
54° 10' N, 158° 14' W		6-8-1955	2		"
53° 47' N, 156° 23' W		26-7-1955	3		"
53° 38' N, 154° 44' W		25-7-1955	2		"
54° 30' N, 152° 49' W		23-7-1955	1		"
53° 26' N, 152° 36' W		24-7-1955	1		"
Naknek-Kvichak	Bristol Bay Alaska	15-7-1955	10	25	"
Ugashik R.		15-7-1955	5		"
Egegik		15-7-1955	10		"
Karluk R.	Kodiak Island, Alaska	24-7-1955	10	25	"
Red R.		24-7-1955	5		"
Larsen Bay		11-8-1955	10		"
Seldovia, Cook Inlet, Alaska		21-7-1955	25		"
Copper River, Alaska		7-6 to 8-7-1955	25		"
57° 01' N, 149° 32' W	Gulf of Alaska	17-7-1955	2	8	"
56° 29' N, 148° 49' W		11-8-1955	1		"
57° 26' N, 143° 26' W		14-7-1955	2		"
57° 35' N, 141° 21' W		13-7-1955	2		"
57° 44' N, 139° 09' W		12-7-1955	1		"
Stikine	Petersburg, Southeast Alaska	5 and 21-7 1955	2	24	"
Snettisham		26-7-1955	12		"
Taku		3 and 4-7 1955	10		"
Mouth of Skeena R., B. C.		21-7-1955	25		"
Rivers Inlet, Central, B. C.		22-7-1955	25		"
Mouth of Fraser R., B. C.		26-7-1955	25		"
Cellilo Falls, Columbia R., Wash.		26-7-1955	25		"
TOTAL NO. ADULTS			398		
Alert Bay, Vancouver Island, B. C.		28-6-1955	50		Marine juvenile
" " " " " "		14-7-1955	42		" "
TOTAL NO. MARINE JUVENILES			92		
TOTAL NO. OF SOCKEYES EXAMINED			966		

Locality		Date of capture	No. of fish examined		Life History Stage
			PINKS		
Port John, Central, B. C.		June 1955	50		Fry
Old Tom Creek, Prince of Wales Is., Southeast Alaska		8-6-1955	50		Fry
TOTAL NO. OF FRY			100		
51° 22' N, 154° 00' E	Sea of Okhotsk	30-6-1955	5	25	Adult
53° 25' N, 153° 50' E		10-7-1955	5		"
52° 42' N, 154° 12' E		20-7-1955	5		"
52° 02' N, 154° 30' E		30-7-1955	5		"
52° 03' N, 154° 20' E		10-8-1955	5		"
49° 48' N, 156° 50' E	Western area of Japanese commercial fishery.	27-7-1955	8	25	"
48° 36' N, 157° 27' E		10-8-1955	9		"
50° 18' N, 158° 52' E		30-7-1955	8		"
52° 48' N, 161° 02' E	Central area of Japanese commercial fishery.	13-7-1955	8	25	"
53° 29' N, 164° 21' E		13-7-1955	9		"
48° 33' N, 165° 30' E		1-6-1955	8		"
48° 45' N, 168° 00' E	Eastern area of Japanese commercial fishery.	23-6-1955	8	25	"
48° 35' N, 168° 36' E		1-6-1955	8		"
48° 43' N, 170° 23' E		18-5-1955	9		"
Gravel Pit	Attu, Aleutian Islands, Alaska.	7 to 28-8 1955	15	25	"
Peaceful River		30-8-1955	7		"
Unknown locality		?	3		"
Cold Bay	King Cove, Alaska Peninsula	19-7-1955	11	25	"
Pavlov and Volcano Bay		2-8-1955	8		"
Unga Strait, Balboa and Korovin Bay		1 and 2-8 1955	6		"
Alitak Bay	Kodiak Is., Alaska	5 and 6-8 1955	12	25	"
Larsen Bay		11-8-1955	13		"
Seldovia, Cook Inlet, Alaska		12-7-1955	25		"
57° 18' N, 145° 28' W	Gulf of Alaska	15-7-1955	1	25	"
57° 26' N, 143° 26' W		14-7-1955	18		"
57° 35' N, 141° 21' W		13-7-1955	6		"
Taku	Petersburg, Southeast Alaska	6 and 7-7 1955	5	25	"
Tenakee		12-7-1955	4		"
Windham Bay		18-7-1955	4		"
Port Houghton		25-7-1955	2		"
Farragut Bay		1-8-1955	4		"
Stikine		9 and 15-8 1955	4		"
Cape Addington		22-8-1955	2		"

Locality	Date of capture	No. of fish examined	Life History Stage
Mouth of Skeena R., B. C.	4-8-1955	25	Adult
Namu, Central, B. C.	1-10-1955	25	"
Mouth of Fraser R., B. C.	2 and 3-8 1955	24	"
La Conner, Skagit Bay (Puget Sound) Wash.	24-8 to 2-9-1955	25	"
TOTAL NO. OF PINK ADULTS		349	
Alert Bay, Vancouver Is., B. C.	28-6-1955	41	Marine juvenile
" " " " " "	14-7-1955	3	" "
Gnarled Is., Northern, B. C.	29-6-1955	50	" "
TOTAL NO. OF MARINE JUVENILES		94	
TOTAL NO. OF PINKS EXAMINED		543	

s, BY SPECIES AND AREA, IN SOCKEYE SMOLTS.

ACANTHOCEPHALA	NEMATODA				COPEPODA	
...echinorhynchus rutili	Capillaria	?Rhabdochona	Philonema onchorhynchi	Nematode larvae	Ergasilus	Salmincola
...	...	...	...	...	...	...
...	...	...	...	...	80(2)	...
...	...	...	...	...	...	...
6(1)	...	12(1)	...	38(2)	...	...
91(4)	...	...	1(1)	100(35)	...	15(1)
...	...	...	...	...	...	...
2(1)	...	...	2(1)	100(8)	...	6(1)
2(3)	...	...	48(1)	100(20)	...	...
6(1)	...	...	22(1)	38(4)	...	...
4(1)	...	...	...	100(11)	...	...
16(1)	12(1)	...	...	100(32)	52(3)	...
...	...	...	...	100(10)	...	...
...	...	...	...	100(35)	4(1)	...

TABLE III. INCIDENCE AND INTENSITY OF PARASITES, BY SPECIES, IN JUVENILE MARINE SOCKEYES FROM ALERT BAY, B.C.

Date of collection	TREMATODA	CESTODA		NEMATODA	
	Lecithaster gibbosus	Diphyllobothrium	Proteocephalus	Contracaecum	Nematode larva
28-6-1955	50(3)	6(1)	10(2)	22(1)	58(5)
14-7-1955	24(1)	...	...	26(1)	...

TABLE IV. INCIDENCE AND INTENSITY OF PARASITES, BY SPECIES AND AREA, IN ADULT MARINE SOCKEYES

	TREMATODA											CESTODA					ACANTHOCEPHALA				NEMATODA						COPEPODA	PROTOZOA
	Gyrodactyloides strelkowi	Podocotyle shawi	Baciger	Diplostomulum	Hemiurus levinseni	Parahemiurus	Brachyphallus crenatus	Tubulovesicula lindbergi	Lecithaster gibbosus	Derogenes varicus	Aponurus	Nybelinia surmenicola	Phyllobothrium caudatum	Diphyllobothrium	Eubothrium	Diplocotyle	Bolbosoma	Corynosoma	Hipporhynchus	Echinorhynchus gadi	Anisakis	Terranova	Contracaecum	Dacnitis truttae	Ascarophis skrjabini	Philonema oncorhynchi	Lepeophtheirus salmonis	Henneguya salmonicola
Okhotsk Sea 51° 22' - 53° 20' N 153° 50' - 154° 30' E	16(9)	...	...	4(1)	44(3)	...	64(2)	...	40(3)	8(6)	...	...	100(24)	64(5)	...	...	44(2)	...	...	76(7)	100(22)	...	36(15)	8(1)	4(1)	68(40)	12(1)	...
50° 18' - 51° 33' N 158° 52' - 159° 04' E	28(4)	...	...	...	56(3)	...	44(3)	...	4(1)	...	...	...	92(17)	80(3)	...	...	36(2)	...	...	96(6)	100(28)	...	68(8)	...	...	72(19)	4(1)	...
48° 32' - 49° 18' N, 167° 50' E	...	...	...	...	28(4)	...	24(3)	...	4(1)	20(1)	...	...	76(21)	52(3)	...	...	56(4)	...	8(1)	4(1)	100(16)	...	52(4)	4(2)	...	64(10)	4(1)	...
48° 35' - 48° 50' N, 168° 36' - 173° E	...	...	...	...	36(2)	...	28(2)	...	8(1)	8(1)	8(2)	...	64(14)	48(5)	...	...	64(6)	...	4(2)	....	100(22)	...	64(2)	...	...	64(17)	...	...
Attu, Aleutian Islands	...	...	...	8(2)	21(2)	...	29(2)	...	79(99)	8(2)	4(1)	...	92(13)	...	...	8(32)	8(4)	13(2)	...	4(1)	96(13)	4(1)	63(6)	...	...	80(109)	...	...
King Cove, Alaska Peninsula	40(10)	...	...	24(4)	...	...	96(77)	4(5)	88(122)	4(1)	...	...	92(20)	...	4(1)	...	4(3)	...	...	...	100(13)	...	92(10)	...	...	...	24(1)	...
52° 14' - 54° 30' N, 152° 36' - 165° 27' W	6(5)	...	...	18(2)	...	...	71(38)	...	35(59)	6(1)	...	...	41(4)	29(2)	...	...	24(2)	...	...	...	100(11)	12(1)	60(6)	...	...	60(3)	...	...
Bristol Bay, Alaska	28(2)	...	24(8)	4(1)	4(1)	...	64(19)	...	88(12)	...	...	...	92(14)	48(3)	4(2)	...	44(1)	4(1)	...	...	96(23)	...	72(16)	...	...	96(43)	...	...
Kodiak Island, Alaska	24(10)	...	...	48(3)	...	...	100(253)	8(1)	96(198)	...	...	8(1)	96(28)	92(7)	...	...	12(1)	4(1)	...	...	100(18)	8(1)	36(4)	...	...	100(31)	40(3)	...
Cook Inlet, Alaska	8(8)	...	...	4(1)	...	...	92(20)	4(9)	92(50)	4(1)	4(1)		100(21)	4(2)	...	...	28(1)	4(1)	...	...	100(21)	4(1)	40(2)	...	...	96(21)	...	...
56° 29' - 57° 44' N 139° 09' - 149° 32' W Gulf of Alaska	38(11)	...	...	...	...	...	25(5)	...	50(9)	...	...	...	100(32)	13(1)	...	...	38(2)	...	...	...	100(14)	...	63(3)	...	...	75(15)	...	25
Copper River, Alaska	...	...	...	...	...	...	12(1)	...	...	...	...	...	36(4)	...	...	...	40(3)	...	...	...	100(18)	...	84(4)	...	...	64(6)	...	4
Southeast Alaska	...	...	...	...	...	...	75(11)	8(2)	100(31)	...	...	...	100(32)	...	...	...	33(2)	...	...	8(3)	100(11)	...	25(4)	...	...	96(44)	4(1)	...
Skeena River, British Columbia	40(10)	...	...	...	...	...	44(11)	12(1)	92(69)	12(1)	8(1)	4(1)	92(17)	21(1)	...	...	16(3)	...	...	4(1)	100(16)	...	64(4)	...	...	100(12)	4(1)	...
Central British Columbia	...	...	...	...	4(1)	...	16(2)	12(1)	88(116)	...	...	...	84(17)	4(1)	...	...	4(1)	...	...	...	100(12)	...	44(3)	...	...	100(24)	12(1)	...
Fraser River, British Columbia	8(6)	...	...	...	...	4(1)	...	8(3)	68(70)	...	8(6)	...	80(10)	44(3)	...	...	4(1)	...	4(1)	...	96(5)	...	56(4)	...	...	12(35)	...	...

TABLE V. INCIDENCE AND INTENSITY OF PARASITES, BY SPECIES AND AREA, IN JUVENILE MARINE PINKS

		TREMATODA					CESTODA	NEMATODA	COPEPODA
Locality	Date of capture	Hemiurus levinseni	Parahemiurus	Brachyphallus crenatus	Lecithaster gibbosus	Genolinea oncorhynchi	Diphyllobothrium	Contracaecum	Lepeophtheirus salmonis
Alert Bay, B.C.	28-6-1955	2(1)	...	...	39(2)	2(2)	...	29(1)	...
Alert Bay, B.C.	14-7-1955	...	...	...	33(3)	...	33(1)	...	...
Gnarled Is., B.C.	29-6-1955	4(3)	8(1)	10(1)	50(3)	...	...	2(3)	2(1)

TABLE VI. INCIDENCE AND INTENSITY OF PARASITES

	TREMATODA									
	Gyrodactyloides strelkowi	Bucephaloides	Bacciger	Hemiurus levinseni	Parahemiurus	Brachyphallus crenatus	Tubulovesicula lindbergi	Lecithaster gibbosus	Derogenes varicus	Syncoelium katuwo
(Okhotsk Sea) 51° 22' - 53° 23'N 153°50' - 154°30'E	...	...	...	80(4)	...	92(10)	...	36(5)	...	8(1)
48° 36' - 50° 18'N 156°50' - 158°52'E	...	4(3)	...	60(4)	...	84(6)	...	...	...	20(3)
48° 33' - 52° 48'N 161°02' - 165°30'E	...	...	...	40(8)	...	56(6)	...	28(1)	...	12(1)
48° 35' - 48° 45'N 168°00' - 170°23'E	...	...	...	8(1)	...	44(4)	...	...	...	...
Attu, Aleutian Islands, Alaska	...	4(4)	...	76(34)	...	52(3)	...	100(711)	...	...
King Cove, Alaska Peninsula	...	16(4)	4(2)	...	...	100(316)	4(1)	100(404)	8(3)	...
Kodiak Island, Alaska	56(21)	12(14)	...	4(1)	...	100(1498)	4(1)	100(1346)	...	4(1)
Cook Inlet, Alaska	4(13)	...	...	4(1)	...	88(12)	...	92(42)	...	8(2)
57° 18' - 57° 35'N 141°21' - 145°23'W (Gulf of Alaska)	8(9)	16(4)	...	4(1)	...	64(5)	4(1)	40(5)	...	8(2)
Southeast Alaska	28(5)	20(8)	...	16(1)	...	100(133)	24(3)	100(349)	8(1)	...
Skeena River, British Columbia	52(10)	36(2)	...	28(1)	4(1)	80(74)	56(2)	100(291)	16(2)	4(1)
Central British Columbia	44(5)	52(7)	...	24(2)	44(4)	76(48)	76(3)	100(332)	12(1)	4(3)
Fraser River, British Columbia	58(27)	4(1)	...	79(11)	29(1)	...	88(17)	96(303)	21(1)	...
Puget Sound	...	20(1)	...	80(3)	8(1)	8(12)	92(11)	100(221)	16(5)	16(1)

SPECIES AND AREA, IN ADULT MARINE PINKS

	CESTODA			ACANTHOCEPHALA						NEMATODA				COPEPODA
surmenicola	Phyllobothrium caudatum	Eubothrium	Diplocotyle	Balbosoma	Corynosoma strumosum	Corynosoma villosum	Corynosoma sp.	Nipporhynchus	Echinorhynchus gadi	Anisakis	Terranova	Contracaecum	Ascarophis skrjabini	Lepeophtheirus salmonis
	100(126)	12(1)	...	92(7)	...	...	...	...	72(3)	92(4)	...	8(1)	28(2	8(1)
	92(74)	...	...	92(21)	...	...	4(1)	...	92(5)	96(6)	...	24(1)	...	...
	100(210)	12(3)	...	76(8)	...	...	...	4(1)	56(4)	100(8)	...	36(4)	24(2	4(1)
	92(39)	...	...	80(5)	...	...	...	12(2)	...	96(13)	...	48(3)	...	4(1)
	100(247)	64(2)	48(14)	72(6)	...	...	25(2)	...	4(1)	64(2)	4(1)	76(5)	4(1	...
)	100(189)	44(4)	...	52(3)	...	4(2)	...	...	8(1)	84(2)	4(1)	100(10)	20(1	12(1)
	100(241)	96(11)	...	36(2)	4(1)	...	4(1)	...	...	36(2)	...	100(16)	...	92(3)
	100(180)	20(5)	...	36(3)	...	...	...	...	...	60(2)	...	72(7)	4(1	92(2)
	100(107)	16(4)	...	32(2)	...	...	...	...	...	92(4)	...	76(3)	...	44(3)
	100(96)	72(14)	...	36(2)	...	...	...	...	32(2)	76(3)	...	100(4)	4(1	32(2)
	100(29)	64(15)	...	16(1)	...	...	...	...	8(2)	96(4)	...	92(10)	...	80(3)
)	100(34)	92(29)	...	4(1)	...	...	...	...	12(2)	100(4)	...	92(12)	...	100(4)
.	100(40)	92(25)	...	...	...	...	...	...	17(3)	88(3)	...	100(19)	...	29(2)
)	100(114)	88(19)	...	...	...	...	...	...	16(3)	96(5)	...	96(9)	...	100(7)

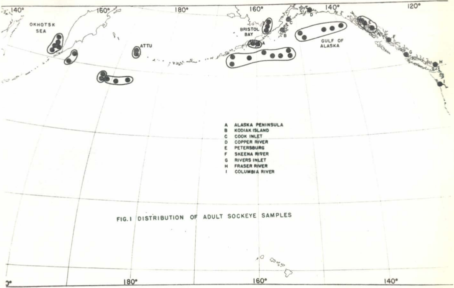

FIG. I DISTRIBUTION OF ADULT SOCKEYE SAMPLES

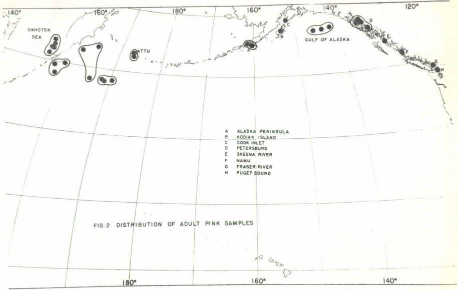

FIG. 2 DISTRIBUTION OF ADULT PINK SAMPLES

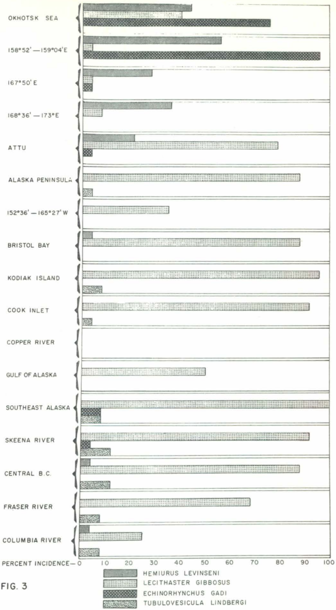
OKHOTSK SEA
158°52' — 159°04' E
167°50' E
168°36' — 173°E
ATTU
ALASKA PENINSULA
152°36' — 165°27' W
BRISTOL BAY
KODIAK ISLAND
COOK INLET
COPPER RIVER
GULF OF ALASKA
SOUTHEAST ALASKA
SKEENA RIVER
CENTRAL B.C.
FRASER RIVER
COLUMBIA RIVER
PERCENT INCIDENCE — 0 10 20 30 40 50 60 70 80 90 100
HEMIURUS LEVINSENI
LECITHASTER GIBBOSUS
ECHINORHYNCHUS GADI
TUBULOVESICULA LINDBERGI

FIG. 3

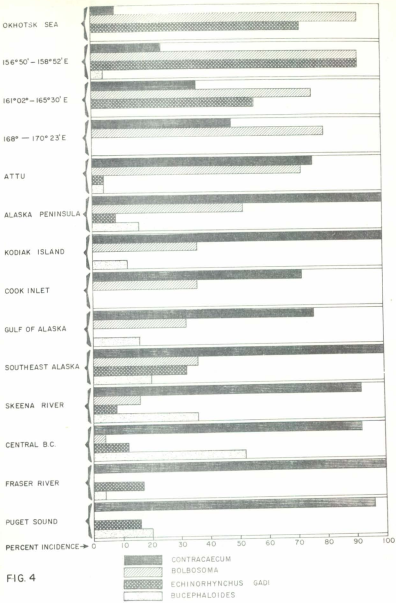
OKHOTSK SEA
156°50' – 158°52' E
161°02° – 165°30' E
168° — 170° 23' E
ATTU
ALASKA PENINSULA
KODIAK ISLAND
COOK INLET
GULF OF ALASKA
SOUTHEAST ALASKA
SKEENA RIVER
CENTRAL B.C.
FRASER RIVER
PUGET SOUND
PERCENT INCIDENCE
0
10
20
30
40
50
60
70
80
90
100
CONTRACAECUM
BOLBOSOMA
ECHINORHYNCHUS GADI
BUCEPHALOIDES

FIG. 4

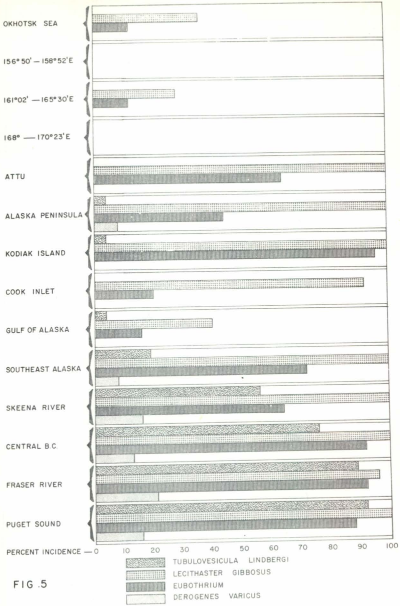
OKHOTSK SEA
156° 50' — 158° 52' E
161° 02' — 165° 30' E
168° — 170° 23' E
ATTU
ALASKA PENINSULA
KODIAK ISLAND
COOK INLET
GULF OF ALASKA
SOUTHEAST ALASKA
SKEENA RIVER
CENTRAL B.C.
FRASER RIVER
PUGET SOUND
PERCENT INCIDENCE — 0 10 20 30 40 50 60 70 80 90 100
TUBULOVESICULA LINDBERGI
LECITHASTER GIBBOSUS
EUBOTHRIUM
DEROGENES VARICUS

FIG. 5