S. Dabala

Confidential

FISHERIES RESEARCH BOARD OF CANADA

# ANNUAL REPORT

of the

## BIOLOGICAL STATION

NANAIMO, B.C.

for

1955

A. W. H. NEEDLER, Director

## INVESTIGATORS' SUMMARIES



NANAIMO, B.C.

MAY, 1956

In December, 1955, a multigraphed Annual Report of the Fisheries Research Board's Biological Station at Nanaimo, B. C., was prepared. It included a summary by the Director of results of research during the year, a list of publications and statements on staff and organization.

The summaries by investigators presented here review the work to March, 1956, in somewhat greater detail. Summaries of this sort formerly appeared as appendices to the Annual Report mentioned above, and the two volumes can be read to advantage together.

AWHNeedler

A.W.H. Needler,
Director.

Nanaimo, B.C.,
May, 1956.

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# YOUNG SALMON IN THE SEA - F. Neave

In 1955, for the first time in the history of Pacific salmon investigations at this Station, a sustained effort was made to find and catch young fish during the first few months of their life in the ocean. The desirability of investigating this phase, in order to learn something of the pattern of marine distribution with the attendant possibility of improving prediction of runs, had been recognized previously. The active participation of Canada in the work of the International North Pacific Fisheries Commission brought about the provision of funds and personnel for initiating such a program.

It was considered expedient and economical for the first season's work to begin the investigation of populations of young salmon at points close to the Canadian streams from which they could be assumed to have recently emerged. The work in 1955 was breaking new ground and consequently involved development of methods. The main effort was to find, catch, identify and tag young salmon; this was accompanied by observation of physical conditions, taking of plankton samples, measuring of length and weight, and examination of stomach contents.

Field operations were carried out from early June until early September, in two coastal areas: (1) a northern area (Chatham Sound and adjacent waters) where it was anticipated that the seaward dispersion of young salmon from the Skeena River and various smaller streams could be followed, and (2) a southern area (Johnstone, Broughton and parts of Queen Charlotte Strait) where concentrations of fish emerging from the Strait of Georgia were expected. The Station's vessel Investigator No. 1 was used during the first part of the northern survey, and the Loligo during the latter part. The Alta was used in the southern area. Each survey vessel carried a purse seine, a beach seine, small-mesh gill nets, several tow nets of 1-metre diameter of various mesh sizes, and equipment for fishing at night with lights. Preliminary experiments with a mid-water trawl developed by the Station were unsuccessful in catching young salmon.

In general it proved very easy to find and collect young salmon (all five species being represented) during the first two months of their ocean life, a period when they frequented the shallow inshore waters in large concentrations. Their subsequent evacuation of these habitats into the deeper water offshore introduced greater difficulties in sighting and capturing the schools. Sufficient experience was gained, however, to promote good hopes for following the movements of the growing fish farther afield in the future. Tagging of small salmon (about 4 inches in length) was accomplished with little immediate mortality, although the ultimate results remain to be determined.

Plans are now advanced for an expanded program in 1956 which will include exploratory fishing for larger salmon over wide areas of the North Pacific, in conjunction with similar surveys by American and Japanese vessels. The offshore migrations of younger fish will be investigated by the provision of increased facilities for purse-seining and the experimental use of a "sea scanar" for locating schools.

## Distribution, movement and relative abundance of juvenile salmon in the sea

J.I. Manzer

Studies of seasonal and local changes in the numbers of young salmon during their early ocean residence were carried out in the two major areas of investigation, with special emphasis on pink, chum and sockeye salmon. A short survey was also conducted between Masset Harbour and Masset Sound, Graham Island, during July 26 to 29.

The catches of young salmon were made by several types of gear, each varying in fishing efficiency and method of operation; hence the data for each kind of gear are not strictly comparable. The sum of these observations, however, gave a general picture of spatial distribution. Changes in abundance during the course of the season were best shown, especially in the Chatham Sound area, by comparing beach-seine catches.

The types of gear and number of times each was used are tabulated below, according to area:

| Area | Beach seine | | Purse | Tow | Gill | Night |
|---|---|---|---|---|---|---|
| | Beach set | Circling set | seine | net | net | light |
| Chatham Sound | 320 | 12 | 46 | 45 | 5 | 3 |
| Johnstone Strait | 106 | 2 | 19 | 2 | 1 | 3 |
| Graham Island | 17 | 4 | 3 | .. | .. | .. |
| Total | 443 | 18 | 68 | 47 | 6 | 6 |

### 1. Chatham Sound and adjacent waters

(a) Pink salmon. During early June pink salmon were found along all the beaches sampled but were most abundant along the islands forming the western and southern boundaries of Chatham Sound where single beach-seine sets sometimes caught thousands of individuals. None was caught in the Skeena River. During the last two weeks of June the numbers of fish along the mainland remained unchanged but elsewhere they were reduced by approximately one-half. Along the southern islands at this time, pink salmon were also caught 200 yards from shore. During July further reductions in numbers occurred along the islands, and catches were made as far as 500 yards offshore, indicating that migration away from the beaches was well underway. By mid-August, pink salmon were no longer available along the beaches. Some, however, were caught off White Rocks in Hecate Strait. By the end of August seaward occurrence in Dixon Entrance was established at 12 miles from the nearest point of land (south-west of Zayas Island).

(b) Chum salmon. Chum salmon were generally present in the same areas as pink salmon but, on the average, were less abundant. During early June they were most abundant along those beaches at the southern end of Chatham Sound (100 to 500 fish per set). During the latter half of June, their abundance at the southern end of the sound decreased to the level found earlier in other areas (less than 100 fish per set). One large concentration (1,000 to 5,000 fish per set), however, was found at one of the small western islands (Whitesand Island), hitherto unsampled. During mid-July, except in two instances (at

Whitesand Island where the numbers decreased and in Beaver Passage where the numbers increased), the number of chum salmon remained unchanged from the previous period. In this period chum salmon were caught 500 yards offshore. During the first half of August, except in a few scattered southern localities, fish were no longer present along the beaches. By the end of August some were taken at least one mile from land.

(c) Sockeye salmon. Sockeye salmon were caught only during the early summer and always in small numbers (less than 100 fish per set). During the first two weeks of June sockeye were most abundant in the Skeena River. They were also present along the mainland beaches and, in much smaller numbers, along a few scattered beaches on the west side of Chatham Sound. During the following two weeks they were generally found in the same localities but in reduced numbers. By mid-July sockeye were rarely found on the beaches, one individual was taken 100 yards from shore. None was caught after mid-July.

2. Johnstone, Broughton and Queen Charlotte Straits G.T. Taylor

(a) Pink salmon. This species, in general, was less abundant in Johnstone Strait and adjacent waters than in Chatham Sound, although the numbers of fish varied locally. Large concentrations were found in the first two weeks of June at the eastern end of the Strait, and later near Alert Bay. In the latter locality during early June pink salmon occurred in moderate numbers, but thereafter decreased continually until by mid-August they were no longer available along the beaches. This lack of pink salmon along the beaches was also observed in Queen Charlotte Strait during the following two weeks.

(b) Chum salmon. During June chum salmon were caught along the beaches from Discovery Passage to Alert Bay, but were most abundant at the eastern end. Near Alert Bay during the latter part of June, fish were relatively scarce but subsequently increased in abundance during the latter part of July and early August. In Queen Charlotte Strait from mid-August to early September chum salmon were virtually absent along the beaches.

(c) Sockeye salmon. Of the three species, sockeye were most abundant. During June they were absent from the beaches along the eastern end of Johnstone Strait to Alert Bay, where they were abundant. By mid-August only moderate numbers were present. In Queen Charlotte Strait in September, moderate numbers were caught over deep water around the rocky offshore islands.

3. Masset Harbour to Masset Inlet J.I. Manzer

(a) Pink salmon. This was the most numerous species during the period (late July) when observations were made. Catches were comparable in size (less than 100 fish per set) to those made in Chatham Sound at about that time. Movement to sea was indicated by the fact that in Masset Inlet fish were absent along the beaches but were present offshore close to the mouth, and along the beaches in Masset Sound and Masset Harbour adjacent to Dixon Entrance.

(b) Chum salmon. Chum salmon were relatively scarce. A few were found off the beaches in Masset Inlet and in Masset Harbour.

To summarize: The observations made in 1955 indicate the spread of young pink and chum salmon seaward; they concentrate along the shore until late July or early August when their movement away from shore starts. In the Chatham Sound area, young sockeye were not caught as successfully as pinks and chums, perhaps because of their failure to concentrate on the beaches in the same manner. Such catches as were made suggest a similar movement and disappearance from inshore areas.

## Size and sex of juvenile salmon

During 1955 almost 7,000 small salmon were examined in the laboratory and length, weight and sex ratios recorded. The number of fish of each species examined is tabulated below, according to area.

| Area | Pink | Chum | Sockeye | Coho | Spring | Total |
|---|---|---|---|---|---|---|
| Chatham Sound | 2667 | 1775 | 179 | 608 | 40 | 5269 |
| Johnstone Strait | 330 | 644 | 338 | 147 | .. | 1459 |
| Graham Island | 170 | 25 | .. | 2 | .. | 197 |
| Total | 3167 | 2444 | 517 | 757 | 40 | 6925 |

In Chatham Sound from June to mid-August the beaches were periodically sampled during four cruises. As fish moved off the beaches sampling was extended to offshore waters. In Johnstone Strait sampling started at the eastern end and moved progressively westward into Queen Charlotte Strait. Only the Alert Bay locality was repeatedly sampled over any period of time.

1. Changes in size. The average monthly fork length (in millimetres) and weight (in grams) for pink, chum and sockeye salmon caught in Chatham Sound and Johnstone Strait during the summer of 1955 are presented in the accompanying table. Values in parentheses are based on less than 25 fish. Since the larger fish are probably the first to leave localities where most of the fish were caught, the recorded monthly changes in size do not necessarily show the true growth rate.

| Species | Area | Sex | Average length (mm.) | | | | Average weight (gr.) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Jun | Jul | Aug | Sep | Jun | Jul | Aug | Sep |
| Pink | Chatham Sd. | F. | 65.5 | 77.3 | 115.9 | .. | 2.5 | 4.8 | 15.6 | .. |
| | | M. | 64.9 | 76.6 | 116.1 | .. | 2.5 | 4.8 | 15.8 | .. |
| | Johnstone St. | F. | 76.5 | 74.9 | (96.0) | .. | 5.4 | 4.0 | (7.7) | .. |
| | | M. | 77.4 | 74.0 | (85.8) | .. | 5.5 | 4.1 | (6.7) | .. |
| Chum | Chatham Sd. | F. | 63.6 | 67.0 | (112.3) | .. | 2.6 | 3.3 | (15.0) | .. |
| | | M. | 62.9 | 66.5 | (107.2) | .. | 2.6 | 3.2 | (16.6) | .. |
| | Johnstone St. | F. | 77.4 | 67.2 | 81.4 | (98.0) | 4.8 | 3.1 | 5.6 | (8.3) |
| | | M. | 76.8 | 70.9 | 83.4 | .. | 4.8 | 3.4 | 6.0 | .. |
| Sockeye | Chatham Sd. | F. | 79.4 | (73.8) | .. | .. | 4.8 | (4.4) | .. | .. |
| | | M. | 77.6 | (82.3) | .. | .. | 4.4 | (4.5) | .. | .. |
| | Johnstone St. | F. | (78.9) | 75.8 | 93.5 | 101.4 | (5.0) | 4.4 | 7.9 | 9.6 |
| | | M. | (77.0) | 77.1 | 94.2 | 98.9 | (4.7) | 4.5 | 8.1 | 8.8 |

The average size of pink salmon in the samples from Chatham Sound area increased with each successive month from June to August. From June to July the average increase in length for both males and females amounted to 15.3%; this was roughly doubled from July to August (33.3% for males and 34.0% for females). In the Johnstone Strait area the monthly average values for length and weight fluctuated, July values being less than those for either June or August. In both areas females generally were slightly larger than males.

The general pattern of change in average size for chum salmon in the Chatham Sound and Johnstone Strait areas is similar to that for pink salmon in the same area. In the Chatham Sound area, for both sexes the percentage increase from June to July was considerably less (approximately 5% for both sexes) than that for pinks but was considerably greater from July to August (38% for males, 41% for females).

Length and weight data for sockeye salmon in the Chatham Sound area are sufficient only for June. Again females were longer and heavier than males. In the Johnstone Strait area, throughout June to September, neither the length nor the weight of one sex consistently exceeded that of the other.

The pattern of change in size of pink and chum salmon in the Chatham Sound area differs from that in the Johnstone Strait area. It is evident, from the monthly values, that in the latter area the populations sampled were not always the same. The fluctuations in length and weight could be caused by arrival at the sampling localities of stocks originating in different streams or migrating from fresh water at different times.

2. Sex ratios. Comparatively little is known about the sex ratios of salmon, or the possible changes in ratio due to differential mortality, prior to the time when they enter the commercial fishery as adults. In an attempt to fill in part of this gap in our knowledge of the life history of the Pacific salmons, the sex proportions in the areas of study were examined. The sex ratios (females/males) during early ocean residence are given in the accompanying table, according to species followed by the numbers in the samples in brackets.

| | Chatham Sound | Johnstone Strait | Graham Island |
|---|---|---|---|
| Pink | 0.98 (2228) | 0.86 (330) | 0.77 (170) |
| Chum | 0.87 (1385) | 0.96 (643) | 1.50 ( 25) |
| Sockeye | 1.05 ( 113) | 0.93 (313) | |
| Coho | 1.05 ( 471) | 1.08 (106) | |
| Spring | 1.0 ( 40) | | |

At present there is no reason to suspect a departure from a 1:1 ratio during early ocean residence except in the case of Chatham Sound chum salmon.

## Food of juvenile salmon

The number of stomachs examined and the percent containing food is indicated, according to species, in the accompanying table:

| Species | Chatham Sound | | Johnstone Strait | |
|---|---|---|---|---|
| | No. stomachs examined | Percent with food | No. stomachs examined | Percent with food |
| Pink | 574 | 96.5 | 85 | 95.3 |
| Chum | 421 | 95.3 | 133 | 93.2 |
| Sockeye | 98 | 90.8 | 85 | 95.3 |
| Coho | 142 | 85.2 | 30 | 76.7 |
| Spring | 9 | 77.7 | .. | .. |

Over 90% of the stomachs were found to contain some food. In general the incidence of food was greater for pinks, chum and sockeye salmon than for coho and spring salmon.

In Chatham Sound, copepods occurred most frequently in pink (49%) and sockeye (41%) but were dominant by volume only in sockeye. Larvacea ranked first in frequency for chum and second for pink (39%) and sockeye (26%). They were the most important item by volume for pink (36%) and chum (51%). Amphipods were found in less than 10% of the stomachs examined for each species. Other minor items in the diet of these species included chaetognaths, ostracods, cirripedians, mysidaceans, cumaceans, isopods, decapods, insects, and fish (larvae). For coho, fish (herring larvae and sand-lance) occurred in 53% of the stomachs and formed 70% of the total volume of food.

In the Johnstone Strait area the organisms eaten were much the same but their relative importance differed. Copepods were found in 86% of the sockeye and pink and 80% of the chum, roughly two-thirds of the total volume of food. Amphipods, of minor importance in the northern area, ranked second (25%) in frequency but did not comprise more than 10% of the volume. Euphausiids, present but not important in pink salmon, occurred in 18% of the chum and sockeye, and accounted for 15% of the volume. For coho, fish were important. This item occurred in only 30% of the stomachs but formed 84% of the total volume.

Differences in the consumption of various food items suggest that small salmon of the five species differ in feeding habits. In general, pink, chum and sockeye salmon were invertebrate feeders; coho and, it is suggested, spring, were piscivorous. There is also a tendency for chum and pink taken together in the same locality to select different food, the chum being more catholic in its diet.

## Tagging

Experiements testing various types of tags were carried out in aquaria and at the Lakelse River counting weir to provide information on their suitability and effects upon fish in confined and in natural conditions. Also, on the basis of early experiences and results from experimental taggings, small salmon were tagged in the field in an attempt to determine their distribution offshore.

In all experiments, fish were anaesthetised in chlorotone solution (1 gr. dissolved in 2,500 cc. of water) before handling.

1. <u>Experimental tagging</u>

(1) <u>Aquaria experiments</u>. Three- to four-inch sockeye salmon were tagged in the dorsal-fin region with various types of tags which included:

(a) plastic sleeves, 0.039 inch in diameter and 0.25 inch in length, attached with No. 26 gauge silver wire;

(b) type (a) tag but attached with 15-pound test monofilament nylon;

(c) toggle tag consisting of two small plastic balls threaded on nylon which was wound into twisted wire;

(d) hook tag with streamer; and

(e) five- to six-inch length of temflex "spaghetti" tubing, 0.039 inch in diameter, the free ends knotted to form a loop.

The effectiveness of the various tags, after 11 months, is shown by the following table:

| Group | No. fish | Percent lost | Occurrence of death or loss of tag (days) |
|---|---|---|---|
| Wire | 13 | 84.6 | 10, 12, 21, 32, 33, 55, 66, 70, 206, 265, 290 |
| Monofilament | 5 | 60.0 | 1, 14, 46 |
| Toggle | 2 | 100.0 | 17, 96 |
| Hook | 2 | 100.0 | 46, 154 |
| Spaghetti | 12 | 58.3 | 7, 10(2), 45, 51, 57, 166 |
| Control | 20 | 20.0 | 85, 109, 121, 226 |

Toggle and hook tags, while easy to apply, caused irritation at the point of attachment shortly after tagging. The maximum periods during which these tags were effective were 96 days and 154 days respectively. Wire tags showed considerable cutting of the flesh in some instances. Eleven of the 13 fish with this tag either died or lost their tag within 290 days, 8 of the 11 within 70 days. Monofilament nylon and "spaghetti" tags appear to be most effective, 40% of the fish with these tags are still surviving or roughly one-half the survival of the control fish. Some of the losses are attributed to accident. The "spaghetti" tag has the additional advantage of easy application, and therefore appears most promising.

(2) <u>Lakelse River experiment</u>. In early June, 722 migrating sockeye smolts were tagged with wire tags and another 597 smolts with "spaghetti" tags. Some information on the usefulness of these tags for tagging fish in nature may be available in 1956 when some of the individuals return as "jacks".

2. <u>Field tagging</u> J.I. Manzer and G.T. Taylor

A total of 4,222 small salmon were tagged during 1955. The number of fish of each species tagged in the Chatham Sound and Johnstone Strait areas follows. In these experiments, polyethylene tubing replaced temflex tubing as material for "spaghetti" tags, on the basis of chemical properties.

| Species | Chatham Sound | Johnstone Strait | | Total |
|---|---|---|---|---|
| | Spaghetti | Spaghetti | Wire | |
| Pink | 614 | 114 | 61 | 789 |
| Chum | 129 | 497 | 98 | 724 |
| Sockeye | .. | 1945 | 154 | 2099 |
| Coho | 48 | 284 | 243 | 575 |
| Spring | .. | 5 | 30 | 35 |
| Total | 791 | 2845 | 586 | 4222 |

Four recoveries have been made. Three chum salmon, released in Alert Bay, were recovered in the same area from one to three days later. The fourth, a coho tagged in Hardy Bay, was recovered eight days later in a commercial purse seine operating in Queen Charlotte Strait, 6 miles from the point of release.

## Oceanographic features of Dixon Entrance and distribution of young salmon

R.J. LeBrasseur

Plankton sampling, together with limited oceanographic observations, was included as a part of the investigation of the life history of young salmon after they leave the fresh water. The stations selected cover the northern (Chatham Sound) area.

The observations were made during the latter part of August and early September. At each station an oblique plankton tow and salinity and temperature observations were made. In sampling for the zooplankton a fine mesh nylon net (with 0.282 mm. openings) was towed at 2 knots for a 10-minute period from 100 feet to the surface.

The plankton samples were analysed by determining their volume and their major constituents. The plankton volumes showed a wide variation which, when plotted on a map, divided the area into two distinct zones. Along the western and southern section of Dixon Entrance large volumes were taken; while to the north and east were much lower concentrations. The zooplankton in the richer zone was made up of crustaceans, predominately copepods. In contrast to this, the smaller zooplankton volumes in the other zone were made up of a wide assemblage of different organisms, including annelids, tunicates, cladocerans and medusae.

The variation in the zooplankton concentration and composition indicates the presence of two different water masses. Good growing conditions are generally characterized by "blooms" (large concentrations) of one particular organism, whereas poorer conditions are characterized by a variety of organisms. In this instance the large concentration of copepods suggests that the water mass with which they are associated has originated to the west of Dixon Entrance. From there it extends eastward along Graham Island and thence north towards Dundas Island. Its constituents of the other zone besides indicating poor growing conditions, are typical of coastal low salinity water. It seems likely that this water has originated in Chatham Sound.

Temperature and salinity observations taken at the same time support the view that two different water masses were present. One is an inshore movement of cold oceanic water and the other is a warm body of low-salinity water formed by the freshwater discharge from the Skeena and Nass Rivers.

In general, young salmon were found most frequently in the warm, brackish, plankton-poor water. In particular they were observed on seven occasions in water warmer than 52° F. and only twice in colder water. The observations suggest that at this relatively early stage the seaward migration is more closely related to surface-water temperature than to high zooplankton concentrations or to any particular salinity.

## P A R A S I T O L O G Y - L. Margolis

During the past year the Station's parasitological work has been devoted, almost entirely, to a systematic survey of the parasites of sockeye and pink salmon throughout the North Pacific area. In the summer of 1955 a seasonal employee was engaged in a study of the normal anatomy of salmon in order to facilitate the detection and diagnosis of diseases and parasites. As usual, services have been rendered in the diagnosis of diseased conditions in fish and the identification of parasites.

### Studies on parasites of Pacific salmon

In co-operation with the U.S. Fish & Wildlife Service a study of the parasites of sockeye, pink and chum salmon is in progress in an effort to determine whether there are qualitative or quantitative differences by which stocks may be distinguished. Our investigation has directed its attention to sockeyes and pinks. The salmon used in these studies were collected through the co-operation of Canadian, American and Japanese agencies. Table I indicates the areas from which salmon were examined and the number of fish in each sample. Samples on hand but not yet examined are not shown in this table.

Table I. - Area, number of fish, and life-history stage of salmon samples studied for parasites.

| Species of salmon | Area | No. of fish examined |
|---|---|---|
| Sockeye - smolt | Cultus Lake, Fraser River, B.C. | 68 |
| " " | Chilco Lake, Fraser River, B.C. | 50 |
| " " | Port John, Central, B.C. | 50 |
| " " | Lakelse Lake, Skeena River, B.C. | 50 |
| " " | Babine Lake, Skeena River, B.C. | 50 |
| " " | Redfish Lake Creek, Columbia River, Idaho | 23 |
| " " | Okanagan River, Columbia River, Wash. | 5 |
| " " | Wenatchee Lake, Columbia River, Wash. | 20 |
| " " | Baker Lake (Skagit River), Puget Sound, Wash. | 34 |
| " " | Lake Aleknagik, Bristol Bay, Alaska | 26 |
| " " | Brooks River, Bristol Bay, Alaska | 50 |
| " - young marine | Alert Bay, B.C. | 92 |
| " - adult marine | Bristol Bay, Alaska | 25 |
| " " " | Attu, Aleutian Islands, Alaska | 24 |
| " " " | King Cove, Alaska Peninsula | 25 |
| " " " | Okhotsk Sea | 25 |
| " " " | Western North Pacific (51°33'N., 159°04'E.) | 15 |
| " " " | Eastern North Pacific Japanese catch (48°43'-48°50'N., 170°23'-173°00'E.) | 15 |
| " " " | Fraser River, B.C. | 20 |
| Pink - fry | Port John, Central B.C. | 50 |
| " " | Southeast Alaska | 50 |
| " - young marine | Alert Bay, B.C. | 44 |
| " " " | Gnarled Island, Northern B.C. | 50 |
| " adult " | Fraser River, B.C. | 24 |

1. Literature review

L. Margolis and J.R. Adams

As a preliminary step in the salmon parasite studies a bibliography and a list of recorded parasites from all species of Oncorhynchus has been compiled. About 130 species have been recorded but do not all seem to be valid. These records are from many different localities with intensive surveys limited to very restricted areas.

2. Pink salmon

Since the number of pinks studied is relatively small and from restricted areas, information applicable to the distinction of stocks is not yet available. However, the data will be discussed briefly and some comparisons with sockeye from the same areas will be made later.

The pink fry from British Columbia and Alaska were entirely free of parasites, indicating that seaward migrating pinks carry with them to sea, few, if any parasites.

Tables II and III show the incidence and intensity of parasitism with the common species of parasites encountered in the young marine and adult marine pinks respectively. The underlined numbers represent the percentage of individuals infected with each species of parasite and the numbers in parentheses are the average number of parasites, of each species, per infected fish (i.e., not including fish that were free of the parasite). This average rather than an average based on the total sample is given because it is felt that it gives a more accurate picture of the situation, particularly when the incidence of a species in a sample of fish is low but the intensity is high in the infected group. This method of indicating incidence and intensity will be followed in all subsequent tables.

In addition to the parasites shown in Table II, five other species not encountered elsewhere in the survey were discovered. One appears to be a previously undescribed species.

Two further species, a trematode and a nematode, were each found once in the Fraser River adult pinks and are not shown in Table III.

From Tables II and III it is apparent that three species of trematodes and one copepod from the adult pinks were first seen in young marine pinks. Whether the presence of these parasites in adult pinks is an indication that they have been carried throughout the marine life of pinks or whether they are the result of new infections cannot yet be determined. It is further seen from Tables II and III that the trematode Brachyphallus was found only in the northernmost sample (Gnarled Island, B.C., near Alaska) and was absent from Alert Bay and the Fraser River, B.C. The absence of this trematode from the more southerly areas was also evident in the sockeye studies (Tables V and VI).

Table II. Incidence and intensity of parasites, by species in young marine pinks, 1955.

| Species | Alert Bay June 28 | Gnarled Island June 29 |
|---|---|---|
| Trematoda | | |
| Hemiurus levinseni | 2(1) | 4(3) |
| Parahemiurus | .. | 8(1) |
| Brachyphallus crenatus | .. | 10(1) |
| Lecithaster gibbosus | 39(2) | 50(3) |
| Nematoda | | |
| Contracaecum larva (from coelom) | 29(1) | 2(3) |
| Copepoda | | |
| Lepeophtheirus salmonis | .. | 2(1) |

NOTE: In this and subsequent tables the underlined number is the percentage of individual fish infected with each species of parasite and the numbers in brackets are the average number of parasites of each species per infected fish.

Table III. - Incidence and intensity of parasites, by species, in adult marine pinks from the Fraser River, B.C., August 2 and 3, 1955.

| | |
|---|---|
| Trematoda | |
| *Hemiurus levinseni* | 79(11) |
| *Parahemiurus* | 29( 1) |
| *Tubulovesicula lindbergi* | 88(17) |
| *Lecithaster gibbosus* | 96(303) |
| *Derogenes varicus* | 21( 1) |
| *Gyrodactyloides strelkowi* | 58(27) |
| Cestoda | |
| *Eubothrium* | 92(25) |
| *Phyllobothrium caudatum* | 100(40) |
| Nematoda | |
| *Contracaecum* (alimentary tract) | 100(19) |
| *Anisakis larva* | 88( 3) |
| Copepoda | |
| *Lepeophtheirus salmonis* | 29( 2) |
| Acanthocephala | |
| *Echinorhynchus gadi* | 17( 2) |

3. Sockeye salmon

L. Margolis, M. Knightly and D. Wakhroucheff

Table IV summarizes the findings in sockeye smolts. In addition to the 10 species noted, 7 other species were encountered infrequently. The parasite picture in sockeye smolts from different localities is by no means uniform, although many species have a wide distribution.

Table IV. - Incidence and intensity of parasites, by species, in migrant sockeye smolts, 1955.

| Area | Date | Acanthocephala: Neoechinorhynchus rutili | Nematoda: Philonema oncorhynchi | Nematoda: Nematode I larva | Trematoda: Diplostomulum sp. larva |
|---|---|---|---|---|---|
| Cultus Lake, Fraser R. | Apr 25 | 88(4) | 2(1) | 100(35) | .. |
| " " " " | May 30 | 100(4) | .. | 100(35) | .. |
| Chilco Lake, " " | Apr 20 | .. | .. | .. | .. |
| Port John, Central B.C. | May 20 | 2(1) | 2(1) | 100( 8) | .. |
| Lakelse Lake, Skeena R. | " 20 | 6(1) | 22(1) | 38( 3) | 6(1) |
| Babine Lake, " " | Jun 10 | 2(3) | 48(1.4) | 100(20) | .. |
| Redfish Lake, Columbia R. | May 19 | .. | .. | .. | 48(3) |
| Okanagan River, " " | " 17 | .. | .. | .. | .. |
| Wenatchee Lake, " " | " 10 | .. | .. | .. | .. |
| Baker River, Puget Sound | Apr 15-Jun 22 | 6(1) | .. | 38( 2) | .. |
| Lake Aleknagik, Bristol Bay | " 20 | .. | .. | 100(35) | 54(1.3) |
| Brooks River, Alaska | May 31 | .. | .. | 100(10) | 10( 2) |

| Area | Date | Cestoda: Eubothrium | Cestoda: Diphyllobothrium sp. larva | Cestoda: Proteocephalus | Cestoda: Triaenophorus crassus larva | Copepoda: Salmincola falculata | Copepoda: Ergasilus |
|---|---|---|---|---|---|---|---|
| Cultus Lake | Apr 25 | .. | 80(2.5) | 6(14) | .. | 14(1) | .. |
| " " | May 30 | 6(1) | 100(2.8) | 17( 6) | .. | 17(1) | .. |
| Chilco Lake | Apr 20 | 2(2) | 88(2.3) | 30(10) | .. | .. | .. |
| Port John | May 20 | .. | 86(2.7) | 2(11) | .. | 6(1) | .. |
| Lakelse Lake | " 20 | 4(1) | 14(1) | 2(2) | .. | .. | .. |
| Babine Lake | Jun 10 | 10(1) | 16(1) | .. | .. | .. | .. |
| Redfish Lake | May 19 | .. | .. | 78( 5) | .. | .. | .. |
| Okanagan River | " 17 | .. | 80(5) | 20( 1) | .. | .. | 80(2) |
| Wenatchee Lake | " 10 | .. | 50(2) | 55(16) | .. | .. | .. |
| Baker River | Apr 15-Jun 22 | 12(4) | 3(1) | 6(1.5) | .. | .. | .. |
| Lake Aleknagik | " 20 | .. | 4(1) | 23( 2) | 37(1) | .. | 4(1) |
| Brooks River | May 31 | 8(1.5) | 8(1) | 4(40) | .. | .. | .. |

Table V. - Incidence and intensity of parasites, by species, in young marine sockeyes from Alert Bay, B.C., 1955.

| Species | June 28 | July 14 |
|---|---|---|
| *Lecithaster gibbosus* | 50(3) | 24(1.2) |
| *Contracaecum larva* (coelom) | 22(1) | 26(1) |
| Nematode I larva | 58(5) | .. |
| *Diphyllobothrium larva* | 6(1) | .. |
| *Proteocephalus* | 10(2.4) | .. |

Table VI. Incidence and intensity of parasites, by species, in adult marine sockeye, 1955.

| Area | Date | Trematoda | | | | | Cestoda | |
|---|---|---|---|---|---|---|---|---|
| | | *Gyrodactyloides strelkowi* | *Brachyphallus* | *Lecithaster gibbosus* | *Hemiurus levinseni* | *Diplostomulum* sp. | *Diphyllobothrium* sp. | *Phyllobothrium caudatum* |
| Fraser R., B.C. | Jul 26 | .. | .. | 75(109) | .. | .. | 40(3.5) | 75(11) |
| Bristol Bay, Alaska | " 15 | 28(2) | 64(19) | 88( 12) | 4(1) | 4(1) | 48(3) | 88(15) |
| Attu, Aleutian Islands, Alaska | " 28- Aug 9 | .. | 29( 2) | 80( 99) | 21(1.6) | 8(2) | .. | 92(13) |
| King Cove, Alaska Peninsula | Jul 7 Aug 4 | 40(10) | 96(77) | 92(122) | .. | 24(4) | .. | 92(19) |
| 48°43'-48°50' N., 170°23'-173°E. | May 18 | .. | 27(3) | 13(1) | 27(1.5) | .. | 60(5) | 87(17) |
| 51°33'N., 159°04'E. | Jul 14 | 47(4) | 53(3) | 7(1) | 87(3) | .. | 80(3) | 100(19) |
| Okhotsk Sea | Jun 30- Aug 10 | 16(9) | 64(2) | 40(2.5) | 40(3.5) | 4(1) | 64(5) | 100(24) |

| Area | Date | Nematoda | | | Acanthocephala | | Copepoda |
|---|---|---|---|---|---|---|---|
| | | *Philonema oncorhynchi* | *Contracaecum* | *Anisakis* sp. larva | *Bolbosoma* | *Echinorhynchus* | *Lepeophtheirus salmonis* |
| Fraser R., B.C. | Jul 26 | 10(42) | 50(5) | 95(5) | 5(1) | .. | .. |
| Bristol Bay, Alaska | " 15 | 96(43) | 72(16) | 96(23) | 44(1.3) | .. | .. |
| Attu, Aleutian Islands, Alaska | " 28- Aug 9 | 80(108) | 62(6) | 96(13) | 8(3.5) | 4(1) | .. |
| King Cove, Alaska Peninsula | Jul 7- Aug 4 | .. | 92(9) | 100(15) | .. | .. | 24(1) |
| 48°43'-48°50'N., 170°23'-173°E. | May 18 | 80(20) | 67(2) | 100(28) | 80(6) | .. | .. |
| 51°33'N., 159°04'E. | Jul 14 | 73(19) | 53(3) | 100(26) | 27(1.5) | 93(7) | 7(1) |
| Okhotsk Sea | Jun 30- Aug 10 | 85(40) | 36(15) | 100(22) | 44(1.6) | 76(7) | 12(1) |

As seen in Table VI the only smolt parasites that were seen again in adult sockeye are Philonema oncorhynchi, Diphyllobothrium and Diplostomulum. Nematode I larvae were seen in young marine sockeye (Table V) but not in adults. The exact identity of these nematodes remains unknown. It is possible that they are very early stages of P. oncorhynchi. Work is now in progress to determine if this relationship is correct. All other smolt parasites, except T. crassus, are so located in the fish that they are lost, presumably because of the changes accompanying the migration from fresh water to a marine environment, and hence cannot be used to identify the source of marine stocks of sockeye. Philonema oncorhynchi, Diphyllobothrium and Diplostomulum are located in the coelomic cavity, in cysts on the outer wall of the stomach and pyloric caeca, and in the eye, respectively, and hence are relatively free of the effects of the marine environment. Triaenophorus crassus larva, found encysted in the muscles, is also apparently free of external environmental effects. Its apparent absence from adult fish is probably due to its restricted distribution. Table IV shows that T. crassus was found only in Lake Aleknagik, Alaska, which empties into Bristol Bay. All Bristol Bay adults examined were returning to spawning areas south of the Lake Aleknagik area, and in which T. crassus is known not to occur. Sockeyes known to be returning to spawn in the Lake Aleknagik area were not available. It would be most interesting and valuable to examine such fish to determine if T. crassus survives throughout the salmon's marine life. Because of the restricted distribution of Triaenophorus it would be easy to identify stocks of Triaenophorus-infected sockeyes, particularly because the incidence of T. crassus in smolts in the infected areas has been known to be as high as 70%.

One possible use of the data on smolt parasites lies in the apparent ability to distinguish stocks of migrating smolts in a large river having several contributing tributaries. The separation of Cultus Lake from Chilco Lake smolts in the Fraser River, B.C., is seen to be readily accomplished when examining Table IV. Neoechinorhynchus rutili and Nematode I larva were extremely common in Cultus smolts and completely absent from Chilco smolts. Similarly, Okanagan River, Wenatchee Lake and Redfish Lake smolts from the Columbia drainage system can be differentiated parasitologically. Okanagan smolts have a high incidence of Diphyllobothrium and Ergasilus, low Proteocephalus, and lack Diplostomulum; Redfish Lake smolts have a high incidence of Diplostomulum and Proteocephalus, and lack Diphyllobothrium and Ergasilus; a high proportion of Wenatchee Lake smolts carry Diphyllobothrium and Proteocephalus but are free of Diplostomulum and Ergasilus. In the Skeena drainage system, Babine Lake smolts can be distinguished from Lakelse Lake smolts by the much higher incidence and intensity of Philonema oncorhynchi and Nematode I larva.

Table V summarizes parasitism in young marine sockeye from Alert Bay, B.C. Lecithaster gibbosus and Contracaecum represent newly-acquired marine parasites, whereas Nematode I larvae, Diphyllobothrium and Proteocephalus are hold-overs from the freshwater fauna. The absence of these freshwater parasites from the second lot of fish is probably indicative of a different freshwater origin of the two lots. Since smolts were not examined which were likely contributing to the Alert Bay population, it is impossible to speculate on the origin of these young sockeyes.

Table VI presents a summary of the more common and significant parasites encountered in examination of adult marine sockeyes. The tabulation of areas is somewhat condensed. The sample from Bristol Bay represents catches from three distinct localities, as do the Attu (Aleutian Islands), the King Cove (Alaska Peninsula) and the high-seas sample from the Japanese Eastern Pacific catch. The sample from Okhotsk Sea represents catches from five different positions and the westernmost Pacific sample two. In addition to the 13 species in Table VI, 16 rarer species, of which at least one appears to be new, have been recorded from the adult sockeyes.

In Table VI it is noted that the distribution of parasites in marine sockeyes was not homogeneous. Some species were found everywhere without major differences in the level of infection or else were sporadically distributed and hence apparently are insignificant in the separation of major sockeye populations. Other species seem to be valuable aids in distinguishing stocks.

Two important differences between the eastern and western catches of sockeye present themselves. The samples from eastern areas (e.g., Fraser River, Bristol Bay, Attu and King Cove) showed a high level of infection with the trematode Lecithaster gibbosus whereas in the more westerly areas (170° to 173° E., 159° E. and the Sea of Okhotsk) the parasite was of much rarer occurrence. Furthermore, trematode infection in general appeared to be at a higher level in the eastern sockeye.

Secondly, the acanthocephalan Echinorhynchus was absent from North American samples, and was very common in the samples from Okhotsk Sea and 159° E. The absence of Echinorhynchus from the 170° to 173° E. sample must be treated with caution, since this sample was caught in the middle of May, whereas all other samples were taken in the last day of June, July or early August. This fact could readily imply that seasonal variations are present and that the infection with Echinorhynchus takes place in June and July. By analogy with what is known of Echinorhynchus elsewhere, the life span appears to be just short of one year. Hence by May the fish may have rid themselves of the Echinorhynchus acquired the previous year. The date of catches of the Alaska, British Columbia and far western sockeye are comparable and hence the difference in Echinorhynchus infection may be of some significance. Examination of sockeye from intermediate high-seas areas and from more North American areas will shed greater light on the importance of the observed differences.

Further reference is made here to the absence of Brachyphallus from sockeye taken in southern areas (Fraser River, B.C., and Alert Bay, B.C.), as shown in Tables V and VI. In addition, some sockeyes from high-seas areas taken between 175° W. and 180°, and 48° and 50° N. showed this same trend. (This sample is not included in Table VI because the fish were in extremely poor condition, the intestine being almost entirely decomposed and hence the assessment of intestinal parasites such as Phyllobothrium caudatum and Lecithaster gibbosus could not be made. Brachyphallus inhabits the stomach and stomach trematodes have a much greater resistance to post-mortem decomposition than do intestinal trematodes, particularly when the stomachs are empty or nearly so.) Table VII shows the distribution of Brachyphallus in this sample and indicates that 48° N. may be a critical line in the distribution of this trematode. There is apparently no relation between presence of Brachyphallus and longitude. Brachyphallus may serve to distinguish northern from southern stocks of sockeye, but more information is required.

Table VII. - Incidence and intensity of Brachyphallus in a sockeye sample from 48°00'-50°00' N. and 175°00' W-180°, 1955.

| | Date of capture | Brachyphallus |
|---|---|---|
| 48°00' N., 177°00' W. | Sep 7 | .. |
| 48°00' N., 180° | " 4 | .. |
| 49°00' N., 175°00' W. | " 4 | 100(1) |
| 50°00' N., 177°00' W. | " 3 | 84(101) |

Table VIII. - Incidence and intensity of Diphyllobothrium and Philonema in Okhotsk Sea sockeyes, 1955.

| | Date of capture | Philonema | Diphyllobothrium |
|---|---|---|---|
| 51°22' N., 154°00' E. | Jun 30 | 60(47) | 40(7) |
| 53°25' N., 153°50' E. | Jul 10 | 40(52) | 40(2) |
| 52°42' N., 154°12' E. | " 20 | 40(39) | 40(4) |
| 52°02' N., 154°30' E. | " 30 | 100(41) | 100(7) |
| 52°03' N., 154°20' E. | Aug 10 | 100(32) | 100(5) |

The low intensity of Anisakis in Fraser River adult sockeyes as compared to all other samples (Table VI) may be another difference between northern and southern stocks of sockeyes.

It was mentioned earlier that three parasites, namely, Diplostomulum, Diphyllobothrium, and Philonema, have freshwater life-histories and are detectable in seaward migrant smolts and the returning spawners. Unfortunately the results indicate that these parasites are so distributed through the North Pacific area that they cannot be used to differentiate eastern and western stocks of sockeye. They do, however, permit the separation of the three Alaskan samples and hence may be of value in separation of local stocks. For example, the Bristol Bay sockeye showed approximately 50% incidence with Diphyllobothrium, which was entirely absent from Attu and King Cove (Alaska Peninsula). Furthermore, Philonema was completely lacking in the King Cove sockeyes but was present in a high percentage of Bristol Bay and Attu sockeyes.

The data also show that if we carry these local differences one step further, it may be possible to recognize the ultimate spawning localities of a mixed population of fish taken from a specific coastal or inshore area. In the King Cove area, samples were taken from three localities, namely Cold Bay, Pavlov Bay and between Popof and Unga Island. In Cold Bay the incidence of Diplostomulum was 40% whereas this parasite did not appear in the other two localities. With further information on smolt parasites it could be possible to predict where these fish were destined to spawn. Similarly in the Okhotsk Sea sample which was taken from five localities on five different dates, we can distinguish two apparently distinct spawning populations on the basis of Diphyllobothrium and Philonema. As shown in Table VIII this differentiation is based on the time of arrival in the fishing area rather than on the specific locality at which the fish were caught. Sockeye from the first three localities shown in Table VIII, taken between June 30 and July 20, appear to be a homogeneous group, with Philonema incidence of 40 to 60% and Diphyllobothrium incidence of 40%. The samples from the last two areas, with Philonema and Diphyllobothrium intensity of 100%, were taken on July 30 and August 8, respectively. These samples are similar to one another but differ from the first three samples. 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.

It should be pointed out that there are several notable differences between the parasite fauna of pink and sockeye adults from the Fraser River estuary (cf. Tables III and IV) and hence any conclusions re distribution of parasites in sockeye are not necessarily applicable to pinks.

4. Summary of pink and sockeye studies — L. Margolis

(1) Pink fry appear to be free of parasites when on their downstream migration.

(2) Three parasites, Diplostomulum (Trematoda), Diphyllobothrium (Cestoda) and Philonema (Nematoda), are acquired by sockeye smolts, retained through the life of the sockeye and return to fresh water with spawners. These parasites have a freshwater life cycle. Because of their wide distribution none of these species can be used to distinguish Asiatic from North American sockeye populations but do seem to have use in separating local populations.

(3) Two species of helminths present interesting facts which may assist in separating Asiatic and North American stocks of sockeye. Echinorhynchus was almost absent from North American sockeye and was of frequent occurrence in sockeye from the Okhotsk Sea and far western Pacific. Lecithaster gibbosus was very abundant in North American sockeye and found in small numbers in the Okhotsk Sea and North Pacific samples from 159° E. and 170° to 173° E.

(4) The trematode Brachyphallus was found in all samples of sockeye from the high seas taken north of 48° N. and absent from sockeyes and pinks taken south of 48° N. on the high seas and south of the Queen Charlotte Sound in British Columbia coastal areas. This parasite may be of value in separating northern and southern stocks of salmon. Similarly Anisakis (Nematoda) infection was much lower in the Fraser River, B.C., sockeyes than the northern samples and may also serve to separate northern from southern stocks of salmon.

(5) There is considerable 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.

(6) The interpretations from data accumulated from sockeye studies is not necessarily applicable to other species of salmon. Fraser River, B.C., adult pinks showed several major differences from Fraser River adult sockeye.

(7) All the data indicates that considerably more sampling is required before parasitological distinction of stocks can be used effectively.

## Anatomy of Pacific salmon

M.D.F. Udvardy

Considerable time was spent at the beginning of the study in compiling the literature on the internal anatomy of the Salmonidae in general, and of the most closely related species (*Salmo salar*, *S. fario*, etc.) in particular. There is no substantial publication on the gross anatomy of *Oncorhynchus* salmon except for detailed studies on *O. tshawytscha*.

Ten specimens of *O. nerka*, 6 of *O. kisutch*, and 25 of *O. gorbuscha* were dissected for detailed study.

Emphasis was placed on the descriptive anatomy of the visceral organs together with measurements and accurate color determination.

This material is adequate for a detailed description of the organs considered, and is being worked up for eventual publication.

There is, however, a particular circumstance that has to be pointed out. All the investigated specimens were adult males and females, approaching their spawning season. There is a gradual, but marked change in size, shape, color and structure of the visceral organs of adult salmon that culminates at the time of spawning. In consequence, the cohoes (caught in June), the sockeyes (caught in June and July) and the pinks as well (caught in early August) showed no uniformity in these characters, but exhibited an amount of variation that was beyond the limit of an expected individual variation. An investigation of the data indicates that there is no correlation with size variation or with gonadal development.

The material studied was too limited, both in number of specimens and in number of collections, to establish the sequence of changes leading to the spawning condition in the species investigated. On the other hand, it could serve as an excellent basis for continued investigations on larger series, uniformly distributed throughout the life cycle of each species.

An exploratory study of the musculature of the three species resulted in the description of a previously undescribed muscle in the tail fin.

## Routine diagnosis and identification of parasites

L. Margolis

During the past year six collections of parasites from fish or marine mammals have been identified. The collections were sent in by members of other Board Stations or of Canadian Universities. The collections yielded some interesting parasites as well as probable new species.

The diagnosis of diseases in fish has been carried out for a variety of organizations and individuals, not only locally, but from distant areas. The diseased conditions were mainly tumors and abnormalities produced by parasitic invasions.

## SALMON SAMPLING FOR THE INTERNATIONAL NORTH PACIFIC FISHERIES COMMISSION

D.R. Foskett

During 1955 salmon samples and measurements in connection with the International North Pacific Fisheries Commission investigations were collected at several locations. These samples were obtained from fresh water, seaward migrants, the commercial fishery, and spawning runs. They were for anatomical studies, bone structure studies, meristic information and parasitological examination. Adult salmon obtained numbered about 600 sockeye, 600 pinks, 400 chums, 100 coho and 50 springs. About 1000 young salmon were obtained, including all species in fry and yearling stages from both salt and fresh water.

Measurements in connection with the United States Fish and Wildlife Service meristic program were obtained from sockeye, pink and chum salmon in the northern, central and southern areas. About 3000 fish were handled in this program. The inability of the measuring machine to measure many of the large-size chums considerably reduced the numbers handled and must have resulted in a considerable bias in connection with this species.

## SALMON MANAGEMENT IN THE SKEENA AREA

F.C. Withler

To improve the management of the Skeena River salmon fisheries, a Committee composed of the Chief Supervisor of Fisheries for the Pacific Area and the Director of the Nanaimo Station was set up in October, 1954. The Fisheries Research Board is conducting research projects to provide the necessary background knowledge for improvement of management techniques. The investigations contributing directly to the Committee's work are summarized in the following appendices.

Five species of salmon are taken in the Skeena River fishery. Of these the sockeye has received most attention because it is of prime commercial importance. Since the sockeye stock originating in the Babine watershed provides about two-thirds of the Skeena commercial sockeye catch, management of Skeena sockeye is primarily concerned with Babine salmon. The need for improved management has become most acute since 1951 and 1952 when the Babine spawning escapements were drastically reduced by a slide in the Babine River.

The main problem in managing any sockeye stock is to provide spawning runs of such a size as to insure fullest possible utilization of the food resources of nursery lakes, because the number of adults available to the fishery is closely related to the output of young fish to the sea. To determine the optimum escapement to Babine, several projects are under way. For the past 5 years, the spawning escapement to Babine has been counted and the numbers of resultant seaward migrating smolts has been estimated. The remarkable 1955 smolt run of about 30 million (as compared to 3 to 5 million in other years) resulted from the largest escapement so far recorded. This fact indicates that Babine spawning stocks have been too low in recent years to provide maximum outputs of young sockeye. However, evidence has been obtained that, even though total escapements are increased, maximum utilization of Babine Lake still may not be achieved. In 1955, collections of underyearling sockeye were made in different areas of the Babine Lake system. These showed that the distribution of young sockeye parallelled the distribution of the parent spawning population, and that about 70% were concentrated in 12% of the total nursery area available. It therefore appears that almost 90% of the lake was being under-utilized in 1955. If the spawning distribution could be changed to provide more young fish in the poorly used areas, it is probable that smolt production exceeding that of 1955 could be achieved.

If changes in the distribution of Babine sockeye spawning are found to be desirable, it will be necessary to control, by regulation of the fishery, the sizes of runs to specific areas of Babine Lake. To obtain information on the timing of runs, special test fishing and tagging was carried out above the Skeena commercial fishing boundary. The results indicate that the times of passage of most of the major runs to Babine are sufficiently distinct to allow the required protection to certain spawning areas. To permit special regulation, it will be necessary to measure the escapements to specific areas as they leave the fishery. Analysis of 1955 test-fishing data indicates that the catches made do, in general, reflect the abundance of fish above the boundary. Further test fishing will be needed before the catches can be used as an accurate measure of abundance of runs to specific areas.

Next to Babine, Bear and Morice Lakes are the most productive sockeye areas on the Skeena. Since growth of young sockeye is an indication of the ability of a lake to support sockeye and since growth bears an inverse relationship to population abundance when crowding occurs, collections of smolt migrants were made in both these areas. The Bear Lake smolts proved to be the largest so far obtained on the Skeena River, suggesting that the lake's capacity to support young sockeye was not taxed by the 1953 seeding and that provision of larger escapements would increase the run. Further study is needed to determine if sufficient spawning area is available to accommodate increased escapements. Sampling at Morice Lake was less successful and further observation will be necessary to obtain reliable data. Along with other projects, the adult to smolt relationship at Lakelse Lake, a minor producer, has been studied for several years.

It may be possible to improve production in areas other than Babine through regulation of the fishery. Recovery of test fishing tags in these other areas will provide the necessary information concerning the time of passage of runs through the fishery.

On the Skeena, pink salmon rank second to sockeye in commercial importance. The spawning runs which support the fishery are mainly confined to the larger tributaries of the lower Skeena. To manage pink salmon, it is necessary to determine the number of spawners required to produce the greatest number of fry from a particular stream, with the assumption that the carrying capacity of the sea is not now limiting survival and growth. The distribution and abundance of Skeena pink spawning stocks are not as well known as those of sockeye, and no information is available concerning the size of fry outputs.

To assess production from egg to fry, attempts are being made to obtain gross estimates of adult escapements and fry outputs in the major spawning areas. In 1955 a start was made through tagging and stream surveys to estimate the size of the important Lakelse River spawning run. Preparations are under way to estimate the resultant fry output in the spring of 1956. The results of these studies may indicate that special protection of specific spawning stocks is necessary to provide maximum production. In this case the test fishing and tagging program will provide essential information on the pink escapement from the fishery and on the timing of runs.

No specific research is being carried out on spring, coho or chum salmon, but the test-fishing program embraces all species and should aid in formulating special protective regulation if required, in the same manner as for sockeye and pinks.

## The 1955 Skeena salmon catch

The 1955 Skeena sockeye catch was the lowest ever recorded: 157,390 fish were taken over the period June 4 to September 24 (almost entirely by gill net). As indicated by catches, sockeye at no period were abundant in the fishing area, and the peak week (ending July 16) netted only 32,700 sockeye. In spite of the reduced 1955 fishing week (96 hours), a special total closure during the week ending July 30, and a special partial closure of the area during the week ending August 6, the escapement was estimated to be only about 150,000, of which 102,000 (30% of which were "jacks") arrived in the Babine watershed. Examination of samples of sockeye taken from the commercial catch (treated elsewhere in these reports) showed a markedly low proportion of $4_2$ fish (about 15%). This age-group was that whose parents were blocked severely by the Babine River rockslide of 1951.

On the other hand, a catch of 1,329,945 pinks was obtained, largely from gill nets, in Area 4 (Skeena), and it is believed that part of the Area 5 catch made in Ogden Channel would also consist of Skeena-bound pink salmon. This is a greater odd-year pink salmon catch than any since 1939, and approaches the 1952 catch which nearly equalled any catch since 1930. The largest weekly catch in 1955 was made during the week ending August 16; the catches prior to this week were affected by the special closures mentioned above. The fish were of large size. The escapement was better than in the brood year (1953) in nearly all streams, and was reported to have been exceptional in such pink spawning rivers as the Kispiox.

The gill-net catch of nearly 22,000 Skeena spring salmon was average for the six-year period 1950-55. Highest catches were made during the week ending July 16. Since spring salmon are also taken extensively by troll before reaching the river estuaries, it is impossible to distinguish the river origin of offshore stocks, and hence the total Skeena catch of springs cannot be estimated. The escapement of spring salmon was moderate. Spring salmon fishing received some special curtailment in 1955 over previous years, in that the upriver fishing boundary for spring salmon was the same as for sockeye salmon (Mowitch Point to Vietch Point), which boundary is several miles below the 1954 early-season spring salmon fishing boundary. The shortened fishing week (96 hours) also applied to early spring salmon fishing.

The gill-net catch of coho salmon amounted to 92,453 which is above the average for the period 1950-55. Greatest numbers of coho were taken during the week ending August 13. The catches prior to this week were affected by the total and partial special closures, primarily for sockeye, mentioned above. The escapement of coho to spawning tributaries was reported good. As with spring salmon, it is to be expected that many Skeena coho would be caught in outside waters by troll fishermen, and therefore it is difficult to estimate the total Skeena coho catch.

Chum salmon fishing was exceptionally poor, the gill-net catch of about 29,000 being the lowest recorded during the period 1950-55. The escapement of chum salmon was equally poor. The further restrictions (the lowered fishing boundary and shorter fishing week) applied to chum salmon fishing as well as to fishing for the other species.

## Test fishing and tagging in the Skeena estuary

F.C. Withler and W.F. Pinckard

To obtain an index of the size and composition of salmon escapements from the Skeena fishery early enough to be useful for regulation, and to secure salmon for tagging to determine the timing through the fishery of the runs to various spawning areas, special fishing was carried out by two chartered gill-net boats above the Skeena commercial fishing boundary in 1955.

A total of 291 drifts of approximately one-hour duration each was made from May 26 to September 28. Fishing was carried out only on slack tides, and the procedure was made as uniform as possible in all respects in order that catches might be compared. Up to July 17 a 200-fathom, 50-mesh commercial nylon net of 5 1/8 inches stretched measure was used; after July 17 fishing was carried out with a 200-fathom gillnet composed of different meshes ranging from 3 1/2 inches to 8 inches stretched measure.

The numbers of each species of salmon caught, the numbers tagged, and the numbers of recoveries are given in the following table:

| | | | No. recovered | |
|---|---|---|---|---|
| | No. caught | No. tagged | from fishery | from upriver |
| Sockeye | 1173 | 822 | 113 | 69 |
| Spring | 782 | 376 | 48 | 22 |
| Pink | 3590 | 1488 | 28 | 34 |
| Coho | 483 | 233 | 27 | 2 |
| Chum | 124 | 45 | 1 | 0 |
| Total | 6,152 | 2,964 | 217 | 127 |

Analysis of the deviation of sockeye catches from the trend line shows that the state of the tide when the drift was made (high-water slack as opposed to low-water) did not affect the catches significantly. A similar analysis to determine whether or not sockeye catches are affected by an open or closed period in the fishery shows this factor to be highly significant: catches were higher during closure of the fishery, lower when the fishery was open. These results indicate that the method employed will provide a reliable index of the abundance of salmon immediately above the fishing boundary. It will require one or two more seasons to relate the size of catches above the fishing boundary to the size of escapements to the spawning grounds.

Before such information can be used to permit desirable escapements by regulation, it is necessary to determine the times at which stocks bound for various spawning areas are present in the fishing area. The tagging data of 1944-48 have been re-analyzed and added to the information obtained in 1955: in all years 10,741 tags have been applied to sockeye salmon and of these 1486 have been recovered on spawning grounds or enroute.

In general, the recoveries show the following with regard to time of passage:

(a) Babine sockeye are present in the fishing area throughout the sockeye fishing season (approximately June 15 - August 10).

(b) Lakelse and Alastair Lake sockeye are present up to the end of June.

(c) Bulkley River sockeye (migrating largely to Morice Lake) are present from June 15 to July 30.

(d) Kitwanga and Johanson Lake sockeye have been found to be present during the period July 19 to July 27.

Considerable separation of sockeye runs to different spawning areas <u>within</u> Babine Lake are also possible on the basis of tagging in the ocean and estuary:

(a) Babine sockeye bound for Nine Mile, Six Mile, Pendleton and Sockeye Creeks are present in the fishery in June.

(b) Sockeye migrating to Twin, Pierre, Tachek and Four Mile Creeks are present from about June 15 to July 10.

(c) Sockeye migrating to Fifteen Mile, Morrison, Grizzly and Five Mile Creeks are present from about July 7 to July 21.

(d) Those bound for Fulton and the Upper and Lower Babine Rivers are present from about July 15 to August 10.

Tagging data to provide information on the timing of runs of other species is still too scant to be useful, but some is now available for pink and spring salmon.

## <u>Salmon enumeration at the Babine fence in 1955</u> K.V. Aro

The runs of sockeye salmon to the Babine Lake watershed have been counted annually since 1946 at the Babine River adult counting fence with the exception of 1948 when floods damaged the structure. The size of the 1948 run was estimated by observations on the spawning grounds. The weir count has been accepted as the best single measure of the sockeye escapement to the Skeena River since the initial discovery that the runs to the Babine watershed constitute about 70% of the Skeena escapement. The data from the fence took on further importance since 1951 when the blockage occurred on the Babine River.

The 1955 adult count, which is reported below, is of great interest because the 4-year-olds, which are usually the most important single component of the run, were the progeny of those fish which surmounted the rock slide in 1951. In addition the 3-year-old sockeye were the young of the slide-affected fish of 1952.

The counts of the five species of salmon which passed the Babine fence during the period of operation (July 4 to October 3) in 1955 are compared in the following table with counts obtained in other years.

| Year | Sockeye No. | Sockeye % "Jacks" | Spring | Pink | Coho | Chum |
|---|---|---|---|---|---|---|
| 1946 | 475,705 | 12.2 | 10,528 | 28,161 | 12,489 | 18 |
| 1947 | 522,561 | 50.0 | 15,614 | 55,421 | 10,252 | 7 |
| 1948 | 560,000* | | | | | |
| 1949 | 509,132 | 9.4 | 7,433 | 13,663 | 11,938 | 5 |
| 1950 | 543,658 | 33.0 | 6,838 | 38,728 | 11,654 | 7 |
| 1951 | 152,457 | 7.2 | 2,778 | 50 | 2,122 | 0 |
| 1952 | 376,947 | 7.4 | 5,915 | 2,706 | 10,554 | 1 |
| 1953 | 714,614 | 3.9 | 8,353 | 1,108 | 7,648 | 17 |
| 1954 | 503,422 | 1.9 | 5,925 | 4,604 | 3,094 | 66 |
| 1955 | 101,976 | 30.0 | 3,528 | 2,151 | 8,947 | 3 |

*Estimated from comparison with stream survey counts and fence counts of previous years.

The count of <u>sockeye</u> salmon in 1955 was the lowest recorded since fence operations began in 1946. The first sockeye passed the fence on July 6. Thereafter the count increased very slowly until August 1 when 2750 sockeye passed the fence. Following this early peak the count declined to 810 sockeye on August 10 and then rose to the main peak of 5505 sockeye on August 24 after which the run declined until only 40 sockeye were counted on October 3, the last day of counting. The low total count is due in part to a poor return of 4-year-old sockeye which are the progeny of the small run which managed to pass the Babine River rock slide in 1951. However, even when the effects of the slide are taken into account the run was below expectation, as were many sockeye runs from the Fraser to Alaska.

The run of <u>spring</u> salmon was smaller in 1955 than in any non-slide year but was larger than in the slide-blocked run of 1951 from which many of the 1955 spawners were derived. The count provides an index of the run to the Babine River. Spring salmon spawn below the fence as well as above it.

<u>Pink</u> salmon passed the fence in numbers twice that in the cycle year 1953 and 40 times that in the slide-blocked cycle year 1951. Though the pink salmon runs are still much smaller than prior to the Babine River rock slide, the recent increases indicate a gradual recovery of the Babine River pink salmon runs. As with springs, some pinks spawn below the fence. In 1955 it was estimated that equal if not slightly greater numbers spawned immediately below the fence than above it.

The <u>coho</u> salmon run was slightly smaller than in 1952, the cycle year, and in the pre-slide years.

A few <u>chum</u> salmon again reached the Babine River.

## Sockeye sampling at the Babine fence

In order to obtain details on the size and sex ratios of Babine sockeye, samples amounting to 2% of the previous half day's count were measured and sexed throughout the period of the run. The numbers of "jacks" (3-year-old males) as compared to larger sockeye were calculated from the "jack count" which is made for an hour daily. The proportions of normal, injured and net-marked individuals among the larger sockeye were also noted.

The jack count (22% of the total sockeye count) indicated that 30% of the run were jacks and 70% were larger sockeye. The calculated number (71,352) of larger sockeye in 1955 was only one-half of that in the previous low year, 1951. The jack count showed that among the larger sockeye 6.1% had net marks, 6.7% were injured, and 87.2% were normal. The percentage of injured fish was slightly higher, and that of net-marked fish lower than in other non-slide years. The lower percentage of fish with net marks probably indicates the effectiveness of the special closure in the Skeena gill-net area in permitting escapement of the main portion of the Babine sockeye run.

From the 2% sample, the sex ratio of the larger sockeye was 47.2% males and 52.8% females. Length-sex frequency plots suggest that about 60% of the larger sockeye were 4-year-olds and 40% 5-year-olds. The sample also showed that the average size of the jacks, larger males, and females was 38.2, 55.7 and 57.9 centimetres, respectively. In each case the sockeye were smaller than the nine-year average.

A probable egg content of 3126 was calculated by applying the average length of the females to the egg-length regression formula which had been determined from the egg samples of previous years. The potential egg deposition, the product of the probable egg content and the calculated number of females (37,700) was 118 million eggs. This seeding was lower than the low seedings recorded during the years when the Babine River rock-slide was in effect.

## Size of Babine sockeye smolt runs, 1951-1955

Since 1951 estimates have been made of the size of the sockeye smolt emigration from the Babine watershed by a marking and recovery technique employing smolt traps at the outlets of Babine and Nilkitkwa Lakes. Using estimates (from Babine fence data) of potential egg depositions from 1949 to 1953, it has been possible to calculate survival to smolt stage from eggs carried into the system each year. The egg depositions in 1951-52 were much below normal because of the effect of the Babine River rock slide, while the 1953 egg deposition was much above normal because of the large escapement which entered Babine Lake as a result of the special closure in the Skeena gill-net area. The smolt runs which have emanated from these variable egg depositions have provided information on the relationship between broods of varying size and subsequent smolt production.

Employing the technique used from 1951 to 1954 to obtain an estimate of the size of the Babine smolt run, the 1955 smolt run was estimated to be 30.9 million, several times greater than the largest run in the previous five years of operation. The method employed involves the capture and marking of portions of the run as it passes the outlet of Babine Lake, and the subsequent recovery of some of the marked fish in examination of the catches at the outlet of Nilkitkwa Lake some eight miles downstream from the Fort Babine trap site. Ratios of marked to unmarked smolts in the samples are used to estimate the size of the run passing the upstream trapping device.

The total numbers of smolts marked and released, the total numbers of marked fish recovered, and the total samples recovered in each year are given in the following table. Final estimates of the run for each year have been adjusted to conform with known changes in the mark/catch ratio at Fort Babine and to allow for the late installation of trapping structures in 1951 and 1955, when portions of the run had passed before trapping began.

| Year | No. of smolts marked | No. of marked smolts recovered | Size of sample examined | Estimated size of runs | 95% limits |
|---|---|---|---|---|---|
| 1951 | 34,689 | 200 | 21,855 | $4.2 \times 10^6$ | $3.7$ to $4.8 \times 10^6$ |
| 1952 | 33,880 | 646 | 86,391 | $4.5 \times 10^6$ | $4.2$ to $4.9 \times 10^6$ |
| 1953 | 61,950 | 2,498 | 124,396 | $3.1 \times 10^6$ | $3.0$ to $3.2 \times 10^6$ |
| 1954 | 42,631 | 1,156 | 81,082 | $2.8 \times 10^6$ | $2.7$ to $3.0 \times 10^6$ |
| 1955 | 113,931 | 1,287 | 270,546 | $30.9 \times 10^6$ | $28.6$ to $32.6 \times 10^6$ |

Certain errors associated with the possibility of increased mortality due to marking by fin-clipping and with the likelihood of disproportionate intensities of marking with relation to the run passing Fort Babine each day cannot be assessed and have been treated as constant each year.

Assuming that all smolts are 1-year-olds, survival from eggs potentially available in the spawning run to resulting smolts have been calculated and are shown in the table below for the brood years from 1949 to 1953.

| | 1949 | 1950 | 1951 | 1952* | 1953 |
|---|---|---|---|---|---|
| Eggs potentially available | $869 \times 10^6$ | $583 \times 10^6$ | $198 \times 10^6$ | $411 \times 10^6$ | $1254 \times 10^6$ |
| Year smolts appear | 1951 | 1952 | 1953 | 1954 | 1955 |
| Estimated no. of smolts | $4.2 \times 10^6$ | $4.5 \times 10^6$ | $3.1 \times 10^6$ | $2.8 \times 10^6$ | $30.9 \times 10^6$ |
| Survival egg to smolt | 0.48% | 0.77% | 1.57% | 0.68% | 2.46% |

*Only about one-third of this run spawned successfully, reducing the potential egg deposition and raising smolt survival to about 2%.

A tendency for greater numbers of smolts to result from increased egg depositions seems to obtain at Babine; an increase in the survival to smolts from smaller egg depositions is also indicated for the adult runs from 1949 to 1952. However, the egg to smolt survival from the 1953 spawning run, which was by far the largest recorded in the years of Babine Fence operation, was higher than that of any other run. Recent work by Johnson (elsewhere in these reports) shows that the Babine Lake system appears to be composed of several distinct nursery areas. The survival rate within these areas may vary considerably depending upon a number of factors, including the food available and the concentration of young sockeye. It is known from spawning stream surveys that the proportions of adult sockeye spawning in the streams tributary to these areas may vary considerably from year to year. Therefore the survival rates obtained for Babine Lake as a whole are composites of the survivals in the several nursery areas and may not show a consistent relationship to the size of the annual broods.

The 1956 smolt run will be the product of the 1954 brood which produced a potential egg deposition of 1020 million eggs.

## Age, sex, growth, and parasite studies of Babine Lake sockeye smolts

Since 1950, samples of sockeye smolts have been taken either for special study or in conjunction with the smolt run estimation project. The sampling site has varied between the Babine fence, the Nilkitkwa Lake smolt trap and the Fort Babine smolt trap. In 1955, because of water-level conditions, the sample was taken first at the Nilkitkwa Lake trap and later at the Fort Babine trap.

Examination of scales has shown, as indicated in the following table, that the smolts leaving Babine Lake are predominantly 1-year-old fish. The table also indicates that the sex ratios in each age-group do not depart significantly from a 50:50 assumption.

| | 1-year-old | | 2-year-old | |
|---|---|---|---|---|
| Year | Males | Females | Males | Females |
| 1950 | 1296 | 1320 | 5 | 9 |
| 1951 | 1428 | 1367 | 6 | 4 |
| 1952 | 826 | 828 | 6 | 5 |
| 1953 | 629 | 605 | 8 | 14 |
| 1954 | 467 | 505 | .. | .. |
| 1955 | 966 | 978 | 1 | 1 |

Lengths and weights of all smolts have been recorded also. That considerable differences exist in average sizes between years and between samples taken at the Nilkitkwa Lake and Fort Babine traps is shown in the table below:

| | | Fork length (mm.) | | Weight (gm.) | |
|---|---|---|---|---|---|
| Year | No. in sample | Range | Average | Range | Average |
| 1950 | 2616 | 54-104 | 83.0 | 1.3-10.6 | 5.5 |
| 1951 | 2795 | 58-111 | 82.4 | 1.6-12.8 | 5.6 |
| 1952 | 1654 | 55-109 | 80.4 | 1.3-12.7 | 4.9 |
| 1953 | 1234 | 70-111 | 86.0 | 2.4-13.5 | 6.2 |
| 1954 | 972 | 62-110 | 86.4 | 2.8-12.6 | 6.3 |
| 1955 N | 431 | 56- 93 | 72.7 | 1.6- 8.2 | 3.8 |
| 1955 FB | 1513 | 60-105 | 83.9 | 2.1-11.0 | 5.8 |

N = Nilkitkwa Lake smolt sample
FB = Fort Babine

When the average size of smolts for each year is compared with the estimated size of the run in that year, an inverse relationship between size of run and size of smolts exists for the years from 1950 to 1954, but this relationship does not hold for 1955. Recent studies indicate that Babine Lake is composed of several nursery areas which contain varying concentrations of smolts differing in size in each area. It is evident from the table above that the smolts in the Nilkitkwa Lake sample were considerably smaller than those sampled at Fort Babine. This suggests that these early-running smolts were from a separate population resident either in Nilkitkwa Lake or the north arm of Babine Lake.

In the examination of smolt samples, notations have been made since 1952 regarding the presence or absence of infection by the cestode Eubothrium salvelini (Schrank, 1790) and the nematode Philonema oncorhynchi (Kuitunen-Ekbaum, 1933). In 1952 and 1953 about 30% of the smolts were infected by cestodes and 10% by nematodes. In 1954 and 1955, however, the percentages have become reversed to 10% cestode and 30% nematode infection. From 2 to 10% of the smolts had both parasites. The 1955 data show that those fish which were sampled at the Nilkitkwa Lake had a higher infection of cestodes and lower infection of nematodes than those sampled at Fort Babine, suggesting that the degree of infection may vary between the nursery areas. Fish infected by cestodes were smaller than uninfected fish or those with nematodes only. Smolts infected by nematodes were larger than uninfected individuals.

## Age, sex and parasites of Bear and Morice Lake sockeye smolts

In order to obtain sockeye smolt samples, Bear Lake was visited for the period from June 21 to June 29 and Morice Lake for the period July 6 to July 16. In both lakes fine nylon gill nets of 3/4" and 1" mesh were placed at the lake outlets. At Bear Lake a total of 694 sockeye smolts were caught; at Morice Lake, because of the lateness of the season, only one sockeye was captured. Many coho smolts and small fish of other species were captured at both lakes.

Examination of scales of the Bear Lake smolts showed that they were all 1-year-olds but that considerable growth had been made in the spring prior to emigration. The sex ratio of 544 Bear Lake fish examined for sex was 276 males to 268 females, which does not depart significantly from a 1:1 ratio. Lengths and weights of the smolts are shown in the following table:

| Fork length (mm.) | | Weight (gm.) | |
|---|---|---|---|
| Range | Average | Range | Average |
| 81-105 | 91.0 | 5.6-12.4 | 7.8 |

Comparison with Babine and Lakelse Lake sockeye smolts shows that the average size of smolts sampled at Bear Lake in 1955 was greater than that of smolts sampled in any year at Babine or Lakelse Lakes.

Examination of 544 Bear Lake smolts showed an absence of adult cestodes and nematodes; however, 15 of the smolts were found to contain larval Diphyllobothrium.

The one sockeye caught at Morice Lake was a male in its fourth year, 132 mm. in length and 20.9 gm. in weight. It appeared to be a non-migratory sockeye rather than a smolt.

## The pink salmon run to the Lakelse River, 1955

J.G. McDonald and
M.P. Shepard

The Lakelse River is one of the main pink-producing areas of the Skeena drainage. As an initial step in a program aimed at laying the basis for management of the Skeena pink salmon fishery to provide optimum escapements, the 1955 adult run to the Lakelse River was estimated by stream surveys and a tagging program. In January, 1956, redd sampling was carried out to provide information on survival during the incubation period. In the spring of 1956 attempts will be made to estimate the numbers of fry moving out of the river.

Estimation of number of adults. To estimate the abundance of the adult run, the number of pinks in yard-wide sample strips extending from bank to bank were counted or estimated at representative points down the 13 miles of river between Lakelse Lake and the Skeena. An estimate of the population could then be gained by multiplying the average figure for the whole river by the length of the river.

To check this method, the Lakelse River fence (located about 600 yards downstream from the upper limit of spawning in the river) was installed and the number of fish spawning in the area above the fence estimated by the sample-strip technique and by tagging. The results suggested that not all the fish in each sample strip were visible and that by multiplying the estimates obtained by the strip technique by 1.3, a more accurate assessment of the runs would be gained.

The results of the survey (and of fence data from earlier years) indicated:

(1) the peak of the pink run to the upstream part of the Lakelse River occurs in mid-September (about September 16 in 1955), while the run in the lower part of the river tended to be somewhat later;

(2) the interval between arrival of fresh fish on the grounds and their death was of the order of three weeks;

(3) the total spawning run to the Lakelse River was about 172,000 (approximate limits 128,000 to 216,000). With an estimated male/female ratio of 0.96 and an average egg content of about 1600 per female, the potential deposition was of the order of 140,000,000 eggs (approximate limits (105,000,000 to 177,000,000);

(4) the fish were present in greatest concentration in the upstream part of the spawning area, with over half the observed spawners being found in the mile immediately below the upper limit of spawning.

Redd sampling. Forty-six redds were sampled between January 18 and 23 in six sections comprising the upper end of the Lakelse River. The total length of river covered was approximately three miles and about 75% of the spawning occurred in this area. The sampling should therefore be fairly representative of the run as a whole.

Living eggs and young were present in almost all stages of development. The majority (75%) were in the late eyed stage while 22% were not yet eyed and 7% were alevins.

The total number of eggs in the 46 samples was 17,626. Of these, 12,679 were alive, indicating a survival of about 72%. The survival in individual redds ranged from 0 to 99%. Survival was generally lower in the uppermost sections of the spawning area. This may be related to three factors; firstly, superimposition by later running coho which spawned in this section; secondly, the relatively large amount of silt observed in the redds at the time of sampling; and thirdly, the relatively high density of spawners in this section.

It was apparent that many dead eggs had been partially eaten, presumably by the insect larvae and nymphs found in the samples. The possibility therefore exists that some loss of dead eggs had occurred and that consequently the survival values are erroneously high. However, a close examination of the samples suggested that the disintegration of eggs either through the actions of the insects or of fungus had not occurred to any great extent. It was concluded that a fairly representative picture of survival up to the time of the examinations had been obtained.

## AGE COMPOSITION OF SOCKEYE CATCHES AND ESCAPEMENTS - D.R. Foskett

Because of the very low sockeye runs in the northern and central areas in 1955, the catch samples, which are taken on a percentage basis, were also small, with the exception of the Nass River sample. A total of 4380 sockeye was taken of which 396 were from the Rivers Inlet escapement.

The Nass River sample of 1448 sockeye was composed of 70% of $5_3$ fish, 15% $5_2$ fish and 12% $4_2$ fish. Small numbers of $3_1$, $4_1$ and $6_3$ fish were also present. The fish were of normal length and weight.

The Skeena River sample of 604 sockeye consisted of 15% $4_2$ fish, 59% $5_2$ fish, 14% $5_3$ fish and 11% $6_3$ fish. A few jacks of both the $3_2$ and $4_3$ age-groups were also present in the catch. Sizes were within the normal range for this system.

The Rivers Inlet catch sample consisted of 685 sockeye of which 45% were $4_2$ fish and 54% $5_2$ fish. A few $5_3$ and $6_3$ fish were also present in the sample. Sizes were normal for this population. Through the courtesy of the Fisheries Department, lengths and scales of 231 sockeye were obtained from sockeye seined above the boundary incidental to spring salmon tagging operations and from 165 sockeye examined on the redds. Age-class representations in the seined fish were $3_2$ and $4_3$ fish (jacks), 1%; $4_2$ fish, 79%; and $5_2$ fish, 20%. The $4_2$ age-group in the seined fish consisted largely of small fish, the average length being 19.8 inches while the average length of this age-group in the catch was 21.1 inches. Samples taken on the redds generally have eroded scales and though separation into age-classes by means of length frequencies is fairly reliable, the problem of representative sampling is extremely difficult. Nevertheless, the stream samples support the figures obtained from the seining in that the $4_2$ fish were the most numerous group in the escapement. It is regrettable that we have no knowledge of what effect securing most of our escapement from the smaller fish will have on future runs.

The Smith Inlet catch sample consisted of 762 sockeye of which 42% were $4_2$ age-group and 58% $5_2$ age-group. One $5_3$ fish was also present in the sample.

In addition to the above sampling, sockeye, from both the seine and gill-net fisheries in the Dean and Burke Channel areas, were sampled when possible. As is normal there were differences in the percentage composition of the samples obtained by the different gear though it is impossible to say how much of these differences are due to gear selectivity and how much due to differences in the populations fished. However, it is certain that much of the difference between the 0.3% jacks ($3_2$ fish) in the gill-net catch and the 8.2% jacks in the seine catch is due to gear selectivity. The bulk of the sockeye examined, 85% in the overall sample, were 4-year-old fish.

Results of the 1954 sampling have been published as No. 40 in the series "Contributions to the life-history of the sockeye salmon" in the 1954 report of the British Columbia Fisheries Department.

## SOCKEYE SALMON STUDIES AT THE PORT JOHN FIELD STATION - J.G. Hunter

### Adult sockeye salmon escapement, Port John, 1954 and 1955

Every year adult sockeye migrate into the Port John system well in advance of spawning time. High water conditions in late June usually herald the arrival of the first few fish. Stream water levels control to a large extent the time at which these fish go upstream and into the lake. The first of these sockeye enter the tributary stream, Tally Creek, to spawn about the second week of September.

Almost the entire run of sockeye salmon spawn in Tally Creek; all other streams are examined and stream counts of spawning sockeye are made. A loss of about 25 to 30% of the sockeye entering the system occurs before spawning. This loss is believed to be natural mortality during the long lake-residence period.

The escapement into the Port John system in 1954 and 1955 was 1470 and 2566 sockeye respectively. The numbers spawning for these two years were 1000 and 1800 respectively.

A large proportion of the sockeye entering Hooknose Creek are "jack" sockeye. A total of 572 jacks was recorded in 1954 and 935 in 1955. Sockeye salmon egg depositions in Port John were 789,000 in 1954 and 1,180,000 in 1955. The 1955 run of sockeye was the largest yet recorded at Port John.

Production of sockeye salmon fry in 1955 and experimental planting in sea

The sockeye fry migration from Tally Creek began about the middle of April and finished about the middle of June. This is an average period of egress although exceptions have been noted.

It was calculated that sockeye deposited 661,484 eggs in Tally Creek in 1954, from which 64,324 fry emerged to pass downstream through the counting weir - a 9.72% survival. Not all adults spawned in Tally Creek, but assuming a similar survival in other spawning areas, a total of 76,714 fry were produced. All the fry from Tally Creek, with the exception of an estimated 3,024 which escaped during a freshet, were transported to and released in the sea. The calculated number of 1955 sockeye fry remaining in Port John Lake is 15,414.

Sockeye fry could not be transferred to sea water until the yolk sac had been completely absorbed; this necessitated holding the young fish until absorption was complete. Heavy mortality resulted from the holding operation and transportation of the fry. A total of 43,088 sockeye fry were released to sea during the spring. In order to check on the survival of these young fish in the sea they must be identified, thus all migrating sockeye smolts (with the exception of 442 smolts which escaped during a freshet) were marked by the removal of the adipose and left ventral fins. Further marking of smolts will be required in 1956 to ensure identification of the transplanted fry.

Sockeye smolt production at Port John in 1955

Sockeye smolts began their downstream movement at Port John April 11 and completed their egress by June 14. A total of 14,866 smolts were counted; a 1% sample was taken for measurements and age analysis. Apart from 504 which were killed in the fence operation and 442 which escaped during a freshet, the remainder, 13,779, were marked by the removal of the adipose and left ventral fins before being released to sea.

The 1955 samples have not yet been examined for age but the 1954 age analysis showed 33% 1-year-olds and the remainder 2-year-olds. This has been the greatest percentage of 1-year-olds found in a Port John run. They were the product of the smallest recorded number of young sockeye in the lake.

In the spring of 1952, 5,075 sockeye fry were marked by the removal of the two pelvic fins to confirm the reading of 1-, 2- and 3-year scales. The recovery of marked fish as smolts was as follows:

| Year | Age | Number of marks recovered | Percent of all returns |
|---|---|---|---|
| 1953 | I | 21 | 3.95 |
| 1954 | II | 500 | 93.98 |
| 1955 | III | 11 | 2.07 |

This marking experiment confirmed the ages of the migrating smolts indicated by scale examination.

## LAKE SOCKEYE SALMON INVESTIGATIONS - M.P. Shepard

The purpose of the investigations is to determine the factors which limit the production of sockeye in fresh water. It is hoped that they will provide the biological basis for practical measures to increase the production of sockeye in lakes. As almost all the mortality that occurs during the sockeye's life takes place between egg deposition and the seaward migration of smolts, and since the output of smolts has been shown to be directly related to the size of the adult return, those factors which influence fresh-water survival are all-important in determining the numbers of adults available to the fishery.

The basic measures of production have been enumerations of the numbers of spawning adults (and hence the related egg deposition) and the resultant fry and smolts. For several years these enumerations have been carried out at Lakelse Lake, a small lake in the lower Skeena area, with an average adult run of approximately 14,000 spawners. In addition to the enumeration program, special studies on the effects of certain environmental factors on sockeye production have been conducted at Lakelse and elsewhere.

### Runs of adult sockeye to Lakelse Lake — M.P. Shepard and R.M. Humphreys

To obtain estimates of the numbers of spawners at Lakelse and of the number of eggs deposited, fences have been operated on the two major tributary streams (which accommodate over 90% of the run) every year since 1949. From 1944 to 1948 the runs to the Lakelse spawning grounds were estimated by stream surveys. In earlier years, some records of the abundance of adults were obtained as part of a hatchery program. The enumeration data are summarized in the following reports.

#### 1. The Williams Creek spawning run, 1955. — R.M. Humphreys

The 1955 run of sockeye to Williams Creek was the smallest yet recorded at Lakelse. Only 3518 spawners passed through the weir. The timing of the run was similar to that observed in earlier years. The first fish ascended the creek on August 3, and the run rapidly built up to a peak on the 10th. By the 17th, two weeks after the first fish, 75% of the total spawners had arrived. The migration continued until the end of September, with a marked rise in numbers about two weeks before the end of the run.

The mean number of eggs per female was estimated at 3538. As the total number of females counted through the Williams Creek fence was 1776 (50.5% of the run), the potential deposition was estimated to be 6,300,000 eggs.

As in all years since 1952, periodic stream surveys were carried out. Since 1952 there has been a continuous shift in the distribution of spawners from the upstream part of the creek to the downstream. In 1952 the lower two-thirds of the spawning ground had a very sluggish flow which provided very poor spawning conditions for the sockeye. In the summer of 1953, blockage of an upstream diversion channel (by personnel of the Department of Fisheries) greatly increased the flow in the downstream area. The autumn freshets of 1953 cleared out the silt and algal growth in the lower reaches of the creek to a limited degree, making it more suitable for spawning. The freshets of 1954 brought about an even greater improvement.

It is felt that the increasing concentration of spawners in the downstream area is, in part, a reflection of the steadily increasing suitability of this area for spawning and for incubation. However, another factor affecting distribution of spawners is the size of the runs. The number of spawners at Williams Creek has decreased each year since 1952. It is likely that there is some tendency for small runs to concentrate near the mouth of the creek, while larger runs tend to be dispersed more evenly throughout the available spawning area. The striking change in spawning distribution occurring from 1953 to 1954 (see table below) is, however, not readily accounted for by changes in numbers of spawners (the 1954 run was only 20% smaller than that of 1953) and changes in the suitability of spawning grounds is felt to be the major cause of the change. In the following table the proportions of spawners in the upstream and downstream areas of Williams Creek at the peak of the run are listed.

| Year | Total run | Distribution Upstream | Distribution Downstream |
|---|---|---|---|
| | | percent | |
| 1952 | 9932 | 67 | 33 |
| 1953 | 8505 | 57 | 43 |
| 1954 | 6789 | 16 | 84 |
| 1955 | 3518 | 0 | 100 |

2. Total spawning run to Lakelse, 1955. R.M. Humphreys

The runs of sockeye to spawning grounds other than Williams Creek were estimated by stream surveys. The 1955 figures are compared with those of earlier years in the following table:

| Creek | 1952 | | 1953 | | 1954 | | 1955 | |
|---|---|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent | Number | Percent |
| Williams | 9,932 | 82.5 | 8,508 | 91.5 | 6,789 | 88.2 | 3,518 | 94.6 |
| Scully | 1,103 | 9.2 | 627 | 6.8 | 714 | 9.3 | 165 | 4.4 |
| Other | 1,000 | 8.3 | 160 | 1.7 | 195 | 2.5 | 35 | 1.0 |
| Total | 12,035 | 100.0 | 9,295 | 100.0 | 7,698 | 100.0 | 3,718 | 100.0 |

Based on the mean egg content of females and the sex ratio observed at the Williams Creek fence, the total deposition in the Lakelse area in 1955 was estimated to be 6,600,000 eggs.

3. The adult runs to Lakelse Lake, 1921-1955. M.P. Shepard

Since hatcheries were established at Lakelse in the early 1900's, information on the abundance of adult sockeye has been obtained every year with the exception of 1940-1943. The records may be divided into four general periods. The first is from 1921 to 1938 where hatchery records and Inspectors' reports provide a gross picture of the runs. The second period is from 1944 to 1948 when the adult runs were estimated from stream surveys and tagging experiments. The third period was from 1949 to 1952, when the runs were estimated from partial fence counts. The final period was from 1953 to the present, when accurate fence counts were obtained of the great majority of each year's run. A fence count of the majority of the run was also obtained in 1939.

(a) 1921-1937. Very gross estimates of the size of spawning runs can be gained from hatchery records and Inspectors' stream surveys. From 1921 to 1934 partial fence counts of the adults moving up Williams Creek were obtained as part of the hatchery egg-taking operation. Using these as a basis, the runs during this period are estimated to have exceeded 25,000 spawners in some years, and may have dropped as low as 2500. The mean level was probably in the order of 15,000 spawners.

(b) 1944-1948. Estimates in these years were based largely on tagging experiments, in which either fish entering the lake or fish congregated off the mouths of the spawning creeks were tagged and surveys conducted to determine the proportion of tagged fish in the spawning population. Experiments at Lakelse from 1952 to 1954, in conjunction with accurate fence counts, indicated that the tagging method tended to over-estimate the population. Approximate correction factors were developed and applied to the tagging experiments of 1944-48 with the following results:

| Year | Tagging estimate | Corrected estimate |
|---|---|---|
| 1944 | 25,000 | 16,500 |
| 1945 | 57,000 | 33,000 |
| 1946 | 40,000 | 29,000 |
| 1947 | 17,000 | 13,500 |
| 1948 | 15,000 | 13,000 |
| Average number | 30,800 | 21,000 |

In general, the corrected estimates are about 30% below the original figures. Comparisons of the total number of fish seen on the surveys with similar total counts made in recent years suggest that the corrected estimates may still be somewhat high, especially in the years when the two largest estimates were made (1945 and 1946).

(c) 1949 to 1952. In 1949, fences were installed in the two main sockeye streams, Williams and Scully Creeks. However, in 1952 a series of stream surveys on Williams Creek revealed that a large number (70%) of sockeye spawners had entered the creek through a flood channel that was not fenced. Early surveys of the Williams Creek area suggest that this flood channel did not exist prior to 1950, and had therefore probably broken through some time between 1949 and 1952.

Based on counts at fences in the creeks, the estimated total Lakelse egg deposition in 1950 was about 2,200,000. The resultant smolt run, counted in 1952, was about 596,000, giving a survival rate from egg to smolt of about 27%. As survival rates of this order have never been observed in any sockeye area it is probable that the estimate of the 1950 adult run was in error, and that a large proportion of the 1950 run had passed into Williams Creek undetected. Thus, it is likely that the break-through first observed in 1952 had been in existence at least since 1950.

As described in previous annual reports, the 1952 run was estimated on the basis of stream surveys. However, as no surveys were conducted in the two previous years it is difficult to estimate the runs of 1950 and 1951. Assuming that the proportions of the run migrating through the diversion channel in those years were similar to that in 1952, it is possible that the 1950 run to Williams Creek was in the order of 5000 adults, while that of 1951 was about 16,000. In these years it is probable that the runs to Williams and Scully Creeks comprised about 90% of the total run.

In the following table the estimated total spawning runs at Lakelse from 1949 to 1952 are listed. The figures for 1949 to 1951 were obtained by adding the Williams Creek estimate to the Scully Creek fence count and multiplying the total by 1.1 to account for the runs to other creeks. The 1952 figure is based on surveys carried out on all creeks.

| Year | Total run |
|---|---|
| 1949 | 7,500 |
| 1950 | 6,200 |
| 1951 | 19,000 |
| 1952 | 12,000 |

(d) 1939, and 1953 to 1955. Since 1953 accurate fence counts have been obtained of the adult runs to both Williams and Scully Creeks. Stream surveys on the other creeks draining into Lakelse Lake indicate, in recent years, that the Williams and Scully runs have composed well over 90% of the run. The total adult counts in these years are listed in the preceding section. In 1939 a complete fence count at Williams Creek showed a spawning run of 24,085. Estimates of runs to other creeks amounted to 7,000-10,000, giving a total run of about 31,000 to 34,000.

(e) Commercial exploitation of the Lakelse adult run. Analyses of data on the timing of the Lakelse run through the fishing area (derived from tagging experiments conducted from 1944-1948 and in 1955) and of fence counts, have permitted gross calculations of the numbers of Lakelse sockeye taken in the commercial fishery. In 1952 it was estimated that 17.2% of the run (4010 fish) was caught, whereas in 1953, 14.7% or 1903 fish were taken. A higher proportion would have been taken in 1953 had a strike not delayed the opening of the fishing season. The calculated rates of exploitation in these two years are much lower than that estimated for the Skeena River as a whole (somewhat over 50%). This is due to the fact that the Lakelse adults migrate earlier than most of the other runs, and that most of them have passed through the fishing area before the fishing season commences. Prior to 1949 the fishing season opened a week later than in recent years. Thus, in the years prior to 1949 an even smaller proportion of the Lakelse run was fished. It is estimated that the rate of exploitation then was approximately 35% lower than that of recent years.

4. <u>Age composition of Lakelse adult sockeye runs, 1952-1955.</u> M.P. Shepard and D.R. Foskett

To determine the age composition of the adult sockeye runs to Lakelse, representative scale samples have been obtained from fish passing through the Lakelse River fence each year since 1952.

Classification of the samples with respect to the duration of fresh-water residence has been difficult in some years due to the presence of an auxilliary "check" near the nucleus of the scale. Preliminary readings of the scales suggested that a considerable proportion of the run consisted of $5_3$ and $6_3$ fish. However, size analyses and examinations of the scales of smolts leaving the lake indicate that only a negligible proportion of the run (never over 1.5% in 6 years of observations) were in their third year when they left the lake. For this reason it must be assumed that for some reason, not yet explained, the scale growth of some of the fish was such that two annuli (one rather indistinctly formed) were laid down during the first year of lake residence and that the great majority of the fish classified as $5_3$'s and $6_3$'s were actually a year younger (i.e., $4_2$'s and $5_2$'s).

In the following table percentages of each age-class in the samples are listed. The fish originally classified as $5_3$ and $6_3$ have been grouped with the $4_2$ and $5_2$ classes. Undoubtedly some of these may have been true 3-year fresh-water fish, but it is felt that they would be so few that the error in classification would not cause any significant change in the age-composition pattern.

| Year | Age-class | | | | No. sampled |
|---|---|---|---|---|---|
| | $3_2$ | $4_2$ | $5_2$ | $6_2$ | |
| 1952 | 0.4 | 11.9 | 87.1 | 0.6 | 927 |
| 1953 | ... | 38.5 | 61.1 | 0.4 | 288 |
| 1954 | 0.3 | 21.3 | 78.4 | ... | 344 |
| 1955 | ... | 27.2 | 72.8 | ... | 77 |

Knowing the age composition of the run and the numbers of fish arriving at Lakelse, the contribution of each brood year to the Lakelse escapement can be calculated:

| Brood year | Age of return | | | | Total |
|---|---|---|---|---|---|
| | $3_2$ | $4_2$ | $5_2$ | $6_2$ | |
| 1946 | .. | .. | .. | 106 | .. |
| 1947 | .. | .. | 15,440 | 47 | .. |
| 1948 | .. | 2,109 | 7,219 | 0 | 9,328+ |
| 1949 | 71 | 4,549 | 6,643 | 0 | 11,263 |
| 1950 | 0 | 1,805 | 2,912 | .. | 4,717+ |
| 1951 | 25 | 1,088 | .. | .. | .. |
| 1952 | 0 | .. | .. | .. | .. |

## Studies on fry production

J.G. McDonald

The objectives of the Lakelse fry studies have been (1) to relate the success or failure of natural reproduction from the egg to the fry stage to stream conditions and escapement size, and (2) to estimate the total sockeye fry output from the spawning tributaries into Lakelse Lake.

Fry production has been measured at Scully Creek from 1950 to 1955 and at Williams Creek since 1954. As over 90% of the Lakelse escapement spawns in these two creeks, enumeration of the two fry runs to these provides a good basis for estimation of the total annual fry output from the Lakelse area.

### 1. Scully Creek production.

With the exception of 1955, fry production has been measured at Scully Creek by the operation of a weir which provided a complete count of the spawners and of their progeny. In 1955 the fry weir was not operated and the number of fry migrants was estimated by operating a small trap, described in previous reports, which captured a measurable proportion of the total number of migrants.

The escapement, egg deposition, number of fry migrants and percentage survival (egg to fry) since 1949-50 is given below:

| Year | Males | Females | Jacks | M/F without jacks | Potential egg deposition | No. of fry migrants | Percent survival |
|---|---|---|---|---|---|---|---|
| 1949-50 | 565 | 485 | 28 | 1:0.86 | 1,766,370 | 242,346 | 13.7 |
| 1950-51 | 195 | 121 | 146 | 1:0.62 | 377,775 | 35,129 | 9.3 |
| 1951-52 | 809 | 384 | 21 | 1:0.48 | 1,221,696 | 165,782 | 13.6 |
| 1952-53 | 556 | 507 | 40 | 1:0.91 | 2,053,350 | 249,882 | 12.2 |
| 1953-54 | 370 | 251 | 6 | 1:0.67 | 958,067 | 97,134 | 10.1 |
| 1954-55 | 263 | 394 | 7 | 1:1.50 | 1,693,806 | 233,195* | 13.8* |

*estimated

Compared to fry production in other areas for which measurements are available (e.g., Port John in the central coast region and Six Mile Creek at Babine Lake in the Skeena watershed) the survival from egg to fry at Scully Creek has been quite constant, varying only from 9.3 to 13.5% (average 12.1%).

The relative constancy in this proportion can be attributed partly to the stable stream conditions which were observed throughout the period of investigation. Although considerable seasonal variations in stream flow was normal (minimum 10 c.f.s., maximum 400 c.f.s.), minimum flows were considered sufficient for the existence of the sockeye while the spring and fall freshets did not result in any drastic change in the nature of the creek. Another stabilizing factor in the production of fry was the fact that more than sufficient suitable spawning gravel was always available to each year's run. Loss in production due to overcrowding on the spawning ground and superimposition of redds was minimal.

There was, however, a tendency for survival to vary with the number of eggs deposited; the two smallest seedings (in 1950 and 1954) provided the two poorest survival rates. These figures support the hypothesis that, at low population levels, predators are able to take a larger proportion of the total run than at high levels, where the number of fry migrating at the peak of the migration would exceed the capacity of the predators to consume them.

2. Williams Creek production.

J.G. McDonald and A.J. Paul

An estimate of the fry output from this creek was carried out in the same way as in 1954. A series of small traps were placed across the mouths of the three outlet channels. These traps were operated throughout the migratory period on the basis of last year's experiments, the proportion of the migrants captured by each trap was considered to be equal to the proportion of the water strained by the traps.

Operations began April 2 and continued until May 29. The number of sockeye fry captured in each outlet, and the estimated total number of migrants is shown below for 1954 and 1955:

| | Total captured | | Estimated total migrants | |
|---|---|---|---|---|
| | 1954 | 1955 | 1954 | 1955 |
| Main Channel | 115,000 | 247,000 | 1,064,000 | 2,288,000 |
| East " | 16,000 | 13,000 | 182,000 | 150,000 |
| West " | 5,000 | 3,000 | 72,000 | 55,000 |
| Estimated total | | | 1,318,000 | 2,493,000 |

At the end of trap operation, in both years, a few fry were still being captured daily. It was estimated that an additional 20,000 fry in 1954 and 35,000 in 1955 migrated after operations ceased.

The rate of production from egg to fry is shown below. Adult counts in both years were obtained by the operation of a weir.

| Year | No. adults | Estimated egg deposition $X10^3$ | Estimated no. fry $X10^3$ | Percent production |
|---|---|---|---|---|
| 1953-54 | 8,505 | 17,765 | 1,378 | 7.8 |
| 1954-55 | 6,789 | 14,662 | 2,528 | 17.2 |

Almost twice as many fry were produced in 1955 as in 1954 despite a smaller egg deposition. This was attributed mainly to a general improvement in stream conditions resulting from a project carried out by the Department of Fisheries in 1953. A few years previous a new flood channel was formed that greatly reduced the flow in the lower two-thirds of the creek, making this formerly important section unsuitable as a spawning area. The blockage of this diversion channel by the Department returned the creek to its former course. The resulting increased flow in the lower section washed out much of the silt and algal growth which had accumulated on the stream bed in previous years and made it suitable for the incubation of sockeye eggs once more.

3. Total Lakelse fry output. J.G. McDonald

The total fry output has been assessed from the production recorded at Scully and Williams Creeks. Spawning ground surveys made in 1954 showed that only 63 sockeye spawned in other Lakelse tributaries. The fry output from these streams has been estimated, using the survival rate recorded at Scully Creek (which is comparable in respect to size, flow and gravel conditions to the other small creeks).

The estimated sockeye fry output into Lakelse Lake in 1954 and 1955 is shown below:

| Year | No. adults | Estimated no. fry | Percent production |
|---|---|---|---|
| 1953-54 | 9,292 | 1,505,000 | 7.9 |
| 1954-55 | 7,698 | 2,780,000 | 16.9 |

4. The influence of light and current on the downstream migration of salmon fry.

The downstream migrations of sockeye, coho and pink fry from the spawning grounds at Williams and Scully Creeks, Lakelse Lake, are restricted almost totally to the hours of darkness. As recorded at trapping sites at the mouths of the creeks, the number migrating per unit of time increased after dark until a "peak" was reached some three or four hours later. The rate of migration then progressively declined and movement ceased with the coming of daylight.

The manner in which sockeye and coho fry initiate this movement was observed in a trough set up to simulate natural conditions. A number of fry were placed in the upstream or head end of the trough in mid-afternoon. Their movement to the downstream end and the changes in light intensity were recorded periodically.

The fry were found to remain in the head end of the trough until the light intensity approached 0-foot candles. Thereafter the number initiating movements per 10-minute interval increased until a peak was reached 60 to 90 minutes after dark. The rate of downstream movement then declined and ceased within 150 to 190 minutes after dark.

On three occasions the influence of artificial light on the movement of sockeye and coho fry was tested. The fry in the trough (a fresh lot was used in each test) were subjected to artificial light until two hours after dark in the first test, three hours in the second and throughout the whole of the night on the third and final test. It was found that the presence of the light almost completely prevented the downstream movement of the fish. In the tests where the light was removed during the hours of darkness, movement began after removal of the light. In the third test where the light was left on all night, the movement of the fry was almost completely prevented for a 24-hour period.

These observations, together with those recorded under natural stream conditions (by weir and trap operation), indicate that the downstream movement of the sockeye and coho, and probably also pink fry is initiated by a loss of visual orientation in the approach of darkness. This is possibly due to a failure of the eye to dark adapt at a rate equal to the decrease in light intensity.

Once movement was initiated, i.e., when the fry entered into the current, their downstream movement continued until the stream was completely evacuated or until daylight approached. During this period the sockeye fry were seen to respond positively to fast currents and for the most part negatively to relatively slow currents. It was concluded that, although a displacement by the current initiated their movement from the gravel into the current, the continued movement downstream was a result of both a displacement by the current and a movement directed on the part of the fry. The horizontal distribution of migrating sockeye and pink fry were found to be related to currents. The proportion of fry captured by each of six traps located at 12-foot intervals across the mouth of Williams Creek was found to be positively related to the relative velocity of the current through each trap ('r' = 0.94 and 0.96, p = .05, for sockeye and pinks respectively). The coho fry, however, appeared to migrate without particular relation to currents (r = 0.65): the numbers captured in each trap were independent of the velocity of current through it.

## Smolt studies

M.P. Shepard and R.M. Humphreys

From 1946 to 1948 and from 1952 to 1954, counts or estimates have been made of the total number of smolts emigrating from Lakelse Lake each spring. In most years representative samples of the fish have been examined to determine the average weight and length of smolts and the sex composition of the runs.

### 1. The smolt run of 1955.

R.M. Humphreys

The smolt weir on the Lakelse River was installed on April 3 and removed on June 9, when rapidly rising water coupled with a low daily count of sockeye made further counting unprofitable. Based on observations made in previous years, it is probable that almost all of the Lakelse migrants had moved out of the lake before the removal date.

A total of 312,461 sockeye smolts were counted through the fence. Of these, 283,500 (90% of the total counted) moved through the fence in the two-week period from May 15 to June 2. It is probable that an additional 2,500 fish moved out of the lake after the fence was removed, putting the total smolt run at about 315,000 fish.

To speed the enumeration procedure and to reduce the amount of handling of the fish, a system of estimation involving calibrated dip-nets was used. The fish were counted out in dip-nets constructed so that each net handled the same volume of fish (about 50 fish, on the average). The total daily runs were estimated by carefully counting one out of every two or three dip-net loads and multiplying the total number of dip-net loads by the daily average numbers of sockeye in the carefully counted samples. This procedure greatly speeded the counting operation and imposed a minimum delay on the fish.

Since the fence was constructed in 1951-1952, continuing efforts have been made to ease the passage of the fish through the fence and to reduce mortality. Over the past four years mortality attributable to the fence has dropped steadily from a high of about 5% in 1952 to 1.61% and 0.74% in 1953 and 1954 to only 0.38% in 1955.

In addition to the sockeye, 98,908 coho smolts were counted at the fence. It is estimated that another 7,000 passed down the river after the fence was removed, indicating a 1955 coho run of about 106,000 smolts. This is very close to the average figure for the 1952-1954 period (approximately 107,000).

To determine the daily pattern of the migration, the pens were completely cleared at two-hour intervals for a 24-hour period near the peak of the run. The observations confirmed those made in earlier years. The major diurnal movements of the smolts followed sudden changes in light intensities. There was a peak in the arrival of sockeye smolts at the weir approximately two hours after dusk and again about two hours after the light intensity increased rapidly at dawn. The coho did not appear to be affected in the same manner, with the numbers of arrivals increasing steadily throughout the morning, and decreasing after a peak about noon.

2. Size, age and sex composition of Lakelse smolts, 1946-1955. — R.M. Humphreys and M.P. Shepard

Since 1952 when the present Lakelse River counting weir was put into operation, a daily sample of smolts has been taken throughout the migration. These have been analyzed for age, sex, length and weight. Less extensive samples were obtained in 1946 and 1948. The results are shown in the following table:

| Year | Sample size | Number of fish | | | | Age I fish | |
|---|---|---|---|---|---|---|---|
| | | Age I | | Age II | | Av. length | Av. weight |
| | | Male | Female | Male | Female | cm. | g. |
| 1946 | 567 | | | | | 7.59 | |
| 1948 | 44 | 43 | | 1 | | 7.63 | |
| 1952 | 1660 | 866 | 776 | 14 | 4 | 8.18 | 5.48 |
| 1953 | 1377 | 724 | 621 | 18 | 10 | 8.39 | 5.63 |
| 1954 | 1579 | 857 | 722 | 0 | 0 | 8.18 | 5.76 |
| 1955 | 1511 | 814 | 685 | 7 | 5 | 8.61 | 6.34 |

The Lakelse smolt migration consists almost entirely of fish which have spent only one year in the lake. The proportion of 2-year-olds in the run has averaged only 1.22%.

In 1955 the migrating smolts were appreciably larger than in any previous year for which records are available. This may have been associated with the fact that growing season in 1954 was considerably longer than normal. The late fall of 1954 was unusually mild, with the mean monthly air temperatures from November to January some 5° F. higher than normal. Plankton sampling suggested that the 1954 zooplankton bloom extended later into the fall than normally.

Gross examination of the samples, similar to those made of smolts from other areas on the Skeena (See report under Salmon Management in the Skeena Area), was carried out to determine the degree of infestation of the smolt with cestodes and nematodes. The results showed that infection with adult and sub-adult cestodes was nil, although 2.9% were observed (on cursory examination) to contain larval forms. The incidence of nematode infection was 2.9%. Compared to the infestation rate at Babine of from 4 to 37% for adult or sub-adult cestodes and 10 to 34% for nematodes, that at Lakelse is quite low.

## Sockeye production at Lakelse Lake, 1944 to 1948.

M.P. Shepard

The above enumeration data provide estimates of the fresh-water production of sockeye at Lakelse. Although the data, in some cases, are very approximate and enumerations of some stages are not available for all years, some conclusions can be drawn. In the following table, figures for the yearly runs of adults (and estimated egg depositions), fry and smolts, and for survival rates between stages are presented:

| | Count or estimate (thousands) | | | | | Survival (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Brood year | Spawners | Potential deposition | Fry | Smolts | Returning adults | Egg-fry | Fry-smolt | Egg-smolt | Smolt-returning adult | Spawners-returning adult | Smolt length (cm.) |
| 1944 | 16.5 | 31,350* | .. | 557 | .. | .. | .. | 1.78 | .. | .. | 7.59 |
| 1945 | 33.0 | 62,700* | .. | 373 | .. | .. | .. | 0.60 | .. | .. | .. |
| 1946 | 29.0 | 55,100* | .. | 600** | .. | .. | .. | 1.09 | .. | .. | 7.63 |
| 1947 | 13.5 | 25,650* | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 1948 | 13.0 | 24,700* | .. | .. | 9.3 | .. | .. | .. | .. | 71.5 | .. |
| 1949 | 7.5 | 14,250* | .. | .. | 11.3 | .. | .. | .. | .. | 150.7 | .. |
| 1950 | 6.2 | 11,800* | .. | 596 | 4.7 | .. | .. | 5.05 | 0.79 | 75.8 | 8.18 |
| 1951 | 19.0 | 36,100* | .. | 394 | .. | .. | .. | 1.09 | .. | .. | 8.39 |
| 1952 | 12.0 | 21,600 | .. | 379 | .. | .. | .. | 1.75 | .. | .. | 8.18 |
| 1953 | 9.3 | 19,000 | 1510 | 315 | .. | 7.9 | 20.9 | 1.66 | .. | .. | 8.61 |
| 1954 | 7.7 | 16,500 | 2780 | .. | .. | 16.9 | .. | .. | .. | .. | |
| 1955 | 3.7 | 6,600 | .. | .. | .. | .. | .. | .. | .. | .. | |

*Potential deposition estimated, assuming a 50:50 sex ratio and an average egg content of 3800 per female.

**Estimate based on a partial count.

The results indicate:

(a) Total fresh-water production (i.e., from egg to smolt).

(1) From 1944 to 1955, estimates of the sockeye spawning runs to Lakelse streams have fallen between 3700 and 33,000 (mean 14,200).

(2) In 7 years for which smolt counts are available, the Lakelse smolt runs have varied between 315,000 and approximately 600,000 (mean 459,000). These runs have resulted from spawnings of from 6200 to 33,000 adults.

(3) Proportionately the smolt outputs have varied less widely than the spawning stocks that produced them. The standard deviation of the numbers of migrant smolts was only 26% of the mean while the standard deviation of the number of adult spawners was over 56% of the mean.

(4) There has been no direct positive relationship between the estimated number of spawners and the resultant number of smolts: small spawnings have given rise to relatively large numbers of smolts, and vice versa.

(5) Associated with the above observations, the survival rate from egg to smolt has tended to bear an inverse relation to the size of spawning run.

(6) The average size of smolts has tended to vary inversely with the number of smolts produced.

The above observations suggest that, within the range of seedings observed, competition for food has exerted a limiting influence on sockeye production at Lakelse. Both the growth and survival rates tended to be lower at high population levels. However, in the years for which records are available, competition has not yet reduced smolt size as greatly at Lakelse as in some other areas (e.g., Nilkitkwa, Cultus and Shuswap Lakes) and it is therefore probable that the capacity of the lake has not yet been reached, and that greater numbers of smolts could be produced.

It should be borne in mind that many of the estimates of runs used in computing production figures have been gross approximations. As the trends discussed in the foregoing paragraphs are not clear-cut, the conclusions drawn must be regarded with caution. Forthcoming counts of the smolt runs resulting from the relatively small seedings of 1954 and 1956 should provide further evidence to strengthen or weaken them.

(b) Survival from egg to fry. The two figures for survival from egg to fry (7.9% and 16.9%) obtained for the Lakelse area as a whole fall within the range of survivals observed in a number of small individual streams examined elsewhere (e.g., Tally Creek at Port John Lake and Six Mile Creek at Babine Lake). See also the section "Studies on fry production" above.

(c) Survival from fry to smolt. Only one figure for this survival has been obtained. No useful conclusions can be drawn until further data are available.

(d) Adult returns. Three years' data are now available on the adult return (spawning run, not including catch) from known seedings. In two years out of the three, the returning adults were fewer than the runs that produced them (29.5% lower for the brood year of 1948 and 24.2% lower for 1950. However, due to a 50.7% increase for the brood year 1949, the average number of returning adults for the three-year period (approximately 8400) was almost equal to the numbers of fish in the parent runs (approximately 8900).

## Studies of Skeena system lakes and their young sockeye populations

W.E. Johnson

The object of these studies is to gain a basic understanding of the lake phase in the life of sockeye salmon and of the environmental factors determining the capacity of such lakes to produce sockeye smolts. The writer began studies along these lines at Lakelse Lake in the fall of 1954. Most of the early work was devoted to devising methods of capturing young sockeye in lakes and of assessing the availability of their zooplankton food. During the period April-October, 1955, periodic sampling of the zooplankton and of the young sockeye population was carried out at Lakelse Lake in order to follow the growth rate of the young sockeye and seasonal changes in availability of zooplankton as food; observations were also made on temperature, light, currents, and (in the fall) phosphate content of lake water. Similar observations were carried out at Kitsumgallum Lake at less frequent intervals. Two visits were made to Babine and Nilkitkwa Lakes in August and October, 1955. Visits were made to Bear and Morice Lakes in late June and early July.

### 1. Method of capturing young sockeye.

The method developed for capturing young sockeye involves the use of a net towed by two boats running parallel about 100 feet apart. The tow-net is simply a cone-shaped bag, the open mouth end of which is given rigidity by means of a stainless steel ring. The size found most suitable has been a net 9 feet in length with a mouth diameter of 3 feet. The use of 5/8-inch (stretch measure) nylon netting for the forward 6 feet of the net and woven nylon material with openings of approximately 5/32 inch for the 3-foot bag end has proven satisfactory for the capture of young sockeye, including the newly-emerged fry. Experience has shown an overwhelmingly greater success of tows made at the surface (fishing the surface 3 feet). However, the time of day is of primary importance in the capture of young sockeye with such surface tows. Tows made during daylight hours are very rarely successful, even when active schools of young sockeye are observed at the surface. As dusk approaches, fishing success increases quickly and reaches a maximum during the first moments of darkness. Then fishing success decreases and catches are rare during the remaining hours of darkness. No such period of high catchability has been observed for the morning twilight period. This same daily pattern of catchability has been observed in all sockeye lakes where this net has been used.

Based on this experience, the following routine method of sampling was adopted: surface tows of 10 to 15 minutes' duration, towing at a speed of approximately 7 miles per hour, were made consecutively for one hour in the evening, spanning the period of dusk and early darkness. This hour of towing has been used as the unit of fishing effort. Towing was carried out at random in the pelagial (offshore) zone of the lake.

Since adopting this standard method in August, 1955, experience at Lakelse Lake points to the consistency of this manner of sampling young sockeye populations. The mean size and variance in size of sockeye shown by repeated samples taken on successive days was reasonably uniform. The catch per unit of effort showed relatively small variation in repeated samplings. However, catchability in all lakes was greatly reduced in the fall as compared to the summer.

### 2. Method of sampling zooplankton.

Sampling of the zooplankton has been carried out by means of Clarke-Bumpus plankton samplers equipped with #10 standard nets. Differences in quantity of zooplankton, both vertically and horizontally, showed that meaningful and adequate sampling must include samples from all depths in all major regions of the lake. Sampling has been carried out in that manner.

3. Zooplankton distribution.

(a) Vertical. During the summer period at Lakelse Lake (and in all other Skeena lakes sampled), there was a consistent concentration of the zooplankton in near-surface waters. At Lakelse Lake 70 to 90% of the total standing crop was commonly concentrated in the surface 6 meters, exceptions occurring with extreme violent circulation accompanying strong winds. This concentration in near surface waters appears to be related to light conditions.

(b) Horizontal. Lakelse Lake lies in a north-south valley and prevailing winds in summer are from the south, north winds occurring only occasionally. With prevailing southerly winds, concentrations of zooplankton were commonly found in the eastern and northern portions of the lake. North winds resulted in a shifting of such concentrations to the west and south. This horizontal distribution of the zooplankters is associated with lake circulation; concentrations are found in the regions of convergence of surface water. Apparently the concentrations result from the fact that the motile zooplankters are able to maintain themselves at their preferred near-surface position in spite of the downward movement of surface water in areas of convergence. Conversely, in areas of divergence, or upwelling of deeper water, plankton-poor water is brought to the surface resulting in a sparser concentration of plankton.

4. Distribution of young sockeye.

Tow-net sampling at Lakelse Lake during the fry run of 1955 indicated that the newly-emerged fry entering the lake took up a pelagic, plankton-feeding existence soon after entering the lake.

(a) Vertical. Experience with tow-net fishing at all depths indicates that the young sockeye are distributed in waters relatively near the surface during daylight hours, that they concentrate extremely near the surface during the evening twilight and then become generally dispersed to all depths during the hours of darkness. The concentration of sockeye in near-surface depths seems related to the near-surface concentration of the zooplankton food.

(b) Horizontal. At Lakelse Lake tow-net sampling and observations on schools active at the surface in periods of calm, indicate that the young sockeye are generally distributed about the offshore region of the lake. However, on two occasions, observations of schools at the surface gave a suggestion that the young sockeye might be more concentrated in areas where zooplankton was found most concentrated horizontally.

At Babine Lake, a very large, multi-basin lake, great differences in horizontal distribution of young sockeye were found; this is discussed below.

Rare capture of species other than sockeye in tow-nets or gill-nets in offshore surface waters indicates young sockeye as the primary pelagic plankton-feeders, with relatively little interspecific competition.

5. Growth rate of age-0 sockeye and environmental factors.

In fish populations of low density, that is, in the absence of high competition, growth rate is believed to be dependent on temperature and the availability of food.

(a) Lakelse Lake and Kitsumgallum Lake. Data on growth of sockeye, availability of zooplankton and temperature for these two lakes is presented graphically in Figure 1. The young sockeye population of Lakelse Lake during 1955 was known to be of low density and a comparable catch per effort in Kitsumgallum Lake indicated a comparable density. Neither lake is believed to have had a population of sufficient size to give an adverse effect on growth through competition.

In Lakelse Lake the highest rate of growth occurred during the month of June when zooplankton was most abundant; water temperature throughout the summer period varied little and it is felt that the decline in growth rate of sockeye after June was due to the declining availability of zooplankton food. Extremely low phosphate levels in August and September and the paucity of the phytoplankton suggest low nutrient levels as the basic cause of decline in zooplankton abundance.

Growth rate of age-0 sockeye in Kitsumgallum Lake was much lower than in Lakelse Lake. Availability of zooplankton in Kitsumgallum was extremely low and temperatures were also lower than at Lakelse Lake; both factors no doubt contributed to the slower growth rate of sockeye. At Kitsumgallum Lake age-I sockeye were also taken and in mid-September they averaged only 4 grams in weight. The low temperatures characteristic of Kitsumgallum Lake are believed to be a primary factor limiting basic production of plankton in this lake.

(b) Babine and Nilkitkwa Lakes. Only two visits were made to Babine and Nilkitkwa Lakes - in August and October. Observations indicate temperature comparable to those of Lakelse Lake and zooplankton abundance greater than or equal to that of Lakelse Lake. Based on catch per unit of fishing effort, the density of the young sockeye population in all parts of Babine Lake except the North Arm was lower than that of Lakelse Lake; rate of growth of the sockeye (Figure 1) was similar. Extremely high catches per unit of fishing effort indicated young sockeye populations of very high density in both the North Arm of Babine Lake and Nilkitkwa Lake, highest in Nilkitkwa Lake. The extremely slow rates of growth of the sockeye in these two areas are perhaps a result of competition owing to density of population.

(c) Bear Lake and Morice Lake. Visits to these lakes were made primarily to obtain samples of the emigrating smolts (reported by Aro elsewhere in these reports). However, it was possible at the same time to carry out plankton sampling and temperature observations.

During the visit to Bear Lake (June 21-29, 1955) water temperatures were comparable to those at Lakelse Lake and the standing crop of zooplankton was higher than any observed there in 1955. These findings accord with the fact that the smolts taken were all 1-year-olds of larger mean size than 1-year-old smolts from Lakelse Lake. Bear Lake is a multi-basin lake and great differences in the plankton populations, both qualitatively and quantitatively, were found in the different basins.

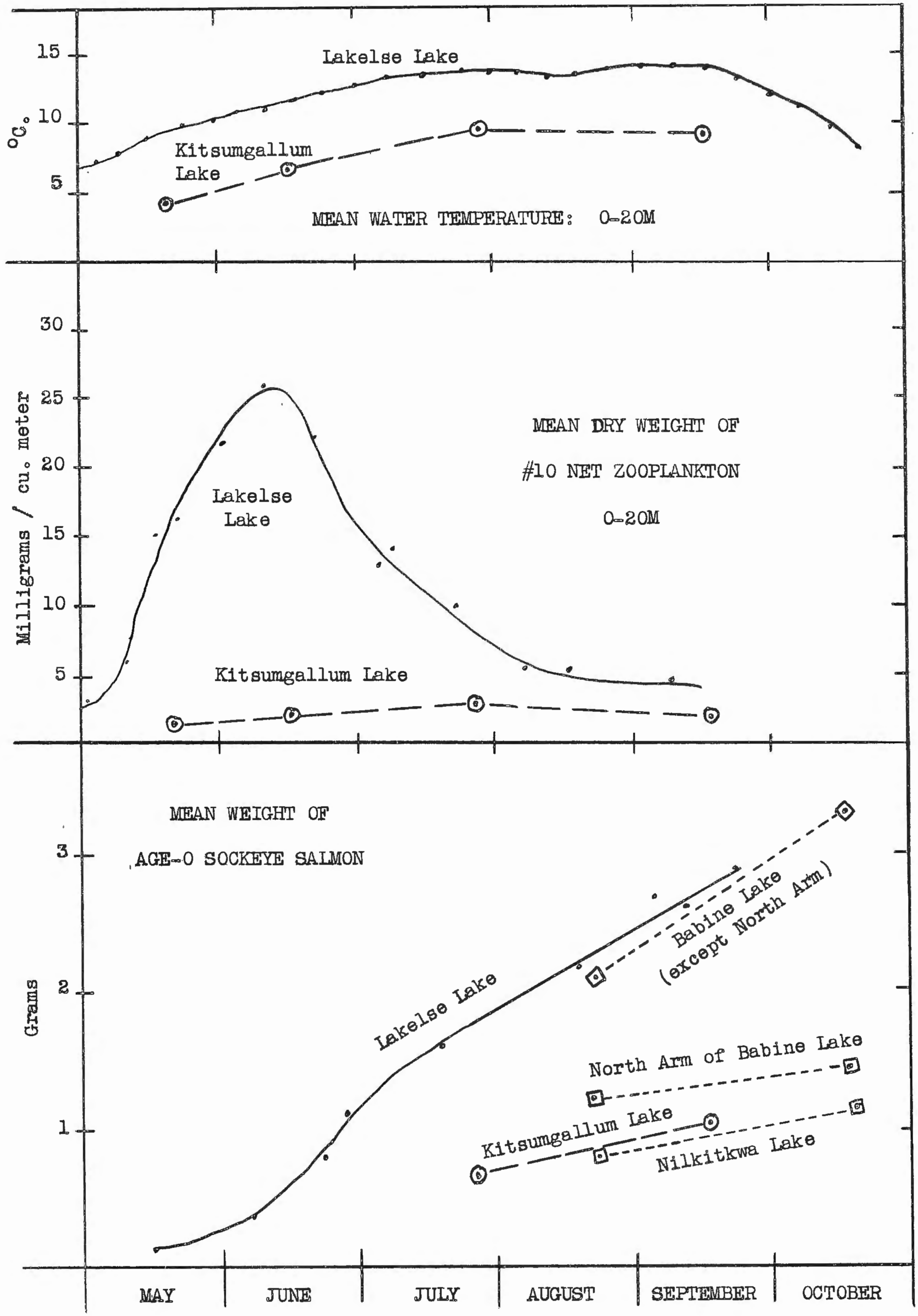



Fig. 1. Growth of age-0 sockeye salmon, standing crop of zooplankton and temperature, 1955.

Morice Lake was visited during the period July 6-16, 1955. This was apparently too late to sample the smolt run as only one sockeye smolt was captured. Both water temperatures and zooplankton abundance at Morice Lake during this period were at levels intermediate between those of Lakelse Lake and Kitsumgallum Lake.

6. Distribution of age-0 sockeye in the Babine-Nilkitkwa Lake nursery area.

Two series of tow-net collections were carried out in Nilkitkwa Lake and various parts of Babine Lake in August and October, 1955. Differences in catch per unit of effort and in mean size of individuals within each series offer evidence of a highly unequal distribution of the young sockeye utilizing the Babine-Nilkitkwa Lake nursery area.

Catch per unit of fishing effort indicated the following percentage distribution of the total age-0 sockeye population of this nursery area:

| | | August | October |
|---|---|---|---|
| | Area as % of total | Sockeye population as % of total | Sockeye population as % of total |
| Nilkitkwa Lake | 1.1 | 9.2 | 12.5 |
| North Arm of Babine Lake | 10.3 | 78.9 | 71.6 |
| Babine Lake south of Halifax Narrows | 88.6 | 11.9 | 15.9 |
| Totals | 100.0% | 100.0% | 100.0% |

Even if the highest catches per effort in the large area south of Halifax Narrows were used as representative of this large part of Babine Lake, the computations would show only 17% (August) and 33% (October) of the sockeye as being in this 88.6% of the total nursery area.

Taking catches per effort in August and October at Lakelse Lake (where the approximate size of the young sockeye population was known) as standards relating catch per effort to population density during these periods, and assuming that catch per effort is related proportionately to population density, the following estimates of population density and size are obtained:

| | August, 1955 | | October, 1955 | |
|---|---|---|---|---|
| | Catch/hour | Sockeye/acre | Catch/hour | Sockeye/acre |
| Lakelse Lake | 28 | 336 | 6 | 294 |
| Nilkitkwa Lake | 384 | 4,608 | 97 | 4,753 |
| North Arm of Babine Lake | 342 | 4,104 | 58 | 2,842 |
| Babine Lake south of Halifax Narrows | 6 | 72 | 1.5 | 74 |

| | Area | Number of age-0 sockeye salmon | |
|---|---|---|---|
| | Acres | August, 1955 | October, 1955 |
| Nilkitkwa Lake | 1,200 | 5,530,000 | 5,704,000 |
| North Arm of Babine Lake | 11,500 | 47,200,000 | 32,700,000 |
| Babine Lake south of Halifax Narrows | 98,500 | 7,092,000 | 7,290,000 |
| Totals | 111,200 | 59,800,000 | 45,700,000 |

Again considering the area south of Halifax Narrows, computations based on the highest catch per unit of effort in that area are made. These computations show an estimated density for this area of 108 sockeye per acre in August and 196 per acre in October. This indicates a population of 10,638,000 in August and of 19,306,000 in October for the area of Babine Lake south of Halifax Narrows; and indicates a total population size of 63,364,000 in August and 57,693,000 in October.

The factors believed responsible for this highly unequal distribution of young sockeye, and hence inefficient use of the lake nursery facilities, are the distribution of the spawning parent population and a limited dispersal of young sockeye from their point of entrance into the lake as fry. Of the total number of spawning sockeye contributing fry to Babine and Nilkitkwa Lakes in 1954, 56% spawned in areas tributary to Nilkitkwa Lake and the North Arm of Babine Lake. Limited dispersal of young sockeye from their point of entrance to the lake as fry is believed primarily due to the morphometry of the lake and resulting independent regions of circulation.

7. Young sockeye collections at Shuswap Lake.

During the period December 3 to 8, 1955, by invitation of the Director of the International Pacific Salmon Fisheries Commission, a visit was made to Shuswap Lake in the Fraser River system. The main purpose of this visit was to demonstrate to Commission biologists the method of capturing young sockeye developed at Lakelse Lake and used on Skeena lakes. From this point of view the visit was successful.

As only a limited amount of effort could be expended, owing to inclement weather, and because low catchability is general at this time of year, only 23 age-0 sockeye were captured. Although this small sampling of young sockeye offers no statistically significant evidence in itself, certain features of it point to the probability of an unequal distribution of young sockeye similar to that found at Babine Lake. A concentration of approximately 98% of the 1954 spawning population on spawning grounds immediately tributary to the outlet region, together with the extremely long, multi-basin character of Shuswap Lake, makes an unequal distribution of young sockeye in this lake appear extremely likely.

## Studies on predator fishes

T.H. Bilton and
M.P. Shepard

To gain information on the extent of predation on young sockeye by other fishes in Lakelse Lake, predator (and, incidentally, forage fish) populations have been sampled by gill nets each year since 1944. In addition to these routine samplings, marking experiments have been conducted from time to time to estimate the abundance of the various species and to gain information of their distribution and migrations. Since 1950 a creel census has been carried out each year to follow changes in abundance of one of the most important predators at Lakelse - the cut-throat trout.

In past reports information on the abundance and distribution of Lakelse fishes and extent of their predation on young sockeye have been summarized. This year's report includes an assessment of the creel census results from 1950 to the present and a report on the relation of predation to predator size and distribution, and on seasonal variations in predation.

### 1. Diet of predator fishes.

At Lakelse Lake cut-throat trout, dolly varden char and squawfish are the chief predators of lacustrine sockeye. Since 1944 annual samples of predator fishes have been obtained by gill-netting, trapping and angling. The stomach contents of many of these fish have been examined to determine the extent of predation by the various species on the young sockeye. In the following report data on the relation of sockeye consumption by predators to location of capture of predators, size of predator and season are presented.

(a) The extent of predation in different areas. In Table I frequency of of occurrence of sockeye in the stomachs of predators and the average number of sockeye found per stomach are shown for predators captured in the inshore and offshore areas of Lakelse Lake. All areas having a depth of 5 meters or less were included in the inshore category. Since 1951 the fishing effort has been quite uniform throughout the lake. Data collected prior to 1951 (when inshore areas were more heavily fished than the offshore) have been omitted.

Table I. Relation of sockeye consumption to area of capture of predators (No. = number of stomachs examined; F(%) = percent of stomachs containing sockeye; Av. no. = average number of sockeye per stomach).

| Species | Inshore | Offshore |
|---|---|---|
| Cut-throat | | |
| No. | 734 | 673 |
| F(%) | 1.6 | 7.7 |
| Av. no. | 0.04 | 0.15 |
| Squawfish | | |
| No. | 504 | 363 |
| F(%) | 1.4 | 3.3 |
| Av. no. | 0.02 | 0.04 |
| Dolly varden | | |
| No. | 198 | 184 |
| F(%) | 2.0 | 7.1 |
| Av. no. | 0.07 | 0.29 |

The results indicate that for all species both the proportions of predators feeding on sockeye and the average number of sockeye per stomach are much higher in the offshore than in the inshore area. This reflects the fact that young sockeye are pelagic plankton feeders, venturing but rarely into the inshore waters.

(b) Effect of size of predator. In Table II the frequency occurrence of sockeye in the stomachs and the average number of sockeye found per stomach are listed for predators of different sizes. All data collected since 1944 have been lumped without regard to area or season of capture.

Table II. Sockeye consumption related to size of predator (No. = number of stomachs examined; F(%) = percent of stomachs containing sockeye; Av. no. = average number of sockeye per stomach).

| Species | Size-class (cm.) | | | | | |
|---|---|---|---|---|---|---|
| | 11-20 | 21-25 | 26-30 | 31-35 | 36-40* | Over 41 |
| Cut-throat | | | | | | |
| No. | 218 | 529 | 758 | 565 | 174 | |
| F(%) | 2.3 | 3.0 | 6.6 | 11.5 | 16.7 | |
| Av. no. sockeye | 0.07 | 0.16 | 0.29 | 0.33 | 0.56 | |
| Squawfish | | | | | | |
| No. | 485 | 489 | 434 | 122 | 33 | |
| F(%) | 4.5 | 3.7 | 2.5 | .9 | 0 | |
| Av. no. sockeye | 0.07 | 0.08 | 0.04 | 0.01 | 0 | |
| Dolly varden | | | | | | |
| No. | 13 | 132 | 98 | 73 | 29 | 36 |
| F(%) | 0 | 0 | 6.12 | 9.6 | 6.9 | 0 |
| Av. no. sockeye | 0 | 0 | .24 | .35 | .52 | 0 |

*All cut-throat and squawfish over 36 cm. are included in this category.

The results indicate:

(1) Both the percentage of cut-throat feeding on sockeye and the average number of sockeye per stomach increases with size. The frequency with which those in the smallest size-group sampled (11 to 20 cm.; largely II-year-old fish) feed on sockeye was only 13% of that of the largest size-group (over 36 cm., mainly V- and VI-year-old fish). The average number of sockeye per stomach of the small fish was also about 13% of that of the older and larger fish.

(2) In squawfish there was an apparent inverse relationship between the extent of feeding on sockeye and size. This is, in part, associated with the fact that large fish were relatively more abundant in the inshore waters where the extent of feeding on sockeye is low, whereas the small fish are more abundant in the catches offshore. However, even when offshore and inshore samples are examined separately, the trend persisted to some extent.

(3) During the fall and winter (the period of lake residence), the small dolly varden sampled (up to 25 cm.) appeared to feed very little. Specimens of intermediate size (26-40 cm.) subsisted largely on sockeye. The average number taken tended to vary with size, although the frequency occurrence of sockeye in the stomachs bore no clear-cut relation to size of the predator. The very large fish (41 cm. and over) fed mainly on other kinds of fish, generally of a larger size than sockeye (e.g., sculpins, cyprinids and even cut-throat trout III-year-olds up to 27 cm.).

(c) Seasonal trends in predation. Data on the seasonal trends in the frequency and average number of sockeye in predators do not necessarily reflect changes in the relative rates of predation from season to season. Changes in digestive rate associated with temperature undoubtedly occur. For example, it would be expected that the summer digestive rates would be higher than those at other times of the year, and that the frequency of occurrence and number of sockeye per stomach would tend to give a low estimate of the relative rate of predation when compared to similar figures for the fall, spring and winter. However, some generalizations can be made. In the following table the data collected since 1951 have been compiled according to season. Data prior to 1951 have been omitted because the sampling period in these years was mainly confined to spring and summer, whereas the sampling in years following 1951 was spread more evenly throughout the year.

Table III. Sockeye consumption related to season (No. = number of stomachs examined; F(%) = percent of stomachs containing sockeye; Av. no. = average number of sockeye per stomach).

| Species | Season | | | |
|---|---|---|---|---|
| | Winter | Spring | Summer | Fall |
| Cut-throat | | | | |
| No. | 221 | 757 | 77 | 471 |
| F(%) | 4.1 | 1.8 | 5.2 | 7.8 |
| Av. no. sockeye | .05 | .04 | .14 | .15 |
| Squawfish | | | | |
| No. | 25 | 458 | 133 | 247 |
| F(%) | 12.0 | 1.3 | .7 | 3.6 |
| Av. no. sockeye | .12 | .02 | .01 | .05 |
| Dolly varden | | | | |
| No. | 23 | 186 | | 173 |
| F(%) | 43.5 | 2.7 | | .6 |
| Av. no. sockeye | .04 | .08 | | .01 |

The data indicate:

(1) For cut-throat the highest frequency of feeding on sockeye and the highest average number of sockeye per stomach was observed in the fall. The figures for the fall were roughly four times those of the spring period, when temperatures tend to be roughly the same. The apparent low frequency of predation in the spring is associated with the fact that most of the larger fish are undergoing their annual spawning

migrations and are not feeding. Although frequency of occurrence and mean number of sockeye consumed for the summer are slightly lower than those observed in the fall, it is probable that the actual rate of predation is higher in the summer when a presumably higher rate of digestion is considered. Data on the effects of temperature on the metabolic rate of cut-throat trout tend to support this suggestion. In the winter, the cut-throat feed primarily on stickleback near the surface and probably take sockeye only incidentally. In general, then, the summer and fall appear to be the times of most active predation by the cut-throat on the sockeye.

(2) When the probable seasonal changes in digestive rate are considered, the rate of predation by squawfish may be quite constant throughout the open-water season. In the winter a larger fraction of the population appears to subsist on sockeye. The squawfish, however, like many cyprinids, are warm-water fish and thus the relatively high average number of fish per stomach may merely reflect a very slow rate of digestion in the winter. Experiments on the effect of temperature on the metabolic rate of this species would aid in interpreting these data.

(3) The major part of the dolly varden population at Lakelse spends only the fall and winter in the lake, migrating out of the lake in the spring and returning in mid-autumn. During the winter over 40% of the dollies were found to be feeding on sockeye and on little else. This is the highest rate of incidence observed at any time of the year for any of the species under study. In general, chars are better adapted for winter existence than trout or minnows, having a temperature optimum for maximum performance (e.g., as reflected by maximum sustained swimming speed) considerably lower than that of the other two groups. The apparent ability of char to take sockeye readily during the winter is a reflection of this phenomenon. The apparent low rates of predation during the spring and fall are no doubt associated with the fact that the fish are migrating during these periods and are not actively feeding.

## 2. Cut-throat creel census, 1950-1955.

T.H. Bilton

During 1955 the coverage of the creel census was reduced considerably; only 11% of the anglers fishing on the Lakelse River during the month of May were contacted to obtain data on their catches (i.e., number of hours fished, number of each species caught, the type of lure used, etc.). However, a close check of the number of anglers observed fishing on the river and the effort expended by each was made. Anglers fishing on the lake were not contacted during 1955.

(a) Catch statistics. Changes in abundance may be reflected in two ways: (1) the return per unit of effort tends to vary with the abundance, and (2) where fishing reduces the population of fish of catchable size the numbers of older and larger fish in the catches tend to decrease.

The age composition (determined from examination of scales) of the catches of trout from both the Lakelse River and the lake has remained quite constant since 1950, with the exceptions of the river catch of 1952 and the lake catch of 1954 when unusually large numbers of older fish were taken (see table below). The age composition of the trout in the river catches in 1955 was similar to that of previous years. No creel census was made on the lake in 1955 but the age composition of trout taken in gill nets was not detectably different from that in other years and it is probable that the age composition of the anglers' catch in the lake had not changed either.

Catch statistics of the Lakelse cut-throat fishery, 1950-1955

| Year | River | | | | Lake | | | |
|---|---|---|---|---|---|---|---|---|
| | Hours fished | Estimated catch | Catch per hour | Average age | Hours fished | Estimated catch | Catch per hour | Average age |
| 1950 | 819.0 | 1148 | 1.40 | 3.23 | 1294.0 | 1342 | 1.03 | 3.21 |
| 1951 | 764.0 | 836 | 1.09 | 3.59 | 885.0 | 768 | 0.86 | 3.41 |
| 1952 | 1026.8 | 1140 | 1.11 | 4.93 | 1240.0 | 1338 | 1.08 | 3.75 |
| 1953 | 1103.7 | 781 | 0.71 | 3.71 | 830.0 | 1068 | 1.29 | 3.45 |
| 1954 | 1206.2 | 765 | 0.63 | 3.48 | 463.7 | 887 | 1.93 | 4.61 |
| 1950-1954 Average | 983.9 | 934 | 0.94 | 3.54 | 942.5 | 1080 | 1.14 | 3.69 |
| 1955 | 726.0 | * | * | 3.40 | * | * | * | * |

*Data not available.

Age III- and IV-trout have predominated in the catch each year. A lesser number of II-, V- and VI-year-old trout are also taken. The proportion of older fish has not declined since 1950 but has actually tended to increase. These findings indicate that fishing has not depleted the population to a point where the age composition has been affected.

Figures on the catch per unit of effort for 1950-1954 indicate that there has been no progressive decline in the abundance of trout in Lakelse Lake proper; the catch per hour has actually tended to increase rather than to decline. No figures are available for 1955 but, due to inclement weather, very little fishing was carried out.

Catches on the Lakelse River tended to decline from 1950 to 1954. In 1955 adequate catch data were obtained for the first week of the season only. Comparison with the opening week catches of other years indicates that the return per effort was greater in 1955 than in the previous two years, but was somewhat lower than in the first three years of the creel census. The lower return per effort on the river in the last three years has probably been associated with a change in the distribution of the fish and in the fishing effort due to the operation of the Lakelse River sockeye counting fence. Prior to the installation of the weir in 1952, the fishing effort was distributed quite uniformly on the Lakelse River between the mouths of Herman and Coldwater Creeks. In March of 1952, the weir, located halfway between the two creeks was installed. Although a boat passage was provided to facilitate the movement of anglers up and downstream, the fishing effort was largely concentrated in the area upstream from the weir. During this year the movements of the trout were also restricted by the fence operation. It is estimated that from 1,000 to 2,000 of the older and larger trout, which normally would have migrated downstream, were confined to the upstream region. This occurrence is reflected in the higher average age of fish caught during this season (see table). Thus, although the area utilized by the anglers was reduced, this restriction of the fish to the upstream area provided them with an unusually heavy concentration of fish. The result was that a catch per effort similar to previous years was attained.

In 1953 and 1954, however, improvements in design resulted in the ready passage of trout downstream through the fence. As in 1952, the anglers ventured but rarely to the fishing grounds below the fence and thus failed to exploit a proportion of the trout population they would normally have fished in former years. Failure to fish the downstream area during the summer, when the spring spawners in the Coldwater area became available to angling, further decreased the extent of their exploitation. It is probable that these conditions are responsible for the catch per unit of effort in 1953 and 1954 being considerably lower than in the previous three years.

In the past three years approximately 1,500 cut-throat trout in both the Lakelse River and in the lake have been marked by the removal of fins or by the application of tags. Population estimates based on these experiments have shown that the population in Lakelse Lake during the summer is in the neighbourhood of 15,000 fish of catchable size. Of these the anglers have removed annually an average of 1,080 trout or approximately 7% of the available stock. The marking experiments have also shown that from 3,000 to 5,000 trout migrate down the Lakelse River each spring. Of these fish up to 3,000 may be mature individuals which are not readily available to the early-season fishermen. The anglers have taken an average of 934 fish from the river annually, which represents between 18% and 31% of the population.

## SPRING AND COHO SALMON - D.J. Milne

In recent years the trollers in British Columbia have expressed concern about the conservation of the stocks of spring and coho salmon which they fish. For the last five years the total catch of spring and coho salmon has amounted to about one-quarter of the total salmon landings in British Columbia. The trollers take approximately two-thirds of the catch of both spring and coho salmon. The rapidly expanding ocean sport fishery in the Strait of Georgia also catches these two species of salmon almost exclusively.

Early tagging experiments indicated that the catch in each area is composed of fish from many streams along the Pacific coast, and that some stocks, especially the Columbia and Fraser River spring salmon, migrate long distances and are fished internationally. Accordingly, a close liaison has been maintained with United States biologists through their coordinating agency, the Pacific Marine Fisheries Commission. In recent years, coastwide tagging, marking and sampling programs have been carried out in friendly cooperation. A summary of the tagging experiments off British Columbia from 1949 to 1952 and a comparison of the results with those from 1925 to 1930 is now ready for publication. The results of the 1955 sampling of the troll catch for size and age of fish and a preliminary review of the distribution of the recoveries of fish marked in United States streams is presented in this report.

In previous reports a discussion of the proposed regulations to protect small salmon has been given, together with recent information on growth, maturity and mortality of releasing small fish. Although the States of Washington, Oregon and California have adopted certain closed seasons and minimum sizes, our studies suggest that these are not good conservation measures. If small fish are caught by trolling gear and released, the mortalities are probably too high for any gain to result from the increase in growth of the survivors. At present only an opening date of June 16 to prevent the capture of small coho salmon has been adopted in British Columbia.

The Columbia River spring salmon catch has dropped to record lows in the last four years. The United States biologists are greatly concerned about the sharp decline in the important fall runs and further restrictive measures have been advocated for trolling along the entire coast. To ascertain how the troll catches off British Columbia have been affected and to assess the present condition of our stocks, new field work was curtailed in 1955. Instead, a review of knowledge of spring salmon and a history of the spring salmon fisheries was undertaken. Recommendations for future work will be based on this review.

## Recent catches of spring and coho salmon

### 1. Commercial catches.

Reliable catch statistics, by species and gear, are available only since the introduction of the sales-slip system in 1951. A summary of the British Columbia spring and coho salmon catches in thousands of pounds (round weight) is given in Table I.

Table I. Spring and coho salmon catches in thousands of pounds (round weight)

| | Total catch all gear | Troll catch | | | Troll catch as % of total catch |
|---|---|---|---|---|---|
| | | Red | White | Total | |
| **Spring Salmon** | | | | | |
| 1951 | 12,920 | 7,210 | 1,190 | 8,400 | 65 |
| 1952 | 14,420 | 8,770 | 1,540 | 10,310 | 71 |
| 1953 | 15,670 | 8,240 | 2,410 | 10,650 | 68 |
| 1954 | 13,490 | 6,420 | 1,880 | 8,300 | 61 |
| 1955 | 12,530 | 7,030 | 1,090 | 8,120 | 65 |
| **Coho Salmon** | | | | | |
| 1951 | 35,140 | .. | .. | 19,510 | 55 |
| 1952 | 22,190 | .. | .. | 17,200 | 77 |
| 1953 | 23,160 | .. | .. | 13,710 | 59 |
| 1954 | 20,690 | .. | .. | 11,710 | 57 |
| 1955 | 23,550 | .. | .. | 13,460 | 57 |

In 1955 the total and the troll catches of <u>spring salmon</u> were the lowest in the last five years. The troll catch of red springs was late and low, as in 1954. For outside waters this was associated with the poor fall chinook salmon runs to the Columbia River in the last four years. The troll catch of white springs was similar to the low catch in 1951 and below the high catches in the last three years. It appears that the survival from the 1950 brood year was good, producing good catches of small fish (3-year-olds) in 1953 and large fish (4-year-olds) in 1954.

The troll catch of coho salmon in 1955 was also late with the peak in August instead of July. The September and October catches were below average and the final total was the second lowest in the last five years. The lower catch in 1954 was a striking failure since it was the return from the record catch in the brood year 1951 (most coho salmon mature and are caught in their third year). This failure is attributed to the poor survival of young salmon in the streams during the dry summer of 1952. The troll catch in 1955 was lower than in the brood year 1952 but in that year a strike of net fishermen allowed a higher proportion (77%) to be caught by troll. Since the total catch in 1955 was higher than the total catch in 1952, the catch this past season can not be construed as a failure.

The total troll catch of both spring and coho salmon and the total numbers of days fished are given in Table II.

Table II. The combined catches of spring and coho salmon.

| | Total troll catch in lb. (round weight) | Troll days | Average pounds per boat-day |
|---|---|---|---|
| 1951 | 27,910,000 | 133,000 | 210 |
| 1952 | 27,510,000 | 130,000 | 211 |
| 1953 | 24,360,000 | 121,000 | 200 |
| 1954 | 20,010,000 | 109,000 | 185 |
| 1955 | 21,580,000 | 113,000 | 192 |

The catch, effort and catch per boat-day was high in 1951 and 1952 and low in the last two years. Thus the trollers experienced poor fishing.

For the first time, fishing licences were restricted to commercial fishermen only in 1955. The result was that fewer troll licences were issued and the number should represent the commercial trolling effort more accurately than in the past which included some sport and weekend fishermen.

2. Sport catches.

The sport troll fishery operates in inshore tidal waters, mainly in the Strait of Georgia but also in local areas such as Rivers Inlet, Gold River and Alberni Canal. Estimates of the catches have been made by the Fishery Officers for the last few years and a summary of the data for the years 1953 to 1955 was released in March, 1956. The catch of coho averages about 60,000 fish (300,000 lb.), springs about 50,000 fish (500,000 lb.) and grilse (salmon less than 3 lb. round) about 120,000 fish (240,000 lb.). The total sport catch is about 6% by number (3% by weight) as large as the total commercial catch of spring and coho salmon. The fish caught by sportsmen are smaller in average size than those taken by commercial fishermen. In the Strait of Georgia by itself the sport catch is about one half as large (by numbers) as the commercial catch of spring and coho salmon. In this region the sport fishery is now a substantial factor and as such should receive more attention in both research and management. To study the stocks of spring and coho salmon the large number of small salmon (grilse) caught by sport fishermen must be separated into species. It is suggested that the best character to use is "black gum" for spring salmon and "white gum" for coho salmon.

Sampling spring and coho catches for studies of growth and migration

The troll landings of spring and coho salmon have been sampled at Vancouver and Prince Rupert since 1952. The following three types of sampling were used in 1955 as in previous years, but no coho salmon were sampled at Prince Rupert: (a) a small random sample of each species was measured for length and weight, scales taken for age determinations, and a color rating of the flesh recorded on spring salmon; (b) a larger random sample of each species was measured for length; and (c) entire loads of individual trollers were tallied for number of fish and total weight of each species. In each type all fish were examined for missing fins.

The number of fish examined by each of the three methods for the years 1952 to 1954 were listed in last year's report. The number examined in 1955 together with the total number of fish with one or two fins missing are as follows:

Table III. Numbers of spring and coho examined and missing fins recovered

| | | | | | Missing fins | |
|---|---|---|---|---|---|---|
| | a | b | c | Total | Double | Single |
| Spring Salmon | | | | | | |
| Vancouver | 697 | 15,714 | 54,134 | 70,545 | 25 | 103 |
| Prince Rupert | 501 | 4,077 | 10,445 | 15,023 | .. | 14 |
| Total | 1,198 | 19,791 | 64,579 | 85,568 | 25 | 117 |
| Coho Salmon | | | | | | |
| Vancouver | 573 | 15,183 | 55,847 | 71,603 | 8 | 70 |

1. Growth studies.

(a) Coho salmon - Since almost all coho salmon are caught during their third year the variation in the size of fish is an indication of the growth achieved in different regions and in different seasons. The average length of fish sampled each month in 1955 are compared in Table IV with the averages of the three preceding years.

Table IV. Average length of coho salmon

| | Fork length of fish (cm.) | | | |
|---|---|---|---|---|
| | June | July | August | No. of fish |
| Caught inside Vancouver Island | | | | |
| 1952 to 1954 (Av.) | 52.3 | 53.9 | 54.3 | 7,222 |
| 1955 | 50.0 | 51.8 | 52.9 | 8,959 |
| Caught outside Vancouver Island | | | | |
| 1952 to 1954 (Av.) | 57.6 | 61.7 | 65.1 | 6,444 |
| 1955 | 56.9 | 62.1 | 62.6 | 4,222 |

In 1955, one week after the season opened on June 1, the minimum size limit (2 1/2 lb. dressed) was removed for coho salmon (bluebacks) caught inside Vancouver Island in the Strait of Georgia. This is the first time the size limit has been changed and it foreshadows a change in 1956 of the opening date from June 1 to June 16 (elsewhere the opening date for coho salmon has been June 16 since 1952). Owing to the removal of the minimum size limit in this area the average size of fish was smaller in 1955 than in previous years. Estimates from the sampling indicate that in June, 24% of the fish caught were less than the minimum weight, compared to 11% in 1954, 2% in 1953 and 4% in 1952.

The difference in the length of fish caught in the two regions is most marked. Fish caught outside Vancouver Island are almost twice the weight of those taken on the inside at the same season. In 1955 the fish caught off the west coast of Vancouver Island were also small, particularly in August. The fish caught in June and July in 1954 were smaller than those taken in the same months in 1955 but the peak catch in 1955 was in August rather than in July. Consequently it appears that poor ocean conditions were encountered in both 1954 and 1955 but they affected the two stocks at different times.

(b) Spring salmon - Previous reports have given preliminary age determinations for some samples prior to 1954 and have discussed the complexity of obtaining consistent age determinations from spring salmon scales. The scales have now been rechecked by using as a guide the circuli count to the first annulus and the average scale measurements to each of the remaining annuli. A summary of the newly estimated percentages in each age group in 1952 to 1955 is given in Table V.

In the first four areas all fish were caught by troll and over 90% are of the ocean-type which means that the young went to sea as fry in their first year. The fifth group of fish were caught by gill net in the Fraser River and one-third are of the stream-type or went to sea in their second year. It is rather surprising that so few stream-type fish are caught by the trollers in the Strait of Georgia but apparently these younger feeding fish are almost all of the ocean-type.

The fish caught off the north and west coasts of the Queen Charlotte Islands are older than those caught in Hecate Strait, and those off the west coast of Vancouver Island older than those in the Strait of Georgia. More young fish are caught in the two southern than in the two northern areas. The Fraser gill-net samples were selected fish of small size (for gonad studies) and do not represent the older age-groups adequately. In 1956 the gill-net fishery will be sampled in a representative manner for the first time.

Table V. Age composition of spring salmon catches.

| Area | Year | No. of fish | Ocean type 2 | 3 | 4 | 5 | Total | Stream type 3 | 4 | 5 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| N.W. Queen | 1952 | 19 | ... | 5 | 79 | 16 | 100 | ... | ... | ... | ... |
| Charlotte | 1953 | 175 | 7 | 48 | 37 | 1 | 93 | 4 | 2 | 1 | 7 |
| Islands | 1954 | 73 | 1 | 25 | 58 | 12 | 96 | ... | 1 | 3 | 4 |
| | 1955 | 107 | 11 | 24 | 34 | 18 | 87 | 4 | 3 | 6 | 13 |
| Average | | | 4.7 | 25.5 | 52.0 | 11.8 | 94 | 2.0 | 1.5 | 2.5 | 6.0 |
| Hecate Strait | 1952 | 396 | 4 | 56 | 33 | 3 | 96 | 1 | 3 | ... | 4 |
| | 1953 | 239 | 4 | 44 | 43 | 4 | 95 | 1 | 3 | 1 | 5 |
| | 1954 | 326 | 8 | 35 | 46 | 7 | 96 | 1 | 3 | ... | 4 |
| | 1955 | 345 | 8 | 61 | 19 | 3 | 91 | 4 | 4 | 1 | 9 |
| Average | | | 6.0 | 49.0 | 35.3 | 4.2 | 94.5 | 1.8 | 3.2 | .5 | 5.5 |
| West coast of | 1952 | 114 | 38 | 54 | 7 | ... | 99 | 1 | ... | ... | 1 |
| Vancouver | 1953 | 269 | 15 | 56 | 11 | 1 | 83 | 12 | 5 | ... | 17 |
| Island | 1954 | 194 | 16 | 47 | 27 | ... | 90 | 5 | 4 | 1 | 10 |
| | 1955 | 361 | 11 | 65 | 20 | 1 | 97 | 1 | 2 | ... | 3 |
| Average | | | 20.0 | 55.5 | 16.2 | .5 | 92.2 | 4.8 | 2.8 | .2 | 7.8 |
| Strait of | 1952 | 156 | 36 | 62 | 1 | ... | 99 | 1 | ... | ... | 1 |
| Georgia | 1953 | 62 | 10 | 82 | 5 | ... | 97 | 3 | ... | ... | 3 |
| | 1954 | 223 | 16 | 64 | 16 | ... | 96 | 1 | 3 | ... | 4 |
| | 1955 | 287 | 15 | 68 | 16 | ... | 99 | ... | 1 | ... | 1 |
| Average | | | 19.3 | 69.0 | 9.5 | ... | 97.8 | 1.2 | 1.0 | ... | 2.2 |
| Fraser River | 1952 | 34 | 32 | 15 | 26 | ... | 73 | 18 | 9 | ... | 27 |
| | 1953 | 103 | 13 | 34 | 18 | 2 | 67 | 15 | 12 | 6 | 33 |
| | 1954 | 40 | 5 | 33 | 28 | ... | 66 | 22 | 10 | 2 | 34 |
| | 1955 | 71 | 6 | 37 | 17 | ... | 60 | 22 | 18 | ... | 40 |
| Average | | | 14.0 | 29.8 | 22.2 | .5 | 66.5 | 19.3 | 12.2 | 2.0 | 33.5 |

2. Mark returns for spring and coho salmon.

From 1949 to 1953 over seven million spring salmon fry and three million coho salmon yearlings were marked and released from hatcheries in Washington, Oregon and California by removing two or more fins, using distinctive combinations for each experiment. No fish were marked in British Columbia or Alaska. To discover the ocean distribution and abundance of these fish, about one-half million fish of each species have been examined for missing fins along the Pacific coast from California to Alaska each year since 1952. In addition to these experiments many single-fin markings have been carried out in United States streams.

Last year a summary was given for 1952 to 1954 of the number of marked fish recovered in the five sampling zones in British Columbia. As in previous years fish with two fins missing were recovered only off southern British Columbia, mainly off the west coast of Vancouver Island. Sampling for marked fish will be reduced in 1956.

Preliminary summaries have been completed by some of the marking agencies and a few of the results will be presented. It should be noted that the total numbers of marks in the catches are calculated from the ratios of marked to unmarked fish in the samples. This means that the low availability of double-fin marks in the large British Columbia catch gives wide confidence limits to the calculated number of marks recovered in British Columbia compared to other regions.

Six coho salmon experiments are in Table VI.

In these experiments about 500,000 yearlings were marked and the total number of calculated returns was about 8000 or 1.6%. Fish from Minter Creek (Puget Sound) migrated both north and south from Cape Flattery and almost one-half of the troll recoveries were caught off the west coast of Vancouver Island. Approximately 50% of the total returns were from the sport fishery in Puget Sound. From Skagit River (Puget Sound) and Willapa River (Washington coast) the fish migrated mainly southward and the majority were later recovered in the net fisheries near the rivers. Most of the fish from the Lewis River (Columbia River) were caught by the troll fisheries in both a north and south direction. The catch to escapement ratios varied from 4:1 to 1:1 in the different experiments.

Six spring salmon experiments are in Table VII.

In these experiments about 1,300,000 fry were marked and the total number of calculated returns was about 11,000 or 0.9%. Fish marked in the Green and Deschutes Rivers in Puget Sound migrated mainly northward from Cape Flattery and about one-half of the troll recoveries were caught off the west coast of Vancouver Island. Most of the recoveries were made by the Puget Sound sport fishery. Fish marked in Kalama River and Herman Creek of the Columbia River system migrated mainly northward and the majority were recovered in the troll fishery off the Washington and British Columbia coasts. Similarly the fish marked in the Sacramento River of California were recovered by the various troll fisheries situated in a northerly direction along the coast. The catch to escapement ratios indicated by the experiments varied from 9:1 to 4:1. The great inter-mixing of stocks during the ocean migration of the fish along the Pacific coast is demonstrated, similar to the results of tagging adult fish, except that few marked Columbia River fish have been recovered from Northern British Columbia or Alaska.

Table VI. Marking experiments on coho salmon.

| Place marked | Number of experiments | Number of fish marked in thousands | Total number of calculated returns | Percentage of returns: Troll fishery: British Columbia | Washington | Oregon | Total | Net fishery | Sport fishery | Escapement |
|---|---|---|---|---|---|---|---|---|---|---|
| Minter Creek | 3 | 240 | 5690 | 6 | 6 | 2 | 14 | 8 | 52 | 25 |
| Skagit River | 1 | 70 | 792 | .. | 10 | 1 | 11 | 41 | 17 | 30 |
| Willapa River | 1 | 85 | 569 | .. | 21 | 10 | 31 | 47 | .. | 22 |
| Lewis River | 1 | 85 | 975 | .. | 20 | 23 | 43 | 3 | 8 | 46 |

Table VII. Marking experiments on spring salmon

| Place marked | Number of experiments | Number of fish marked in thousands | Total number of calculated returns | Percentage of returns: Troll fishery: B.C. | Washington | Oregon | California | Total | Net fishery | Sport fishery | Escapement |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Green River | 1 | 200 | 404 | 10 | 6 | .. | .. | 16 | .. | 59 | 25 |
| Deschutes River | 1 | 205 | 4421 | 6 | 9 | .. | .. | 15 | 3 | 63 | 20 |
| Kalama River | 1 | 200 | 1364 | 20 | 42 | 5 | .. | 67 | 13 | 7 | 13 |
| Herman Creek | 1 | 202 | 535 | 6 | 55 | 3 | .. | 64 | 18 | 7 | 11 |
| Sacramento River | 2 | 470 | 4200 | 2 | 32 | | 22 | 56 | 9 | 10 | 25 |

## History of spring salmon fisheries

In the early days of the British Columbia salmon fishery most of the fish were caught by gill nets and canned. Records of the pack show that from 1910 to 1920 the number of cases of spring salmon increased from 30,000 to over 100,000. Since then both the amount and the proportion which was canned has gradually decreased until in recent years less than 20,000 cases or 10% of the total catch has been processed in this way. The majority is now used in a fresh or frozen state. Before 1945 accurate statistics are not available for the total catch of spring salmon. However, estimates of the catch by type of gear for the period 1920 to 1945 suggest that in the early years the gill nets caught two-thirds of the total catch and the trollers caught one-third. Since then the gill-net catch appears to have remained relatively constant at about 250,000 fish each year. From 1920 to 1925 the trollers caught one-third of the total or about 100,000 fish and from 1926 to 1940 they caught about the same number as the gill nets. During the period 1941 to 1946 the number of trolling licences increased sharply from 3,000 to 5,000 and the troll catch increased until soon they were taking two-thirds of the total catch or about 650,000 fish. During the past decade the total catch has remained at about 900,000 fish, apparently the highest in the history of the fishery. In addition the sport fishery has expanded rapidly in the Strait of Georgia during recent years.

The proportion of white-fleshed spring salmon caught off British Columbia appears to have increased until now it constitutes about one-quarter of the troll catch and one-half of the gill-net catch. Both catch and escapement records suggest that the white spring salmon spawn mainly in certain large coastal rivers of British Columbia, especially the Fraser River, while the Columbia River stocks are composed of red spring salmon. It is of interest that for the last five years the Fraser River gill-net catch of spring salmon is about one-third as large as the gill-net catch in the Columbia River.

The chief factor affecting the outside troll catch of red spring salmon off British Columbia is the recent changes in the Columbia River stocks. Tagging experiments have shown that Columbia River fish are caught off the west coast of Vancouver Island and the Queen Charlotte Islands. For fish tagged off Vancouver Island the recoveries from the Columbia River were much lower (16%) in the recent experiments than those conducted 25 years ago (60%). In contrast, Fraser River recoveries increased from 5% to 12%. Because smaller fish were tagged recently, more were recaptured in the tagging areas before migrating to the rivers as mature salmon. Thus the results suggest that in 1930 the Columbia River stocks contributed over one-half of our outside troll catch but by 1950 they probably accounted for only about one-quarter of the outside catch of 5,000,000 pounds. Based on tag returns and time of fishing, our outside trollers have always fished the late runs to the Columbia River more heavily than the earlier runs.

The Columbia River gill-net catch gradually declined from 1920 (30,000,000 lb.) to about one-half in 1945. Since 1948 the catch has dropped sharply to a record low of 5,000,000 pounds in 1954. Before 1930 the spring and summer chinook runs made up more than one-half of the catch but they were gradually reduced to a low level by 1945. Since then the summer chinook catch has remained constant under a restricted fishing season and the spring catch and escapement has increased slightly. This past decline in the spring and summer chinook stocks no doubt affected our outside troll fishing early in the season.

From 1930 to 1950 the fall chinook gill-net catch remained relatively constant at about 10,000,000 pounds annually, but since then it has dropped sharply to less than 5,000,000 pounds in both 1954 and 1955. The number of fall chinooks counted over Bonneville dam is approximately equal to the spawning escapement. From 1930 to 1950 the count varied between 200,000 and 300,000 fish but since then it has dropped sharply to less than 100,000 fish in both 1954 and 1955. The recent decline in the important fall chinook populations is no doubt affecting the troll catches off British Columbia at the peak of the fishing in the last few years.

Much of the long-term decline in the spring and summer stocks of the Columbia River must be attributed to the construction of many dams, which have rendered about 70% of the river mileage inaccessible to salmon, and to the heavy fishing intensity. The reason for the recent decline in the fall run is not clear. Since 1948 considerable effort ($10,000,000) has been put into the rehabilitation of the lower Columbia tributary streams by improvements to the spawning areas and by increasing the hatchery production. On the other hand, the offshore troll fisheries along the entire Pacific coast have expanded greatly since the war. The recent marking experiments on young fall chinook salmon indicate that the trollers catch 65% of the recoveries, the river fisheries 20%, and 15% escape to spawn. However, the proportion taken by the troll fisheries is biassed because the fish are younger (mostly 3-year-olds) than the river fish (mostly 4-year-olds) and the ocean mortality is still incomplete. Based on recent tagging results and on catch data it is more probable that the trollers now take about 50% of the fall chinook stocks, the river fisheries 30%, and 20% escape to spawn.

Since 1930 the total Columbia River population has probably dropped by one-half and the river fishery by three-quarters; the troll catch of Columbia fish has remained constant because of the greater and more efficient effort in recent years. In any case, in past years the river catch was much larger than the troll catch but now the troll catch appears to be larger than the river catch. Because of the small size of both the catch and the escapement of fall chinook salmon in the last few years, the biologists of Washington and Oregon have recommended further restrictions on the fisheries to increase the number of spawners. In 1956 the opening date for the troll fisheries off Washington and Oregon has been changed from March 15 to April 15 and additional closed seasons are to be placed on the river fisheries.

In conclusion the concern of our trollers in recent years may well arise from over-effort and high operating costs, causing smaller individual catches and profits, without any decrease in fish production, except for the effect of the recent decline in the fall chinook stocks of the Columbia River. Unfortunately it is not known what effect the present high fishing effort is having on the stocks of spring salmon which spawn in the larger streams of British Columbia. It would appear that they are being exploited more heavily in recent years and that in certain areas more immature fish are now being taken than formerly. In 1956 the important Fraser River stocks of red and white spring salmon (probably one-fifth of the fish spawning in British Columbia) will be investigated by field work at the river fishery and in the spawning streams.

## PINK, CHUM AND COHO PRODUCTION FROM KNOWN SPAWNINGS AT PORT JOHN - J.G. Hunter

Adult pink and chum salmon migration in 1954, 1955. The escapement of pink and chum salmon into Hooknose Creek, Port John, shows only slight variation from year to year in the time of entry onto the spawning beds. Chum salmon as a rule follow the pink salmon and these two years were no exception.

The spawnings by the two species in 1954 and 1955 were:

| Species | Year | Number of adults | Percent female | Average egg content | Potential deposition | Percent loss of eggs by retention |
|---|---|---|---|---|---|---|
| Pinks | 1954 | 31,402 | 56.00 | 1,666 | 28,200,382 | 2.03 |
| | 1955 | 1,319 | 55.73 | 1,833 | 1,279,434 | 0.30 |
| Chums | 1954 | 3,336 | 54.98 | 3,097 | 5,580,794 | 1.15 |
| | 1955 | 1,301 | 50.94 | 2,673 | 1,312,443 | 0.15 |

Average egg content and retention for pink salmon was based in 1954 on 177 and 598 samples respectively and in 1955 on 9 and 126 samples. Chum salmon averages were based in 1954 on 22 and 165 samples and in 1955 on 38 and 60 samples.

The area of spawning gravel in Hooknose Creek totals about 12,000 square yards but the area generally utilized by the fish is approximately 7,500 square yards. The mean number of square yards of gravel per fish varies considerably from year to year as is shown by the two years 1954 and 1955. Maximum production of fry appears to result from an escapement of approximately 12,000 fish.

Meteorological, stream discharge, and water temperature recordings were made twice daily.

Output of pink and chum fry in 1955. The downstream weir was installed before the egress of pink and chum fry. The seaward migration for these two species commenced about March 20, with both species emigrating at approximately the same rate. Usually the pink fry precede the chum fry, whereas this year the mid-point of the chum run on April 22 anticipated the mid-point of the pink run by three days. The output of fry in relation to the egg deposition is shown in the following tabulation:

| Species | Potential deposition | Number of fry | Percent survival |
|---|---|---|---|
| Pinks | 28,200,382 | 907,458 | 3.2 |
| Chums | 5,580,794 | 353,761 | 6.3 |

A study of the degree of predation by two of the major predators (sculpins and coho smolts) in the stream provided a basis for estimating the approximate number of fry taken each year, thus permitting calculation of the combined number of pink and chum fry emerging from the gravel. The percent survival of combined pink and chum fry to the emergence stage correlated with the numbers of adult fish in the spawning population shows that over 95% of the variation in survival up to this stage is a result of the density of spawning fish. Variation in stream discharge and freshets were estimated to have an effect on the variation in survival of less than 4% while all other factors combined showed less than 1%. The optimum spawning population for the production of fry is indicated as about 10,000 fish. The "optimum spawning population" here refers to that which produces the greatest numbers of fry rather than the greatest percentage survival to the fry stage.

Some attention has been given to the question of control of predators. Coho salmon are a valuable asset but in many cases their feeding habits are to the detriment of the production of pink and chum salmon fry. It is questionable whether coho should not be excluded from some streams. A major portion of the sculpin population moves downstream to spawn in the intertidal zone and returns upstream after spawning. At Hooknose Creek, upstream movement cannot proceed until the removal of the weir. A large degree of control of the sculpin population could be exercised by the construction of a low dam which, while preventing upstream migration of sculpins, would not affect the movement of adult salmon. Further work has shown that poisoning of the stream to remove sculpins will not damage salmon eggs deposited in the gravel. While poisoning might be effective, the control afforded by each application would be of short duration and hence in the long run the method would be costly.

Ocean survival of pink and chum fry shows considerable variation. The commercial fishery may account for some of this but it is believed that natural variation also occurs in the sea. The ocean survival of pink salmon fry measured by the return of adults is shown in the following table for the years 1947 to 1953.

Pink salmon - Hooknose Creek

| Year of spawning | Spawning stock | Fry produced | Returning adults | Ocean survival |
|---|---|---|---|---|
| 1947 | 5,576 | 33,349 | 1,173 | 5.2 |
| 1948 | 1,160 | 64,312 | 1,857 | 3.1 |
| 1949 | 1,173 | 54,061 | 1,670 | 3.2 |
| 1950 | 1,857 | 234,396 | 8,685 | 3.7 |
| 1951 | 1,670 | 242,993 | 1,599 | 0.7 |
| 1952 | 8,685 | 1,227,025 | 31,402 | 2.6 |
| 1953 | 1,599 | 204,250 | 1,319 | 0.6 |

Ocean survival cannot be readily determined for chum salmon since they return as mature fish at different ages.

Coho studies, 1955. A small run of coho salmon maintains itself in the Port John system. Statistics on these fish are gathered at the adult counting weir in the late summer and fall and at the fry collecting weir in the spring and early winter.

Survival figures of egg to smolt stage in the fresh-water life history, and from smolt to adult stage in the marine phase of their life history were recorded.

The adult coho entering Port John in 1953 deposited a calculated 170,568 eggs which produced an emigrating population of 6,756 smolts, constituting a 4.0% survival for this stage. Survival found at this stage ranges from 0.6% to 4.0% at Port John for the years from 1949 to 1955. The marine survival of the progeny of the 1951 spawning escapement was calculated from a return of 490 jack coho in 1953 and 327 3-year-old coho in 1954 from an escapement of 4,037 smolts to be 20%. Ocean survival for Port John coho over the past eight years has varied from 4.0% to 20.0%.

In the summer and fall of 1955 a large escapement of adult coho into the stream was recorded. A total of 901 coho entered the stream, many of which were "jack" coho. In the spring of the same year, 1970 migrating smolts were marked by the removal of the adipose and right ventral fins and in that fall 147 of these marked smolts returned as "jack" coho. This return showed an ocean survival of 7.5% up to this stage.

The possibility that individuals going to sea as fry may affect survival estimates is at present under investigation by use of a fin-marking experiment.

## CONDITIONS FOR SURVIVAL AND DEVELOPMENT OF SALMON EGGS - W.P. Wickett

### Some effects of low flow through a salmon egg mass

A foot-long vertical column of newly fertilized chum salmon eggs was set up in each of two four-inch diameter glass tubes. One column was used by Mr. Terhune to establish the permeability constant of a mass of eggs of 4.1-mm. radius as approximately 50,000 cm./hr. at 10° C. This column had a flow with an apparent velocity of 1000 cm./hr. At the end of 50 days, only 76 out of 5600 strongly-eyed eggs had died. This column served as a control for the second column which had water flowing at an apparent velocity of 10 cm./hr. up through it.

The most important effect noted was that the development of the embryos was progressively delayed from inlet to outlet. Death was occurring in the pre-eyed and faintly-eyed stages in the centre of the column after eggs near the inlet were strongly eyed. From this we may infer that the high losses in the early stages observed in nature have not necessarily occurred soon after fertilization. Low sub-surface flow is a more likely explanation of natural losses than a sudden catastrophe in early winter.

Despite precautions, water did not pass through the egg mass uniformly but in streams. The use of dye showed that the live eggs were in these streams and the dead eggs in the parts of the column the dye reached slowly, regardless of nearness to the inlet. Although a neat cut-off for development and survival was not obtained by layers, 30% survival was found in the two inches nearest the inlet and 6% in that near the outlet.

The equivalent of two layers of eggs (i.e., 240 eggs) reached the strongly-eyed stage. In the five and a half layers nearest the outlet, 92% (584) of the eggs died undeveloped and only 5% reached the faintly-eyed stage.

The inlet water had 11 mg./l. oxygen, 0.04 to 0.08 p.p.m. ammonia, 10 p.p.m. carbon dioxide; the pH was 6.6. On the twenty-seventh day when many dead eggs were seen near the outlet for the first time, the corresponding values in the outlet water values were 0.7, 2.8, 20; on the forty-third day when the experiment ended, the values were 0.3, 6.4, 23.1 and the pH 6.53. The temperature was 10-12° C. Seventy-one hundred and forty eggs made up 60 layers to a length of 14 inches.

## Instrument for sampling water in gravels and measuring its flow

Last year's study of natural salmon egg survival showed the need to extend the calibration of the "standpipe" to higher values of permeability. In loose gravels the water could be pumped out at rates beyond those given by Pollard in Volume 12 of the Board's Journal.

Calibration studies at the Model Laboratory were started by L.D.B. Terhune of the Pacific Oceanographic Group during the summer. Field studies were carried out by D. MacKinnon at Jones Creek. It was found that the "mark 3" standpipe being used had a liner too small to admit a tube large enough to carry water at the higher rates without interfering with the passage of air down between the liner and the tube. This has led to the design and testing of a new model standpipe as well as extending the permeability calibration up to a value of one million millimetres per hour. This value is reached when water is removed at a rate of 62 cc. per minute under a one-inch head.

The "mark 4" standpipe which resulted retains the same dimensions of the outside tube and perforated chamber as the "mark 3" but has a removable liner and is longer so as to dispense with extensions. The standpipe is driven by means of a bar so that the pointed nose-piece is driven directly, thus avoiding breakages at the top threads that occurred in the "mark 3". The new standpipe has the added advantage of cheaper construction.

Testing of the new standpipe has led to the improvement of the hydraulic gradient readings which are made by following the rate of dilution of a dye introduced into the perforated chamber. Green food dye is used instead of methylene blue. It washes free without adsorption and changes of color intensity are easier to see.

At present the addition of alcohol to bring the dye density to that of water and the use of a rubber diaphragm to confine the dye to the perforated chamber, hold promise of improving the hydraulic gradient readings to the point that when, combined with the already satisfactory permeability readings, accurate absolute values for velocity will be obtained.

## Survival of salmon eggs in natural gravels

From November, 1954 to February, 1955, 130 salmon redds were sampled in statistical Area 14 of Vancouver Island (between Nanaimo and Campbell River) and velocity of flow and oxygen content measured. Pink, chum and coho eggs were recovered and their survival noted in relation to dissolved oxygen and apparent velocity of gravel water.

This was the first test of the hypothesis set out in 1954 that high survival should be related to a high oxygen supply. The oxygen supply (being the product of dissolved oxygen content and the velocity of the water per unit area of egg mass) will satisfy a given oxygen demand per unit area of egg mass with increasing velocity as the oxygen content decreases. Laboratory work with high flow of water showed that the oxygen content could be lowered to two parts per million without affecting survival.

The plot of field data showed that the high survivals were related to high oxygen supply but that the minimum oxygen level was five parts per million. It is suggested that the difference between five and two parts per million is due to the accumulation of waste products at the velocities (40 cm. per hour or less) encountered in nature.

At present the minimum suitable sub-surface water conditions for egg survival in the gravel appear to be a velocity of about ten centimetres per hour and an oxygen content of five parts per million.

## Spawning runs of pink and chum salmon to Jones Creek in 1955

D. MacKinnon

The chief objective of the Jones Creek operations this year was to observe the response of the adult pink and chum spawning runs to the artificial spawning channel. Besides this, daily counts and observations were made of the size, composition, distribution and behaviour of these runs.

The fish moved out of the Fraser into Jones Creek, out of the creek into the artificial channel and immediately moved to the uppermost sections and spawned. The only evidence of delay occurred at the third baffle in the artificial channel where a one-foot head proved difficult enough to cause some of the pinks to make several unsuccessful jumps. It is felt that this factor provided the nucleus for the small group (40) of fish that spawned in the creek below the channel.

The main body of the run, approximately 400 pinks and 150 chums, spawned in the artificial channel. Examination of the dead fish showed that 63% of the pinks and 59% of the chums were female and also showed egg retention to be negligible; an estimated 428,000 pink and 240,000 chum eggs were deposited in the channel.

Many of the planned observations on the dynamics of a spawning population were reduced as a result of the small run (10% of expected). However, certain features stood out. The early pinks chose spawning sites in the uppermost sections and subsequent fish spawned immediately behind them. For this reason it is felt that had a large run materialized it would have distributed itself such that maximum utilization of available space would result. The factor that influenced distribution in this case seemed to be the "cover" provided by the relatively deep turbulent water at the intake and below each baffle. The fish apparently used the relatively deep turbulent water as a hiding or waiting place and when ready would move up over the baffle and spawn immediately above it. Though artificial cover in the form of seine netting stretched above the water was used extensively by the fish it was considered a poor substitute for the deep turbulent water at the intake and downstream from each baffle.

The distribution of the chums was somewhat different from that of the pinks. In general they favoured a section about 1/3 of the way (500 ft.) downstream from the intake. This section was characterized by hardpan covered by a shallow layer of relatively coarse compact gravel. A low truck bridge spanned one part of it. The obvious difference between this and many other areas in the channel was the coarse gravel. It is felt, however, that without the cover provided by the bridge the chums would probably have forsaken the coarse gravel and distributed themselves in the same manner as the pinks.

Depth and surface velocity proved to be factors influencing distribution. Many of the sections in the lower half of the channel are fast (2.8 ft./sec.) and shallow (1.05 ft.). These sections were almost completely avoided by spawning fish. Measurements and observations of the channel as a whole showed that the mean velocity of spawning sites chosen by the fish was lower than the mean velocity available and that the mean depth chosen by the fish was slightly greater than the mean depth available. The channel has a narrow range of both depth and velocity and a general lack of values in the high depth range and the low velocity range. Consequently it proved difficult to establish depth and velocity preferenda for spawning pinks. However, within the limitations of the channel it would appear that the preferendum for depth is 1.21 feet and for velocity is 1.80 feet.

At no time was any area densely populated. The two upper sections were filled to a point at which newly arrived fish spawned in lower sections rather than invade the defended territories of the upstream sections. This took place at a density of 1 pair to each 5 square yards of stream. This situation would undoubtedly be different with an increase of population pressure. It was also evident that the early pink females took more than one spawning site.

There were several cases providing direct evidence of males serving more than one female. In all cases two to four partially-spent males attended fresh or partially-spawned females. Each of these males had attended one female until deposition was complete then joined together in groups to attend another female. At no time was actual fertilization witnessed.

One situation arose that pointed up a potentially serious fault of diked channels. Many of the fish dug redds at the edge of the stream, cutting away the banks. In general, natural spawning beds are "saucer shaped" in cross sections and fish dig at the banks only to a point where their bodies are not exposed to the air. In this artificial channel no matter how far a fish digs in a lateral direction, the depth is constant and its body is not exposed. It is quite probable that with a large population the fish would have broken through the dike.

## Survival of salmon eggs at Jones Creek in winter of 1955-56

Winter conditions were followed and attempts to check egg survival were made at Jones Creek. Some scouring took place in the upper three hundred feet (the most heavily seeded section of the stream). This resulted from increased water flow and narrowing of the channel by the formation of ice on the banks. Some sections silted heavily.

Digging for egg samples both in December and February failed to reveal enough eggs or alevins to estimate survival. Sampling was done in places where fish were known to have spawned. From these results, then, a a poor survival is indicated. It is possible, however, that this mid-stream scouring would roll the eggs and gravel downstream and laterally with the result that instead of mid-stream pockets of eggs there would be individual eggs interspersed with loose gravel at the sides of the stream. The few eggs that were found were found as individual eggs near the edge of the stream. Since the eggs were eyed at the time of scouring it is possible that they withstood this movement. Consequently, there is no real basis for predicting a poor fry survival.

A wolf-type fry trap was installed and is now operating to enumerate the number of fry leaving the channel. This count is necessary to compare ocean survival, or return, from this year which is an "on" year with that of last year which was an "off" year. The count will also provide a fresh-water survival figure for natural spawning which, but for the above-mentioned scouring and silting, would have provided a comparison with the survival of last year's planted eggs.

## EXPERIMENTAL STUDIES ON GUIDANCE AND SURVIVAL OF SALMON - J.R. Brett

The dependence of salmon on a suitable fresh-water environment during migration and early stages of development has placed them in direct competition with other multiple uses of water. Through hydroelectric power developments, water storage, irrigation, and waste disposal, fresh water is both depleted in volume and altered in character. The problems of maintaining anadromous stocks of fish in the face of such demands is dependent in part on a thorough understanding of the limits of environmental change which salmon can tolerate, and in devising means whereby they can be successfully by-passed around obstacles in the path of migration. It is towards a solution of these problems that these experimental studies are devoted.

The urgency of meeting the salmon - power problem has required that most effort be devoted to devising means for safeguarding young, migrating salmon. The work at Lakelse on guiding sockeye and coho smolts by a moving curtain of cables has been pursued, with promising results. Successful guiding, however, is not sufficient in itself to safeguard the fish since they must also enter freely into a by-pass or collecting device. Increasing attention has been devoted to this aspect, and, when it is met, will be followed by the final question of suitable facilities for transporting migrants to the tail-race level of a high dam.

Although techniques for deflecting year-old smolts show significant developments, both in Canada and the United States, relatively little success has attended efforts at guiding salmon <u>fry</u>. The Lakelse deflector has been modified for use in Hooknose Creek, Port John, where it will be tested in conjunction with bright lighting and charged electrodes to determine the feasibility of this approach to the fry problem.

Since the avoiding response causing deflection in smolts is dependent on visual orientation, and migration is frequently an evening or night phenomenon, fundamental studies on vision have commenced. At present these are concerned with determining rates of dark and light adaptation and minimum light levels for adequate vision.

Included under sensory perception studies are the experiments concerning the properties and isolation of the odour present in mammalian skin which is repellent to adult salmon. Field testing of fractions extracted by the Vancouver Technological Station has brought the identification of the active ingredient almost to completion. This research points up the possibility of very practical uses for odoriferous materials in guiding adult salmon, particularly if an attractive odour can be found. The knowledge and techniques derived from the repellent experiments form a basis for research on attractants.

A number of studies on environmental limitations and survival have been conducted, each designed to contribute to a better understanding of factors involved in some more major undertaking. The investigation of conditions limiting egg survival in salmon redds has necessitated knowledge of the minimum oxygen requirements to sustain life and permit normal development.

In conjunction with the planting and culturing of chum salmon for introduction to Hudson Bay, laboratory tests on the tolerance of chum salmon fry and yearlings to temperatures comparable with the low winter levels of the Bay have been performed.

Finally, young salmon tagged in various ways, including the "spaghetti" tag used for tagging young salmon in the sea have been checked for survival and tag suitability.

## Guiding young salmon past obstructions

J.R. Brett and D.F. Alderdice

### 1. Guiding sockeye and coho smolts.

The objective of the Lakelse River research has been to provide information on the problem of guiding young migrating salmon, and to formulate practical measures for their deflection and successful collection. Because of the limited success in 1954 with the vibrated chain, and to obviate the mechanical limitations of dampened wave-form and downstream displacement of the chain with increasing water velocity, a modified deflector was developed. This consisted of a curtain of 1/4-inch cables hanging vertically and travelling horizontally on an endless belt, the upstream or advance row moving in the direction of the by-pass and rotating back across-stream at the by-pass entrance. It was located in the same position as the vibrated deflector and could be experimentally altered to test the significance of different rates of travel (4, 8 and 12 inches per second) and various intervals between cables (4, 6, 8 and 10 inches), with and without illumination.

Biologically, the introduction of a moving curtain increased the chances for effective deflection. Since fish tend to hold position in a stream by taking a visual fix on near objects (rheotropism), those making visual reference with the front row of moving cables would be guided in the appropriate direction. To enhance this property, the face of the cables presented to the upstream side was painted with white enamel to increase the visual stimulus.

Results:

(1) Moving cables can provide good deflection. There appears to be both a critical rate of travel and a critical interval between cables for

effective operation but, in general, the higher the rate and the smaller the interval, the greater the deflection.

(2) The critical rate of travel occurred at about 8"/sec. to 12"/sec. (approximately 1/2 to 4/5 m.p.h.).

(3) The critical interval between cables was from 4 to 6 inches; deflection diminishes at greater intervals.

(4) Experiments at the critical levels of operation resulted in an average deflection of 89% of the sockeye (range 86% to 94%) and 58% of the coho (range 36% to 81%).

(5) Bright artificial lighting at night did not provide better deflection than no lighting. It is assumed that the low level of night light present in northern areas (54° N. Lat.) was sufficient to provide for fish vision. Recent laboratory experiments support this possibility.

2. Design of a by-pass for salmon smolts.

Because of the difficulty of getting young salmon to move into a by-pass, a study of the conditions promoting ready passage was made by introducing various changes in the entrance to the collecting pen. These alterations were based in part on the principle that stream orientation is mainly by vision, when in the presence of adequate light and the absence of bodily contact with the bottom. In addition it was proposed to create a gradual increase in the velocity of the incoming water. Such changes were aimed at sweeping the fish into and through the by-pass without providing them with cues which would stimulate strong upstream responses.

To conform with this approach the walls and floor of the entrance were covered with smooth plywood, painted dark brown and lined part way along one side with mirrors. Near the entrance to the trap the walls were converged inwards and lined on both sides with cross-reflecting mirrors. Water velocity increased from 0.80 ft./sec. at the entrance to 4.3 ft./sec. at the narrowest point. The lack of fixed visual cues, the accelerated but non-turbulent water and the optical confusion from the mirrors, served to meet the new specifications.

Results:

Despite an improvement in the by-pass efficiency, only 32% of the fish guided to the vicinity of the opening passed directly into and through the by-pass. In one instance 13 approaches were made before actually passing through to the trap. The depth of water at the entrance was 1.8 feet, rising abruptly from an approach level of 3.1 feet. The combination of shallow by-pass water and the relatively rapid decrease in depth at the approach, together with the changed light-reflecting qualities of fresh gravel at the entrance, appeared to act as deterrents to efficient operation.

Conclusions:

The most significant findings relate to the effectiveness of a moving row of cables, which served to deter the fish without alarm while guiding them in the direction of the by-pass. The rheotropic response and the reticence of grouped fish to pass through vertical "slits" provide the basis for a simple mechanical deflector which has very little effect on the free passage of water.

The main reasons why the deflector did not provide better deflection stemmed from the poor angle of deflection (90°), the presence of a large number of predators and coarse fish which occasionally scared the young salmon through the deflector, and some unattractive features of the by-pass. With the possible exception of the predator fish, future projects would not be so hampered by the above limitations.

In general, for installations involving the type conditions present in the Lakelse River it can be concluded that sockeye smolts could be successfully deflected and that an extension of some of the techniques would improve the relation for coho. The economic and practical aspects remain to be assessed.

## Studies of sensory perception

J.R. Brett and M.A. Ali

### 1. Sight in young salmon.

The present guiding experiments using visual orientation in smolts are conducted in the absence of any specific knowledge of the actual light sensitivity and visual acuity of the fish. Basic studies of this nature have commenced. The relation of rods and cones, and the masking effects of the heavily pigmented retinal epithelial cells, are under investigation both histologically and experimentally. The histological techniques of staining and sectioning the eye have reached a stage where ready examination at the cytological level is possible. Two pertinent findings have resulted to date. Young salmon require about 30 to 40 minutes to dark-adapt, and this dark-adapted stage is reached about half way through the evening seaward migration of Lakelse sockeye. This means, for instance, that colour vision, as far as it is known in fish, would be eliminated with dark-adaptation, and that a switch in spectral sensitivity occurs during migration. In addition, sensitivity to light increases while acuity decreases during an evening migration, factors of significance in the operation of a deflector based on visual perception, and affecting the entrance of fish into an illuminated by-pass.

Sensitivity to light has been tested with underyearling coho by preliminary training to feed on small crustaceans (Daphnia), followed by experimental reductions in light intensity to a level where feeding was made impossible. Fish were first allowed to adapt to the level of light in any one experiment. Light intensities ranged from a maximum of 8300 ft.-c. to .00001 ft.-c. In absolute darkness no feeding occurred. At the lowest level of light very slight feeding was recorded (3% of normal). The level which just produced a significant reduction from the normal rate of feeding was approximately .001 ft.-c., equivalent to about one-third the intensity from bright moonlight. The brightest lighting did not affect the normal feeding rate of the fish. The remarkable range over which the young salmon eye can function indicates an exceptionally sensitive and adaptable eye.

### 2. Isolation of the factor in mammalian skins repellent to adult salmon.

D.F. Alderdice and J.R. Brett

Aqueous washings from the skin of a number of mammals, including human skin, contain a substance which causes an alarm reaction in adult salmon. The reaction has been exploited experimentally by introducing such aqueous solutions into the path of upstream migration of adult salmon and interrupting upstream movement.

Purification of gross extracts has been achieved. Identification of the molecular components of the active fraction is progressing. Several low molecular weight nitrogenous compounds have been isolated and identified. Repellent activity of several of the components is recognized but total activity of the fractions is less than that of the gross extract at the present stage of research. Identification of repellent characteristics is continuing.

This problem is being studied under a co-operative program. Chemical and physical procedures of isolation and identification are being conducted by the Technological Station while testing of fractions is being carried out by the Biological Station.

## Environmental limitations to survival of young salmon

### 1. Minimum oxygen requirements for developing chum salmon eggs with a note on the effect of carbon dioxide on viability.

The study of effects of a low-oxygen environment on developing chum salmon eggs has continued on an expanded scale, in keeping with the considerable complexity of the problem. A new series of experiments was conducted at 10° C. on eggs at four developmental stages. In addition to the low-oxygen tests a further series was conducted to investigate the effects of carbon dioxide on the respiration and viability of eggs developing at a low but not necessarily lethal level of dissolved oxygen.

Incubation characteristics for the five series conducted are listed:

| Series | Effect studied | Mean incubation temperature, °C. | Age of eggs, days |
|---|---|---|---|
| A | Low oxygen | 10.1 | 12 |
| B | " " | 9.8 | 22 |
| C | " " | 9.5 | 32 |
| D | " " | 9.4 | 48 |
| E | $CO_2$ at reduced oxygen level | 7.7 | 14 |

Experimental conditions in each of the first four series consisted of a set of six oxygen levels, decreasing from saturation to about 0.2 p.p.m. dissolved oxygen, and maintained in an "open" system at these levels. Eggs were exposed to low oxygen concentrations for periods of one week, after which normal incubation was allowed to resume. The samples were followed until death was confirmed or hatching was completed. The fifth series (E) consisted of varying $CO_2$ levels from 6.5 to 243 p.p.m. at an initial level of 2.5 p.p.m. dissolved oxygen in a "closed" system. Eggs were exposed to these conditions for a period of nine days after which their transfer to the incubation troughs allowed assessment of post-experimental mortality up to the time of successful hatching.

Series A. Some mortality occurred through the experimental and post-experimental periods but no correlation with dissolved oxygen level was apparent. The extreme hypoxial conditions at the low end of the series only resulted in a delay of one week in hatching rate. Although mortality was not an immediate effect of hypoxia, subsequent development of eggs exposed to 0.2-0.3 p.p.m.

dissolved oxygen resulted in the production of deformed alevins. Macroscopic examination suggests an interruption in the laying down of somites posterior to the region of the dorsal fin, with subsequent development of fins taking place on the truncated stub of the body.

Series B. Whereas in the first series (A), 0.2-0.3 p.p.m. dissolved oxygen caused delay and disruption of normal development, these conditions were lethal to eggs of more advanced development used in Series (B). Mortality was correlated with dissolved oxygen level and was incipient in the region of 0.6 p.p.m. dissolved oxygen. Hatching was delayed at all experimental oxygen levels below saturation in a manner dependent on the degree of hypoxia.

Series C. Mortality and hatching rate were again related to oxygen level, low levels in the experimental series causing high mortality and delayed hatching.

Series D. Mortality and hatching rate were influenced by oxygen level as in the previous series. A further effect was noted, however, in an accelerated attempt to hatch at about 0.8 p.p.m. dissolved oxygen. Such abnormally early hatching culminated in death. These results agree with previous work in which emergence of pre-hatching-stage eggs is maximized by exposure to dissolved oxygen levels in the region of 1 p.p.m.

Series E. The initial oxygen level of 2.5 p.p.m. to which the series was exposed was chosen to be low but not lethal. Lowest oxygen levels in the series, after respiration in closed bottles for nine days, were somewhat below 0.2 p.p.m. Oxygen uptake was limited only in the higher $CO_2$ tests. Pre-hatching mortality, however, was directly related to $CO_2$ level throughout the whole series from 6.5 to 243 p.p.m. $CO_2$.

In summary the following inferences may be drawn. Successful development of eggs was independent of temperature between $5^{o}$ to $10^{o}$ when eggs were subjected to hypoxial conditions.

The minimum oxygen requirements of developing eggs rises as development proceeds. The incipient level of oxygen concentration above which mortality does not occur rises from about 0.2 to 1.9 p.p.m. throughout the developmental period. Early incubation stages survive critical hypoxial levels with developmental abnormalities occurring. Later incubation stages find the same conditions quickly lethal.

Oxygen consumption at low oxygen levels was independent of $CO_2$ concentration below about 125 p.p.m. $CO_2$ at an incubation stage of 14 to 23 days, but percent live hatch was correlated with $CO_2$ level throughout the entire experimental range.

2. Low lethal temperatures in young salmon.

In conjunction with the planting and culturing of chum salmon for introduction to Hudson Bay, laboratory tests on the tolerance of chum salmon fry and yearlings and sockeye yearlings to low temperatures in salt water have been conducted. For each species, samples of fish were first acclimated to two levels of temperature, $2.5^{o}$ C. and $5.0^{o}$ C., and exposed for a period of one month or more to a salinity of 27.28 0/00. Subsequently tolerance tests were performed at three levels of temperature, -0.5, -1.0, $-1.5^{o}$ C., and at approximately the same salinity.

Fish were considered dead when respiration ceased, and when no further responses resulted when a slight pressure was applied to the caudal end. This stage was frequently accompanied by a stiffening of the body. Each sample was returned to its acclimation temperature for a period of 24 hours. Mean weights and lengths of the fish were: chum fry - 3.5 gm., 3.4 cm.; yearlings - 23.5 gm., 13.9 cm.; sockeye yearlings - 11.3 gm., 10.0 cm.

Results:

No fish survived even the -0.5° C. temperature for more than three days. At -1.5° C. ice crystals formed in the aqueous humour of the eye in both species in a matter of minutes; at -1.0° C. a similar condition was apparent in the eyes of some of the yearlings. Since the freezing point of the blood of smolts in salt water is about -0.70° C. to -0.75° C., rapid death was due in all likelihood to freezing of the body fluids.

At -0.5° C. death probably resulted from an inability to maintain osmotic balance as a result of a greatly depressed metabolic rate. Constriction of the abdomen, a generally leeched appearance, and sinking to the bottom by near-dead fish suggests this cause.

It is doubtful if further experiments will materially alter the conclusion that salmon cannot tolerate a temperature of -0.5° C. Water temperatures of this order and lower occur during the winter in Hudson Bay. These species could only survive, therefore, by migrating south in the winter, or by congregating in the limited brackish waters of estuaries or in the inflowing fresh waters.

## H E R R I N G - F.H.C. Taylor

The objective of herring research is the provision of a basis for the regulation of the herring fishery that will ensure the maximum utilization of the stocks consistent with their future maintenance. Attention is, therefore, centred on the assessment of annual changes in abundance in the various stocks, on the effects of intensive fishing on the populations, on the amounts of spawn deposited, and on the amount of eventual recruitment. The prediction of the annual recruitment to the various populations is also an important consideration. Studies of early life-history stages are in progress, aimed at providing a firmer and more reliable basis both for the prediction and the assessment of the annual recruitment.

Data presented in this report refer to adult studies carried out from April 1954 to March 1955, juvenile studies carried out during the summers of 1954 and 1955, and larval herring studies carried out in the springs of 1947-51.

The accompanying map shows the sub-districts and areas of the British Columbia coast referred to in this report.

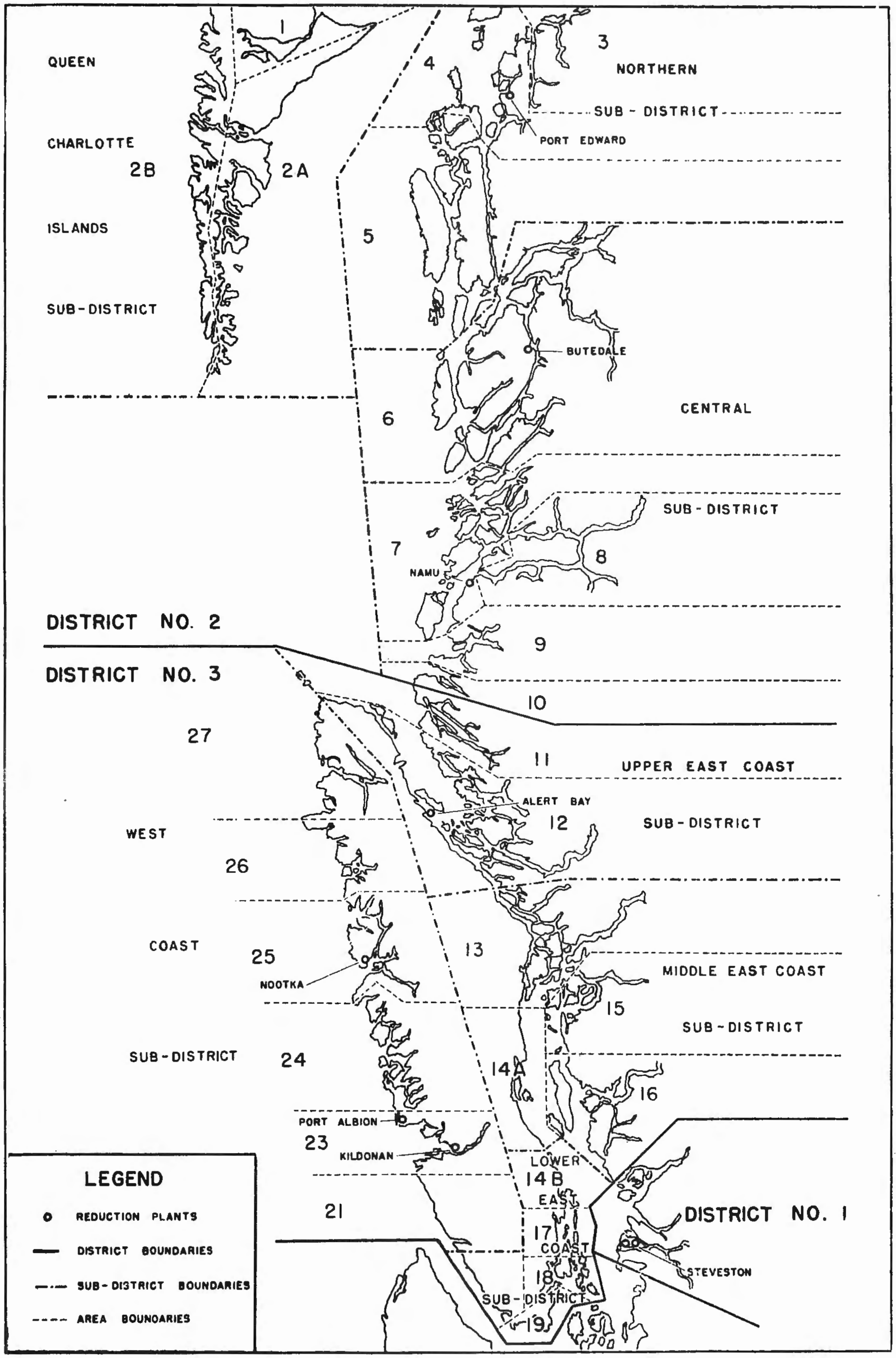



Fig. 1. Map showing the division of the British Columbia coast into districts, sub-districts, and areas.

## Studies on adult herring

Adult herring studies include the collection of catch statistics from the various fisheries, the tagging and tag-recovery program, the sampling of the catches and spawning runs to obtain the age, length and weight composition, and the assessment of the extent and intensity of spawn deposition in all populations.

### 1. The 1954-55 fishery.

G.T. Taylor

The total catch of herring in 1954-55 was 169,163 tons, the lowest for any normal season's fishing since 1946-47. While catches were good in the Queen Charlotte Islands and in the upper, middle and lower east coast of Vancouver Island sub-districts, they were poor in the northern and central mainland and the west coast of Vancouver Island sub-districts. The following tabulation shows the distribution of catch and catch per unit of effort by sub-districts in 1954-55 and 1953-54. The average catch for each sub-district from 1950-51 to 1954-55 (excluding the year of no fishing, 1952-53) is included for comparison.

| Sub-district | Catch 1954-55 | Catch 1953-54 | Average catch 1950-51 to 1954-55 | Catch per seine-day 1954-55 | Catch per seine-day 1953-54 |
|---|---|---|---|---|---|
| Queen Charlotte Is. | 22,350 | 28,550 | 16,312 | 76 | 218 |
| Northern | 20,050 | 29,750 | 39,438 | 51 | 77 |
| North central | 9,700 | 7,500 | 9,350 | 22 | 30 |
| South central | 17,850 | 24,150 | 28,250 | 31 | 68 |
| Upper east coast of Vancouver Is. | 9,200 | 6,650 | 7,600 | 82 | 35 |
| Middle east coast of Vancouver Is. | 24,650 | 19,600 | 16,663 | 40 | 49 |
| Lower east coast of Vancouver Is. | 51,390 | 52,660 | 46,502 | 56 | 82 |
| South-west coast of Vancouver Is. | 6,863 | 31,550 | 17,118 | 18 | 53 |
| North-west coast of Vancouver Is. | 7,200 | 9,800 | 10,485 | 61 | 28 |
| Total (tons) | 169,163 | 210,210 | 189,535 | .. | .. |

While the west coast of Vancouver Island and the Queen Charlotte Islands sub-districts were free from quota restrictions, the regular quotas were applied in the other sub-districts. Four quota extensions were granted, two each in the middle and lower east coast of Vancouver Island sub-districts.

As in 1953-54, almost the entire Queen Charlotte Islands catch came from Skidegate Inlet. Although it was the second highest on record, fish were not as abundant as in 1953-54 when the entire catch was taken in 14 fishing days (February 25 and March 16). In 1954-55 fishing began on November 3. Good fishing with a catch per unit of effort of 110 tons per seine-day ensued until December 11, after which fishing deteriorated rapidly. By the Christmas closure 13,000 tons had been taken. Fishing resumed on January 5 and continued until

February 9 when the area was closed to protect the large numbers of small fish present. In the post-Christmas period the catch was 65 tons per seine-day. In Area 2B-E, 55 tons were taken from Selwyn Inlet during the week of January 16-22. Cumshewa Inlet was scouted but no fish were found.

In the northern sub-district both catch and catch per unit of effort were less than in the previous year, and the quota was not reached for the first time since 1948-49. Although the sub-district was extensively scouted no fish were found until mid-January when they appeared in Kitkatlah Inlet and provided two weeks of fishing. No other bodies of fish were found.

The catch in the central sub-district was the smallest since 1946-47. The quota was not reached for the second year in succession. The catch in the north central region was slightly higher than in 1953-54 while in the south central both catch and catch per unit of effort were considerably lower. The main migratory stocks which usually support the fishery made a relatively small contribution in 1954-55 and the fishery was dependent on the smaller resident stocks. The sub-district was closed at the request of the industry and Department of Fisheries on February 9 with the provision that it would be reopened if substantial stocks should come onto the fishing grounds. This did not occur.

In 1954-55 the catch in the upper-east-coast sub-district was the largest since 1940-41. A new fishing ground in Seymour Inlet and Nugent Sound (Area 11) provided the bulk of the catch in a short, vigorous fishery in late November and early December. Area 12 usually provides the main portion of the catch, but in 1954-55 only 1900 tons were taken in Clio Channel, Retreat Pass, MacKenzie Sound and Belleisle Sound. A quota extension was requested but did not go into effect as the quota was never reached.

The 1954-55 catch in the middle-east-coast sub-district was a record 24,650 tons. Of this, 5100 tons were taken in the summer fishery in early July and early September. This fishery centred in the Cape Lazo and Qualicum - French Creek regions. Catch per unit of effort was 53 tons per seine-day. The main winter fishery occurred in two periods, one in late October, the other in late January, with only sporadic fishing in the interval. A large body of fish was present in Seymour Narrows but until late January remained too deep to be fished. Two quota extensions were granted - one for 5000 tons on November 2, taken by January 18, the other for 10,000 tons on January 23, taken by February 3. In October catch per unit of effort was 56 tons per seine-day and in January, 84 tons per seine-day.

The catch in the lower-east-coast sub-district in 1954-55 nearly equalled the record catch of the previous season. Catch per unit of effort was somewhat lower. The quota was taken in three weeks with fishing improving throughout the period. A quota extension of 10,000 tons was granted on November 7 and taken by November 15 in spite of the hindrance to fishing by strong tides in the Swanson Channel region. The most of the catch (42,000 tons) was taken in Swanson Channel (Area 18), the remainder came almost equally from Nanoose Bay (Area 17A) and Trincomali Channel (Area 17B).

The catch in the west coast of Vancouver Island sub-district was sharply decreased and was the lowest since 1943-44. In Barkley Sound the catch amounted to 6,650 tons, the lowest since 1944-45. Catch per unit of effort was 18 tons per seine-day. No large bodies of fish were found and the fishery was dependent apparently on the inshore movement of a succession of small schools. In Area 25 the fishery was a complete failure for the first time since 1943-44. In Area 24 only 13 tons were taken. Small catches were made in Area 26 in Ououkinsh and Nasparti Inlets. In contrast to other west-coast areas, Area 27 produced a record catch of 6550 tons in a short vigorous fishery centred in Forward Inlet near the mouth of Quatsino Sound. The catch per unit of effort in this fishery was 77 tons per seine-day.

2. Tagging and tag-recovery. F.H.C. Taylor

Herring have been tagged extensively in British Columbia since 1936, with the object of: (1) confirming the existence of the relatively discrete populations deduced from meristic and age-composition studies and defining the inshore regions occupied by these populations, (2) estimating the amount of movement within and between populations, (3) permitting, in some areas, the calculation of certain population statistics. The primary objectives of the extensive coastwide tagging program are considered to have been achieved. The general relationship between most populations are sufficiently well understood for the practical purposes of management. The annual variations in the extent of intermingling between populations are not considered large enough to warrant the expenditure entailed in a coastwide program. Tagging has therefore been curtailed and confined to specific areas to elucidate the more complex relationships existing between certain populations.

Herring tags are recovered either by electronic tag-detectors operated by investigational personnel or by magnets in the meal lines of the reduction plants. Tag-detector recoveries, although considerably fewer in number, yield much more precise information than magnet recoveries. In the latter a considerable degree of uncertainty often exists as to the area and, at times, the sub-district of recovery.

A total of 2318 tags were recovered in 1954-55, 29 by tag-detector and 2289 by magnets in 10 reduction plants.

(a) Tag-detector recoveries (F.H.C. Taylor and G.T. Taylor). During the 1954-55 season one induction-type tag-detector was operated in the Gulf of Georgia plant at Steveston. The percentage efficiency of this detector was only 44% compared to 51% for the same period in 1953-54 and 80% in 1951-52. Because of electrical interference from a nearby weighing machine, the detector had to be operated with the sensitivity reduced to a point where it was only partially effective in recovering tags. The installation in the Colonial plant of a new detector using an "Alnico" permanent magnet was not successful because of continuous electrical interference from a newly installed automatic weighing machine.

Tag-detector construction and operation received close study during the year. The conclusion was reached that the basic fault lay in the fact that the frequency of the impulse produced by a tag was in the same range (0-10 cycles per second) as variations in line voltage and switching transients. Because of the small size of the tag the amplitude of the pulse it produced was little greater than that produced by the transients. There appear to be three possible solutions: (1) an increase in the size of the tag, probably undesirable on biological grounds; (2) the use of tags with a high nickel content to increase the size of pulse produced; (3) screening detector and coil to reduce the effect of transients. Further experiments are under way to determine how effective is each of the above methods and which is the more practical.

In 1954-55 there were 29 tags recovered by tag-detectors, 28 from the Gulf of Georgia plant and one from the Colonial plant. The detector recoveries are shown in the accompanying table by area of tagging and area of recovery.

| Area of tagging | Area of recovery | | | | | | Total no. of recoveries |
|---|---|---|---|---|---|---|---|
| | 6 | 8 | 13 | 17B | 18 | 27 | |
| 4 | 1 | . | . | . | . | . | 1 |
| 6 | 1 | . | . | . | . | . | 1 |
| 7 | . | 1 | . | . | . | . | 1 |
| 15 | . | . | 1 | . | . | . | 1 |
| 17A | . | . | . | 1 | 1 | . | 2 |
| 17B | . | . | . | . | 6 | . | 6 |
| 18 | . | . | . | . | 11 | . | 11 |
| 23 | . | . | . | . | 1 | . | 1 |
| 24 | . | . | . | . | 1 | . | 1 |
| 25 | . | . | . | . | . | 2 | 2 |
| 27 | . | . | . | . | . | 2 | 2 |
| Total | 2 | 1 | 1 | 1 | 20 | 4 | 29 |

(b) Plant-magnet recoveries (G.T. Taylor and F.H.C. Taylor). In 1954-55, 2289 tags were recovered from magnets and plant machinery in 10 reduction plants. A reduction from the record 4528 in 1953-54 was expected because of sharply reduced tagging in 1954 and the smaller total catch in 1954-55.

The greater doubt which attaches to the area of recovery of plant-magnet returns than of tag-detector recoveries is offset at least partially by this much larger number. Because of the very small number of tag-detector recoveries in 1954-55, the assessment of movement between populations based on plant-magnet returns is considered more valuable than that based on tag-detector recoveries. The probable numbers of tags in the catches are calculated by correcting the actual numbers for magnet efficiency and tonnage of fish not searched by plant magnets. Before applying these corrections, "doubtful" recoveries (545 out of 2289 in 1954-55) were arbitrarily assigned to the sub-district of tagging. This procedure probably results in correct assignment in about 80% of the cases. The accompanying table gives the probable numbers of tags in the catches by sub-district of tagging and sub-district of recovery, and (in parenthesis) actual numbers on which the calculations are based. In the new Fairview plant in Prince Rupert no magnet-efficiency tests were carried out; the 134 recoveries at this plant were omitted from the calculations of the probable numbers of tags.

Magnet recoveries of herring tags

| Sub-district of tagging | Sub-district of recovery | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | Queen Charlotte Islands | Northern | North central | South central | Upper east coast | Middle east coast | Lower east coast | South east coast | North west coast | |
| Queen Charlotte Islands | 984 (729) | 66 (45) | .. | .. | .. | 2 (2) | .. | .. | .. | 1052 (776) |
| Northern | 25 (15) | 850 (557) | 9 (7) | 4 (2) | .. | 1 (1) | .. | .. | .. | 889 (582) |
| North central | .. | 26 (17) | 33 (29) | 35 (17) | .. | .. | .. | .. | .. | 94 (63) |
| South central | 2 (2) | 3 (3) | 20 (18) | 276 (120) | .. | 19 (18) | .. | 1 (1) | 8 (6) | 329 (168) |
| Upper east coast | .. | .. | .. | .. | 14 (12) | 22 (21) | .. | .. | 4 (3) | 40 (36) |
| Middle east coast | .. | 2 (2) | 1 (1) | .. | .. | 146 (138) | 3 (3) | .. | .. | 152 (144) |
| Lower east coast | .. | .. | .. | 2 (1) | .. | 60 (58) | 229 (191) | 2 (2) | 1 (1) | 294 (253) |
| South west coast | .. | .. | 2 (2) | 2 (1) | .. | 6 (6) | 13 (13) | 32 (31) | 10 (9) | 65 (62) |
| North west coast | .. | 2 (2) | .. | .. | 1 (1) | 2 (2) | 9 (9) | 2 (2) | 71 (56) | 87 (72) |
| Total | 1011 (746) | 949 (626) | 65 (57) | 319 (141) | 15 (13) | 258 (246) | 254 (216) | 37 (36) | 94 (75) | 3002 (2156) |

As in previous years, most tags were recovered from the sub-district of tagging. In 1954-55 this tendency would appear to have been strongest in the Queen Charlotte Islands, the northern, and the middle east coast of Vancouver Island sub-districts and weakest in the south west coast of Vancouver Island, the north central and the upper east coast of Vancouver Island sub-districts. The indicated dispersion of upper-east-coast tags may have been greater than the actual because all recoveries, with one exception, were from a series of tags put out in 1953 in Retreat Pass and were made largely by one plant late in the season. The later records of this plant indicate the possibility that some of these tags may have come from catches from Knight Inlet (Area 12) rather than from Deepwater Bay (Area 13).

While herring in the Queen Charlotte Islands have been tagged in Area 2B-E for the past four seasons, they were tagged in Area 2A-E in Skidegate Inlet for the first time in 1954. Returns indicated that the main movement (3-4%) of herring from Area 2A-E was to the northern sub-district. Of fish tagged in Area 2B-E, 74% of the 43 recoveries were from the northern sub-district and only 21% from the Queen Charlotte Islands. However, because of the very small catch (550 tons) in Area 2B-E it is unlikely that the returns this year represent a true picture of the dispersion from this area. Only 3 fish tagged in Area 2B-E were recovered from the intensive fishery in Area 2A-E. This suggests that the stocks in the two Queen Charlotte Islands areas may be separate.

The main movement of fish from the northern sub-district was to the Queen Charlotte Islands (3%) and north-central (1%) sub-districts, approximately the same as in 1953-54. Recoveries from herring tagged in the north-central sub-district suggest that approximately the same proportion of fish migrated both to the northern (28%) and south-central (37%) sub-districts as remained within the north-central sub-district (35%). From the south-central sub-district movement was greatest to the north-central (16%) and to the middle-east-coast (6%) sub-districts.

In 1954-55, the dispersion of middle-east-coast tags (4%) was considerably less than the average (45.5%). Approximately 2% were recovered from the lower east coast, compared to 17%. Movement of the lower-east-coast fish to the middle east coast was 20%, compared to 16% in 1953-54. This is the reverse of the average situation where movement in the southerly direction (27.6%) greatly exceeds that in the northerly (6.7%). The movement to the middle east coast of fish tagged in Area 17A (46%) was greater than for fish tagged in Area 17B (14%) or Area 18 (6%). Of fish tagged in Area 17A, more recoveries were made in Area 14 than in Area 13. The complex intermingling of lower-east-coast and middle-east-coast fish is illustrated by recoveries from a series of tags put out in Schooner Cove (Area 17A). Of 70 tags of this series recovered, 57 could be assigned to a definite area. Of these 57, 16 were recovered from the middle-east-coast summer fishery (Area 14), 32 from the winter fishery in the lower east coast, and 11 from the middle-east-coast late-winter fishery (Area 13). While several explanations are possible, the most probable is that some of these fish joined runs that remained throughout the summer in the middle-east-coast sub-district, others joined the middle-east-coast stock that migrated to offshore feeding grounds and returned by way of Johnstone Strait, while others, possibly the largest portion, joined the main lower-east-coast stocks.

Movement of herring from the west coast of Vancouver Island to other sub-districts was 24%, considerably greater than in 1953-54 (3%), 1951-52 (8%), or 1950-51 (15%). Most of the recoveries were from tags put out in 1953; tagging in 1954 was very light. The greater degree of emigration may partially be due to the greater opportunity for mixing arising from most of the tags having been at liberty for more than a year. Movement was mainly to the lower-east-coast sub-district and was greater from south-west-coast areas (20%) than from north-west-coast areas (10%). Movement of lower-east-coast herring to the west coast (1%) was considerably lower than in previous years (13.5% in 1953-54, 7.5% in 1951-52). The disparity in the movements in the two directions between the west coast and lower east coast is the reverse of that noted in 1953-54, when 13.5% of the lower-east-coast herring moved to the west coast and 2.9% of the west-coast herring moved to the lower east coast. Movement of herring from the south-west coast of Vancouver Island to the north-west coast was 15%, whereas the reverse movement was only 2%.

(c) Magnet efficiency tests. (G.T. Taylor). Not all tags which enter a reduction plant are recovered by the plant magnets. As one step in determining the probable number of tags in the catches involves the calculation of the number of tags which entered each plant, the percentage efficiency of each plant in recovering tags must be known. Plant-magnet efficiency is determined from the number of recoveries from 50 test tags placed in fish scattered randomly among fish held in the plant storage bins. Information is also provided on the time-lag involved between the entry of tags into the plant and their recovery in the magnet. Tests are repeated several times a season in each plant.

During 1954-55, tests were carried out at all plants operating, except Namu and Fairview. Namu was rebuilt in 1954, the new construction being such that no magnets could be included in the meal lines. The Fairview plant began operation after tests had been carried out in the other plants in the Prince Rupert area. In the accompanying table figures in brackets are for 1953-54.

| Locality | Plant | Number of tests | Average efficiency |
|---|---|---|---|
| West coast | Port Albion | 1(1) | 92(90) |
| Steveston and vicinity | Imperial | 2(3) | 87(96) |
| | Gulf of Georgia | 3(2) | 94(97) |
| | Colonial | 2(2) | 91(92) |
| | Phoenix | 4(2) | 98(92) |
| | North Shore | 2(3) | 79(97) |
| North and central British Columbia | Butedale | 2(2) | 83(96) |
| | Port Edward | 2(4) | 87(92) |
| | Seal Cove | 3(1) | 64(68) |

The tests at Steveston and on the west coast of Vancouver Island were carried out by investigational personnel; those in northern and central British Columbia by fisheries officers.

In general, the efficiencies of all plants listed showed little change from the previous season. North Shore and Butedale were exceptions. The marked reduction in the efficiency of North Shore is probably accounted for by the remodelling carried out in 1954. Butedale's drop in efficiency may be due to the fact that both tests were unfortunately carried out at the end of a period of operation, just before the Christmas shutdown and at the end of the season. Some tags could thus have been retained in the plant machinery. The low efficiency of the Seal Cove plant results from the use of a cyclone drier and the lack of a magnet in one meal line carrying 60% of the meal.

(d) Tagging during the spring of 1955. Herring tagging in 1955 was confined to the Strait of Georgia, where more infomation is required on the support given to the lower-east-coast fishery by herring spawning in the middle-east-coast sub-district and on the complex intermingling of the stocks in these two sub-districts. It had been planned to tag herring in contiguous American waters, particularly in the Boundary Bay and San Juan Islands region, but no fish were found. Two vessels were employed: Dominion No. 1 loaned by British Columbia Packers Ltd., and the Station vessel *Loligo*. The Dominion No. 1 operated in the middle-east-coast sub-district from February 21 to April 8, and *Loligo* in the lower-east-coast sub-district from February 23 to April 8.

A total of 17,505 tags were inserted in 12 taggings as shown in the accompanying table.

Herring tagging in the spring of 1955

| Code | Area | No. of tags | Place | Date |
|---|---|---|---|---|
| 19A | 13 | 1500 | Frederick Point | March 25, 1955 |
| 19B | 14 | 1483 | French Creek | March 13, 1955 |
| 19C | 14 | 1470 | Comox | March 17, 1955 |
| 19D | 15 | 1516 | Junction Point, Lewis Channel | March 25, 1955 |
| 19E | 15 | 1504 | Scuttle Bay | March 26, 1955 |
| 19F | 17A | 1509 | Nanoose Bay | March 22, 1955 |
| 19G | 17A | 1516 | Departure Bay | April 6, 1955 |
| 19H | 17B | 1424 | Coffin Point | March 4, 1955 |
| 19J | 17B | 1550 | North Cove, Thetis Is. | March 11, 1955 |
| 19K | 17B | 1530 | Ladysmith Harbour | March 20, 1955 |
| 19L | 17B | 1005 | Preedy Harbour | April 1, 1955 |
| 19M | 18 | 1498 | Saanich Inlet | April 18, 1955 |

## 3. Sampling of commercial catches and spawning runs — R.S. Isaacson

Random sampling of the various stocks of herring contributing to commercial catches and spawning runs was continued during the 1954-55 season. Whenever possible each sample consisted of 100 fish. Samples from the fishery were obtained by tag detector operators at Steveston and by members of the plant crews at various other processing plants. Sampling of the spawning runs is carried out in conjunction with the herring tagging program and thus limited to the Strait of Georgia.

Data on length, weight, sex, and stage of maturity were recorded for each fish and a scale (later two scales) were taken for age determination. In conjunction with a current study on the fecundity of the Pacific herring, more than 600 ovary samples were taken and preserved.

In the following table is given the distribution by areas of the 225 samples, consisting of 20,460 herring, taken during the 1954-55 season.

| Sub-district and area | | Fishing samples: No. of samples | Fishing samples: No. of fish | Spawning samples: No. of samples | Spawning samples: No. of fish |
|---|---|---|---|---|---|
| Queen Charlotte Islands 2A(E) | | 13 | 1088 | | |
| Northern | 5 | 14 | 1239 | | |
| Central | 6 | 19 | 1706 | | |
| | 7 | 17 | 1509 | | |
| | 8 | 10 | 963 | | |
| | 9 | 16 | 1584 | | |
| | 10 | 1 | 100 | | |
| | TOTAL | 63 | 5862 | | |
| Upper east coast | 11 | 8 | 770 | | |
| | 12 | 6 | 543 | | |
| | TOTAL | 14 | 1313 | | |
| Middle east coast | 13 | 21 | 2050 | 1 | 100 |
| | 14 | 5 | 419 | 2 | 200 |
| | 15 | .. | .. | 2 | 200 |
| | TOTAL | 26 | 2469 | 5 | 500 |
| Lower east coast | 17A | 4 | 370 | 2 | 200 |
| | 17B | 6 | 442 | 4 | 370 |
| | 18 | 24 | 2270 | 1 | 100 |
| | 20 | 1 | 70 | .. | .. |
| | TOTAL | 35 | 3152 | 7 | 670 |
| West coast | 21 | 1 | 39 | | |
| | 23 | 30 | 2582 | | |
| | 24 | .. | .. | | |
| | 25 | .. | .. | | |
| | 26 | 1 | 78 | | |
| | 27 | 16 | 1474 | | |
| | TOTAL | 48 | 4173 | | |
| Grand Total | | 213 | 19,296 | 12 | 1170 |

(a) Age composition of herring in 1954-55. The average percentage age composition of the herring in the samples from each sub-district is presented in the following tabulation.

| Sub-district | Winter or spawning runs | Age | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | V | VI | VII | VIII | IX | X |
| Queen Charlotte Islands | W | .. | 7.81 | 13.77 | 40.90 | 18.07 | 14.81 | 4.81 | 0.29 | 0.08 | 0.10 |
| Northern | W | .. | 2.78 | 4.90 | 70.78 | 15.32 | 5.02 | 1.04 | 0.15 | .. | .. |
| North central | W | 0.06 | 12.53 | 18.82 | 63.43 | 4.08 | 0.87 | 0.21 | .. | .. | .. |
| South central | W | 0.39 | 5.74 | 10.20 | 69.83 | 10.86 | 2.65 | 0.33 | .. | .. | .. |
| Upper east coast | W | 0.17 | 4.66 | 34.37 | 45.23 | 10.10 | 3.36 | 1.58 | 0.54 | .. | .. |
| Middle east coast | W | .. | 6.02 | 37.71 | 45.88 | 8.25 | 2.01 | 0.12 | .. | .. | .. |
| | S | .. | 1.04 | 29.50 | 52.18 | 12.49 | 3.74 | 1.04 | .. | .. | .. |
| Lower east coast | W | .. | 2.81 | 57.18 | 33.37 | 6.05 | 0.50 | 0.10 | .. | .. | .. |
| | S | .. | 8.69 | 55.95 | 31.23 | 3.48 | 0.50 | 0.15 | .. | .. | .. |
| West coast | W | 0.02 | 13.00 | 50.41 | 30.87 | 4.57 | 0.98 | 0.12 | 0.02 | .. | .. |

The 1951 year-class as IV-year fish was the major contributor to the catches in all but the lower-east-coast and west-coast sub-districts where the 1952 year-class as III-year fish dominated. The proportion of IV-year fish in the catch was definitely above-average, particularly in the northern, central, and middle-east-coast sub-districts. The percentage of III-year fish in the catch was below-average and in some sub-districts it was the lowest it has been in several seasons. The proportion of II-year-old fish (1953 year-class) was higher than in 1953-54 in all but the upper-east-coast sub-district. The overall contribution of this year-class is considered to be about average. The best representation of herring in the older age-groups was found in the samples from the Queen Charlotte Islands sub-district; in many sub-districts there was a decline in the proportion of older fish.

The catch in the west-coast sub-district was the poorest it has been since the 1943-44 season (excepting the strike-bound 1952-53 season). This reduced catch resulted from the partial failure of the fishery in Barkley Sound (Area 23) and the complete failure of the fishery in Nootka and Esperanza Inlets (Area 25). Barkley Sound was the only locality except the lower-east-coast sub-district in which the 1952 year-class (III-year fish) was dominant in the catch. While the 1951 year-class (IV-year fish) was dominant in Area 27, it was poorly represented in Area 23. The representation of II-year fish (the 1953 year-class) was greater this season throughout this sub-district and particularly in Barkley Sound than in 1953-54.

In the lower-east-coast sub-district, the 1952 year-class (III-year fish) was dominant. The percentages of III-, IV-, and V-year-old fish in the catch samples were similar to those in 1953-54, but II-year fish were somewhat better represented. In the spawning samples, the proportion of II-year fish was considerably greater, of III- and IV-year fish about the same and of V-year fish less than in the catch samples.

In the middle-east-coast sub-district the catches from both the summer and winter fisheries had the 1951 year-class (IV's) as the largest contributor. Sampling of the summer fishery in Area 14 was very poor, but, in the samples obtained, IV-year-old fish were the most numerous, then V-year-olds; III-year-old fish were very scarce. Area 13, which supported the winter fishery, depended mainly on III- and IV-year-olds. The III's dominated the pre-Christmas catches, but the IV's those made after the Christmas closure. The 1950 year-class which dominated the fishery as IV-year fish in 1953-54 in this sub-district was well represented this season as V's, particularly in the summer fishery in Area 14. The 1953 year-class (II's), although it did not form a large portion of the catch and was poorly represented in Area 14, showed up strongly in several samples taken in Deepwater Bay (Area 13) in November and January. Although IV-year fish remained in the spawning samples, they were marked by an increase in the representation of older fish (IV, V and VI) and by a corresponding decrease in younger (II and III).

In the upper-east-coast sub-district, where the bulk of the catch came from Seymour Inlet and Nugent Sound (Area 11), localities which have not previously supported a large fishery, the 1951 year-class (IV-year-olds) was dominant. The 1950 year-class (V-year fish) made a larger-than-average contribution to this area's catch, as did the newly recruited 1953 year-class (II-year fish). Area 12 which usually supports the upper-east-coast fishery produced the poorest catch since the 1948-49 season. The few samples obtained from local populations showed that III- and IV-year herring were dominant.

In the central sub-district, in contrast to former years, the fishery was dependent on the local populations, rather than on the main migratory offshore stocks. In these local populations and in the reduced offshore fishery in Area 7, the 1951 year-class (IV-year fish) was dominant. Normally III-year fish dominate the catches but in 1954-55, they showed up poorly in all areas, and particularly in Area 7. The 1953 year-class (II's) also made a very poor entry into the offshore stocks, although it showed considerable strength in some of the small local populations in Areas 6 and 8. The 1950 year-class (V's) was a strong contributor to some of the catches made from small local populations in Areas 6, 9 and 10.

In the northern sub-district the 1951 year-class as IV-year fish was the major contributor, constituting about 70% of the fish sampled. The incoming 1952 year-class (III-year fish) were extremely poorly represented (about 5%). Fish of Age V were less well represented than in recent years, II-year-fish (the 1953 year-class) somewhat better but not above average.

The fishery in the Queen Charlotte Islands sub-district was concentrated in Skidegate Inlet (Area 2A-E). The 1951 year-class as IV-year fish was dominant, comprising almost half the catch. The 1949 year-class which had been dominant as V-year fish in the previous season showed strongly as VI-year olds. The incoming 1952 year-class, III-year fish, was very poorly represented. Fish of Age II (1953 year-class) were better represented than the previous season, and appeared to be relatively numerous.

(b) Growth of herring in 1954-55. The average length (in millimetres) and average weight (in grams) of herring of Ages II to VI in the winter runs (W) and spawning runs (S) for each population in 1953-54 are given in the following tabulation. Populations are designated by initial letters, i.e., Q.C.I. - Queen Charlotte Islands; N. - Northern; N.C. - North Central; S.C. - South Central; U.E.C. - Upper east coast of Vancouver Island; M.E.C. - Middle east coast of Vancouver Island; L.E.C. - Lower east coast of Vancouver Island; and W.C. - West coast of Vancouver Island.

| Population | | Average length (mm.) | | | | | Average weight (gms.) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | II | III | IV | V | VI | II | III | IV | V | VI |
| Q.C.I. | W | 147 | 163 | 184 | 202 | 214 | 40 | 58 | 86 | 115 | 135 |
| N | W | 156 | 182 | 194 | 205 | 218 | 40 | 80 | 96 | 114 | 138 |
| N.C. | W | 146 | 162 | 179 | 194 | 188 | 41 | 64 | 84 | 105 | 97 |
| S.C. | W | 133 | 161 | 181 | 195 | 202 | 30 | 60 | 85 | 109 | 124 |
| U.E.C. | W | 136 | 159 | 165 | 178 | 208 | 33 | 61 | 67 | 86 | 135 |
| M.E.C. | W | 150 | 177 | 190 | 205 | 216 | 45 | 80 | 119 | 124 | 145 |
| | S | 163 | 183 | 196 | 211 | 225 | | | | | |
| L.E.C. | W | 163 | 188 | 200 | 211 | 225 | 57 | 94 | 113 | 132 | 163 |
| | S | 163 | 181 | 199 | 204 | 220 | | | | | |
| W.C. | W | 162 | 182 | 196 | 210 | 218 | 53 | 84 | 106 | 131 | 146 |

The growth index for length (sum of the average lengths of the III- and IV-year fish) and the comparable index for weight for each of the major populations in 1954-55 are given in the following tabulation (comparative figures for the previous season are in parentheses):

| Population | Growth index - length 1954-55 | 1953-54 | Growth index - weight 1954-55 | 1953-54 |
|---|---|---|---|---|
| Queen Charlotte Islands | 347 | (342) | 144 | (118) |
| Northern | 376 | (378) | 176 | (178) |
| North central | 341 | (348) | 148 | (146) |
| South central | 342 | (342) | 145 | (137) |
| Upper east coast | 320 | (334) | 128 | (141) |
| Middle east coast | 367 | (370) | 199 | (175) |
| Lower east coast | 388 | (386) | 207 | (196) |
| West coast | 378 | (385) | 190 | (191) |

In 1954-55 small increases in weight occurred in herring from the Queen Charlotte Islands, south-central, middle-east-coast, and lower-east-coast sub-districts. In the Queen Charlotte Islands, south-central and lower-east-coast populations, increases in weight occurred in all age-groups from II to VI, whereas in the middle-east-coast sub-districts the increase occurred in fish of ages II to IV. In the north-central and west-coast sub-districts growth in 1953-54 and 1954-55 was very similar. In the northern population fish of ages II and III were heavier than in 1953-54, whereas fish of older age-groups were lighter. This would suggest that in this sub-district growth conditions which were poorer in 1953-54 than in 1952-53, had improved somewhat in 1954-55. In the upper-east-coast sub-district the herring caught in 1954-55 were both smaller and lighter than those caught the previous season. These differences probably reflect differences in local population fished rather than difference in growth conditions in the two years.

In general the lengths and weights of herring are such as would suggest that although growth conditions may have improved slightly, no major change occurred in 1954-55.

4. Spawn deposition D.N. Outram

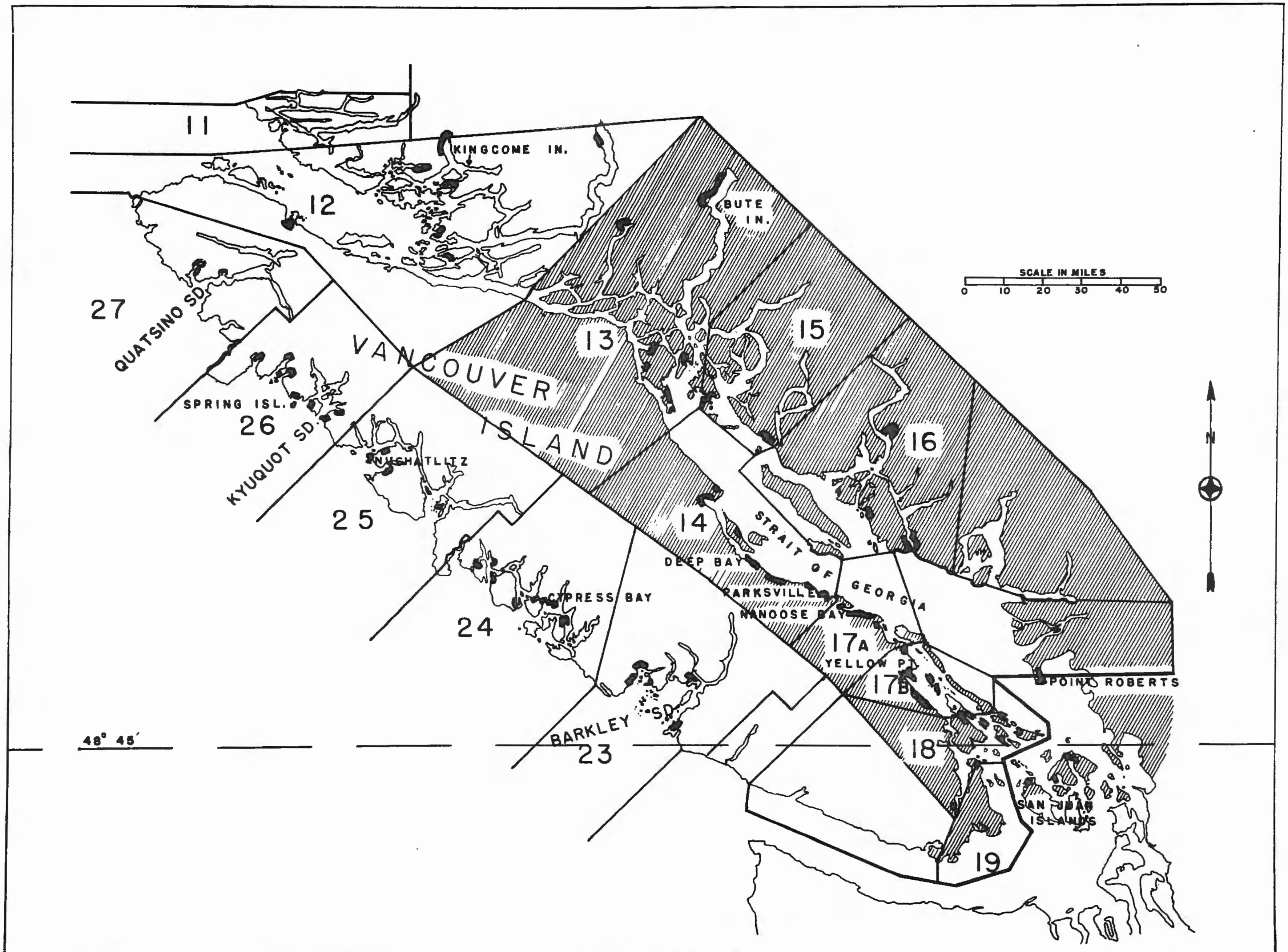
One of the major phases of adult herring studies involves the annual measurement of the extent and intensity of herring spawn deposited on the beaches during the late winter and spring. If the amount and intensity of the spawn deposited is proportional to the number of fish that are left to spawn after the preceding winter fishery has taken its toll, then this phase of the investigation will give an estimate of the relative size of the spawning stocks from year to year. No direct relationship has so far been detected between the amount of spawn deposited and the size of the resulting year-class at recruitment. Thus it would appear that the present amount of spawn deposited is more than adequate for the maintenance of the stocks and that the fluctuations in year-class strength must result from variations in success of survival, most probably in the larval stage.

Every year since 1930, herring spawnings along the British Columbia coastline have been reported by officers of the Federal Department of Fisheries. Independent estimates of spawning have been made by members of the Biological Station staff in the west coast of Vancouver Island sub-district (Areas 23, 24, 25, 26 and 27) from 1947 to 1954, and in the middle-east-coast and lower-east-coast of Vancouver Island sub-districts (as well as in bordering American waters) in 1955. In the accompanying map the new region surveyed in 1955 (shaded area) and the location of the 1955 herring spawning grounds (heavy black zones) in southern B.C. are shown.

For each statistical area, data are obtained on: (1) the sum of the lengths of the individual spawning grounds (found by reference to large-scale charts or by pacing them off along the beach) and (2) the intensity of each individual spawning classified as very light, light, medium, heavy and very heavy according to the number of eggs per unit area, and assigned a value 1, 2, 3, 4 and 5 respectively.

In the following tabulation the statutory miles of spawn at a standard intensity (medium) are given by sub-district for 1955, and for the previous three seasons for comparison. The figures in parentheses represent estimates of the amount of spawn deposition derived from the combined coverage by fisheries officers and members of the Biological Station, Nanaimo, B.C. and are used in the comparisons whenever possible. All other figures are based on fishery officers' reports.

| Sub-district | Statutory miles of spawn of medium intensity | | | |
|---|---|---|---|---|
| | 1952 | 1953 | 1954 | 1955 |
| Queen Charlotte Island | 5.4 | 13.4 | 22.1 | 11.3 |
| Northern | 14.1 | 20.3 | 16.4 | 23.1 |
| North central | 4.3 | 6.8 | 4.7 | 4.0 |
| South central | 22.8 | 43.0 | 36.9 | 39.8 |
| Upper east coast of V.I. | 9.9 | 24.7 | 14.4 | 9.2 |
| Middle east coast of V.I. | 36.1 | 35.7 | 21.8 | 36.6(40.4) |
| Lower east coast of V.I. | 30.3 | 102.5 | 64.2 | 16.8(43.4) |
| West coast of V.I. | 14.6(41.7) | 41.4(76.8) | 26.3(45.1) | 28.4 |
| U.S.A. (Boundary Bay) | | | | (15.6) |
| Total | 137.5(164.6) | 287.8(323.2) | 206.8(225.6) | 169.2(215.2) |




Map of southern British Columbia showing the location of the 1955 herring spawning grounds (heavy black zones). The areas surveyed in 1955 by members of the Biological Station, Nanaimo, B. C. are shaded.

The amount of spawn recorded in 1955 (215.2 miles) while slightly less than that in 1954 (225.6 miles) was still about average for the last 10 years. Increases from the 1954 level occurred in four sub-districts: northern (40%), middle east coast of Vancouver Island (68%), south central (8%) and west coast of Vancouver Island (8%). A marked reduction occurred in the Queen Charlotte Islands (50%), upper east coast of Vancouver Island (36%), and the lower east coast of Vancouver Island (32%). In the last, however, in spite of the continued decline from the record level of 1953 (102.5 miles), the 1955 spawning remained above-average. In the Queen Charlotte Islands and upper east coast of Vancouver Island the 1955 spawning was average or slightly below.

The increased deposition recorded in the northern sub-district included a spawning of 10.1 miles in a new location, Wilson Inlet, in Area 5. Large spawnings along the Parksville-Deep Bay shoreline (Area 14) and at the head of Bute Inlet (Area 13) accounted for the increase in the middle-east-coast sub-district. In the south-central sub-district slight increases occurred in Areas 7 and 9 and a pronounced increase in Area 8, where an unusual spawning over 7 miles long occurred in Burke Channel at the beginning of July. This is the first record of summer spawning on the British Columbia coast except for small spawnings in Area 2A-E in the Queen Charlotte Islands. On the west coast of Vancouver Island the increase in spawn resulted from a substantial increase in Area 26 where a large new spawning occurred in the Spring Island region. The increase in Area 26 was offset by a sharp decrease in Area 27.

A survey, for the first time, of bordering American waters in the Strait of Georgia revealed the presence of an exceptionally large herring spawning at Boundary Bay of over a million square yards partly in Canadian and partly in American waters. Several other spawnings were found in the San Juan Islands region but all were small and of light intensity suggesting that this region may not be important.

### 5. Population abundance in 1954-55 and predicted abundance in 1955-56.

F.H.C. Taylor

The changes shown by the above data to have occurred in population abundance from 1953-54 to 1954-55 and the prospective abundance in 1955-56 are discussed in this section. The size of the catch, the ease with which it was taken and the amount of fish left to spawn provide information on population abundance in 1954-55. An assessment of the relative strength of the various year-classes obtained from a study of the age composition of the catches and spawning runs permits estimation of the amount of recruitment to be expected in 1955-56. The eleventh in a series of annual forecasts of the prospects of the herring fishery was prepared in July, 1955. (Biological Station, Nanaimo, B.C., Circular No. 38.) The various assumptions and the limitations involved in estimating population abundance and in predicting recruitment have been discussed in Appendix 83 of the 1951 report. The predictions made in 1954 were in general agreement with changes in abundance that occurred in 1954-55.

In 1954-55 herring in British Columbia were generally less abundant than in 1953-54. The stocks principally affected were those in northern and central British Columbia and on the west coast of Vancouver Island. The stocks in the Strait of Georgia remained at a high level of abundance.

(a) Queen Charlotte Islands sub-district. The fishery was confined almost entirely to Skidegate Inlet for the second year in succession. Although the catch was almost as high as in 1953-54, much greater effort was expended in taking it; spawning observed in 1955 was negligible. It thus appears that abundance had declined in 1954-55, but possibly not to as low a level as in other northern populations.

Information on relative year-class strength indicates that the 1949 year-class (dominant in the fishery in 1953-54) was stronger than the 1951 year-class (dominant in 1954-55) and that both were stronger than the 1950 and particularly the 1952 year-classes. In 1955-56, the 1952 year-class is not expected to contribute as heavily as did the 1951 year-class in 1954-55. The 1951 year-class may dominate the fishery as V-year-olds. The reported presence in 1954-55 of large numbers of small fish may indicate that the 1953 year-class will contribute well as III-year fish in 1955-56. However, not enough is known of this population to assess properly the significance of the presence of small fish. Unless the 1953 year-class makes a strong entry the level of abundance in 1955-56 is expected to be less than in 1954-55, because of the comparative weakness of the 1952 year-class.

(b) Northern sub-district. Spawn deposition in 1955, although showing an increase of 40% over the reduced deposition of 1954, was little above average. This, coupled with the marked decline in catch and catch per unit of effort for the second successive year, suggests that the level of abundance has declined. Evidence indicates that the 1949, 1950, and 1951 year-classes were probably average or below-average in size. The 1951 year-class, dominant as IV's in 1954-55, may have been stronger than the 1949 or 1950 year-classes. The 1952 year-class made the poorest contribution of the III-year fish in the last 10 years and may be well below average in strength. In 1955-56, the 1951 year-class may dominate the fishery as V-year-olds; the 1952 year-class, as IV's will probably make a relatively small contribution. While the 1952 year-class may be stronger than the 1953 year-class it is not expected to be above average. The level of abundance is, therefore, expected to remain at a low level in 1955-56 and there is little likelihood that there will be an improvement in the catch.

(c) Central sub-district. Abundance was apparently at a low level in 1954-55. The quota was not taken for the second year in succession and the catch was the lowest since 1946-47. The fishery was characterized by poor catches from the major migratory stocks of Areas 6 and 7 and by greater dependence on local populations in all areas. Spawn deposition in Area 7 was up to average, in Area 6 was the lowest recorded for the Area, in Area 8 showed a sharp increase over 1954 due to the large summer spawning in Burke Channel, and in Areas 9 and 10 was below-average.

The 1951 year-class (IV-year olds) was dominant in all areas, but appears to be of no more than average strength. The 1952 year-class made one of the poorest contributions for III-year-olds in recent years and must be considered a weak year-class. The 1953 year-class (II-year olds) was better represented than was the 1952 year-class in 1953-54. In 1955-56, the 1951 year-class may dominate as V-year-old fish, the 1952 year-class is expected to make a relatively weak contribution as IV's and the 1953 year-class as III's a slightly better contribution than did the 1952 year-class in 1954-55. Abundance is therefore expected to be less than in 1954-55 and the quota again may not be taken. Fishing in Area 6 may be better than in Area 7. Catches in Area 9 will be less than in the last two seasons.

(d) Upper-east-coast sub-district. In the past two seasons abundance has been at a fairly high level due to contributions of a strong 1951 year-class, which dominated the fishery in 1953-54 (as III-year-olds) and in 1954-55 (as IV-year-olds). In 1953-54, catch, spawn and availability were about average; in 1954-55 spawning was reduced, but catch and availability were high due to the exploitation of new fishing grounds in Seymour Inlet and Nugent Sound.

In 1955-56 the 1951 year-class as V's cannot be expected to make a large contribution nor can the 1952 year-class be expected to contribute as heavily as IV-year olds as did the 1951 year-class in 1954-55. From their contribution as I and II-year olds in 1954-55, the 1954 and 1953 year-classes appear to be relatively weak. Abundance is, therefore, expected to decrease.

(e) Middle east coast sub-district. Abundance in 1954-55 was at a high level as indicated by the record catch of 24,600 tons followed by a record spawn deposition of 36.6 miles. Indications are that the 1947, 1950, 1951 and probably the 1952 year-classes were strong and the 1948 and 1949 year-classes at least of average strength. The 1950 and 1951 year-classes were probably stronger than the 1952 year-class. The 1953 year-class made a better showing as II-year fish than did the 1952 year-class and should be of at least average strength. In 1955-56 abundance is expected to remain at a high level and good catches should result.

(f) Lower east coast sub-district. Abundance has been at a high level in this sub-district for the past four seasons. The decrease in spawn deposition in the last 2 years suggests that the period of peak abundance may be past. A series of strong year-classes have maintained the high level of abundance. Indications are that the 1950 year-class was a little stronger than the 1951 year-class and that both were stronger than the 1952 year-class which supported the fishery in 1954-55. The 1952 year-class should make a good contribution as IV's in 1955-56 and indications are that the 1953 year-class will be relatively strong. A continuation of the high level of abundance is therefore expected in 1955-56 and good catches should result.

(g) West coast sub-district. Abundance has been at a generally low level in recent years due to a succession of weak year-classes. The level of abundance has been lower in Areas 25 and 26 than in Areas 23 and 24. Spawning, however, in most years and areas has remained at a normal level.

The 1948 year-class was weak, the 1949, 1950 and probably the 1952 were below-average and the 1951 average. In 1953-54 abundance increased somewhat in Areas23 and 24(but not in Areas 25 and 26) with the appearance of the 1951 year-class, which was probably stronger in the south west coast areas than in the north west coast areas. In 1954-55 abundance decreased in all areas except Area 27 because of the dependence on the relatively weak 1952 year-class for III-year fish and the average 1951 year-class for IV-year fish.

In 1955-56 the 1952 year-class is expected to make a poor contribution as IV-year fish. From its showing as II-year fish in 1954-55 the 1953 year-class may be of at least average strength. Some increase in abundance is expected, therefore, in Areas 23 and 24, with catches better than in 1954-55, but still somewhat below-average. In Areas 25 and 26 little improvement is expected. In Area 27, because of a marked decrease in spawning, abundance is not expected to be as high as in 1954-55.

6. Fecundity of British Columbia herring. F. Nagasaki

The results of the annual herring spawn surveys provide information on the initial size of the new year-class and form the basis for an index to the relative size of the spawning population. While such an index is useful, an estimate of the size of the spawning stock in numbers of fish is more desirable. One method of estimating the size of the spawning stock is to translate the total number of eggs deposited into the number of fish responsible, using information on the mean number of eggs spawned per female, and the sex ratio. While information on sex ratio is readily available, information on egg production is scanty. The purpose of this study is, therefore, to provide information on the fecundity of British Columbia herring, on the relationship between fecundity and body length and age and on the variation, if any, in mean fecundity between populations.

Ovaries were collected from approximately 10 fish of each age-class from as many populations as possible. Females were selected on the basis of length categories determined from age-length relationships. The actual ages of the females were determined later from scale readings. A total of about 600 pairs of ovaries were obtained. The number of ovaries in each sample and the distribution of the samples by sub-district, statistical area, and locality are given in Table I.

Table I. Samples of ovaries used in study of fecundity

| Sub-district | Statistical area | Locality | Date | Number of ovaries | Immature ovaries discarded |
|---|---|---|---|---|---|
| Queen Charlotte Island | 2A-E | Skidegate Inlet | Dec. 6, Jan. 12, 20 | 67 | 37 |
| Northern | 5 | Kitkatlah Inlet | Jan. 21, 22, 30 | 62 | 3 |
| North central | 6 | Meyers Pass | Dec. 15 | 22 | 0 |
| | 6 | Thistle Pass | Dec. 16 | 28 | 0 |
| South central | 7 | Thompson Pass | Jan. 6, 7 | 7 | 0 |
| | 7 | Bella Bella | Jan. 9 | 37 | 3 |
| | 7 | Kildidt Sound | Feb. 9 | 7 | 0 |
| | 8 | Fish Egg Inlet | Dec. 16,17 | 75 | 5 |
| | 8 | Cousins Inlet | Jan. 13 | 10 | 6 |
| Middle east coast of Vancouver Island | 13 | Deepwater Bay | Jan. 18 Feb. 2 | 39 | 3 |
| | 14 | Deep Bay | Mar. 1,9 | 37 | 1 |
| Lower east coast of Vancouver Island | 17A | Departure Bay | Apr. 5 | 10 | 0 |
| | 17B | Ladysmith | Mar. 20 | 28 | 0 |
| | 17B | Walker Rock | Jan. 6,20 | 29 | 0 |
| | 18 | Satellite Channel | Jan. 5,21, 24 | 71 | 0 |
| Lower west coast of Vancouver Island | 23 | Effingham Inlet | Jan. 12 | 26 | 0 |
| Upper west coast of Vancouver Island | 27 | Klaskish Inlet | Dec. 6 | 10 | 4 |
| | 27 | Quatsino Sound | Dec. 6 | 35 | 0 |

Some samples could not be used in the analysis of the data: those from Departure Bay, Deep Bay, and Ladysmith because they were obtained from fish in the act of spawning, those from Cousins Inlet, Kildidt Sound, Klaskish Inlet, and Thompson Bay because they were too small to be representative and that from Meyers Pass because the majority of the fish were from a single age-class.

The length, weight and age of each fish were recorded. The total number of eggs in each female was determined, after the ovarious tissue had been removed and the eggs separated from each other and dried, from the total weight of the ovaries and the mean weight of two 250-egg sub-samples. In the analysis of the data it was found that body length was a better criterion of size than body weight. A logarithmic transformation was applied to the 3 variates, age, body length, and fecundity to obtain straight line relationships and to equalize the variances throughout the ranges in body length and age. The mutual relationship between fecundity, age, and body length was determined by the multiple regression technique. The significance of differences between samples in mean number of eggs adjusted to a common body length and a common age was tested by analysis of covariance.

No significant differences in mean numbers of eggs adjusted to a common body length and a common age were found between the six samples from northern British Columbia (Skidegate Inlet, Kitkatlah Inlet, Thistle Pass, Bella Bella, Fish Egg Inlet, and Quatsino Sound) or between the samples from southern British Columbia (Deepwater Bay, Satellite Channel, Walker Rock, and Effingham Inlet). Differences significant at beyond the .01 level of probability were found between the combined northern British Columbia samples and the samples from southern British Columbia, either separately or combined to form one sample. Fecundity in fish of the same body length and age was higher in northern than in southern British Columbia. The multiple regression equations for the northern and southern groups are given below:

Northern group: Log. fecundity $=$ 3.2483 log body length $+$ 0.0814 log age $-$ 3.1746
Southern group: Log. fecundity $=$ 2.1646 log body length $+$ 0.3220 log age $-$ 0.8955

In both the northern and southern groups the standard multiple regression coefficients of log fecundity on log body length independent of log age differs significantly from zero ($t = 13.44$ and $7.24$ respectively, $P > 0.01$). In the northern group the standard multiple regression coefficient of log fecundity and log age, independent of log body length, does not differ statistically from zero whereas in the southern group it does ($t = 3.61$, $P > 0.01$). It would thus appear that, whereas in the northern group the affect of age on fecundity, independent of its relation to body length, is negligible, in southern British Columbia fecundity increases somewhat with age. No obvious explanation has been found to account for this difference in the effect of age in the two groups. From a consideration of the size of variates (of age and body length), it would be seen, however, that the effect of age alone on fecundity is small even in southern British Columbia and that for practical purpose fecundity is dependent only on body length. This is also illustrated in the table below which shows the average number of eggs calculated from the multiple equations, in females of various length in each age-group from northern and southern British Columbia.

| Age | Number of eggs in females of length (mm.) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 160 | 170 | 180 | 190 | 200 | 210 | 220 | 230 | 240 |
| **Northern British Columbia** | | | | | | | | | |
| II | 10,200 | 12,400 | 15,000 | . . | . . | . . | . . | . . | . . |
| III | 10,600 | 12,900 | 15,500 | 18,500 | 21,800 | . . | . . | . . | . . |
| IV | 10,800 | 13,200 | 15,900 | 18,900 | 22,300 | 26,200 | . . | . . | . . |
| V | . . | . . | 16,200 | 19,300 | 22,700 | 26,600 | 31,000 | . . | . . |
| VI | . . | . . | . . | . . | 23,000 | 27,000 | 31,400 | 36,300 | 41,700 |
| VII | . . | . . | . . | . . | . . | 27,400 | 31,800 | 36,800 | 42,200 |
| VIII | . . | . . | . . | . . | . . | . . | 32,200 | 37,200 | 42,700 |
| **Southern British Columbia** | | | | | | | | | |
| II | 9,300 | 12,700 | 12,100 | . . | . . | . . | . . | . . | . . |
| III | 10,600 | 12,200 | 13,800 | 15,500 | 17,300 | . . | . . | . . | . . |
| IV | 11,600 | 13,400 | 15,100 | 17,000 | 19,000 | 21,100 | . . | . . | . . |
| V | . . | . . | 16,300 | 18,300 | 20,400 | 22,700 | 25,100 | . . | . . |
| VI | . . | . . | . . | . . | 21,700 | 24,100 | 26,600 | 29,300 | 32,200 |
| VII | . . | . . | . . | . . | . . | 25,300 | 28,000 | 30,800 | 33,800 |
| VIII | . . | . . | . . | . . | . . | . . | 29,200 | 32,200 | 35,400 |

## Studies on the early life-history of herring

Studies on the relationship of the amount of spawn deposited and the relative strength of the resulting year-class at recruitment have indicated that there is no direct relationship between them and thus, that, in all populations, the amount of spawn deposited may, in general, have been greater than needed to maintain the stock. Fluctuations in year-class strength have been caused by factors affecting survival between spawning and recruitment. These findings pointed the need for studies of each major life-history stage to determine what were the factors influencing survival, their effect at each stage, the earliest stage at which a direct relationship existed with year-class strength at recruitment, and what this relationship was. These studies were begun in 1947 and were carried out principally on the west coast of Vancouver Island. Survival of spawn during incubation and survival during the larval period were studied first, and in 1951 an investigation of survival during the juvenile stage was begun and is still continued.

In 1955 the spawn-survey program and the juvenile herring studies were carried out in the middle- and lower-east-coast instead of the west-coast of Vancouver Island. No spawn survival studies were undertaken this year but such studies are planned in future to determine whether any differences exist in the survival of spawn in the two regions.

### 1. Distribution and survival of herring larvae. J.C. Stevenson

Data from studies on herring larvae carried out from 1947 to 1951 on the lower west coast of Vancouver Island were analysed and the results were reported in a doctoral thesis presented to the University of Toronto in the spring of 1955. The main conclusion was that a great and critical mortality occurs during the larval stage and that this mortality is traceable to the transport of the larvae by water currents from the inshore brood areas out to the open sea. The study indicated that a very large proportion of the larvae that are carried to the open sea do not survive, and that the strengths of herring year-classes depends largely on the numbers of young that remain in inshore areas during the six-week larval period in the spring.

The field studies involved quantitative sampling of the larval broods by horizontally-towed nets in March, April, and May. The main area of study was Barkley Sound where a high proportion of the spawning on the lower west coast of Vancouver Island occurs.

Study of the vertical distribution indicated that herring larvae were most highly concentrated near the surface of the water and during the night. As the larvae grew older, their preponderance in night samples as compared to daytime samples increased, and their preponderance in surface samples as compared to deep samples decreased.

The data suggested that the vertical distribution of larvae was influenced by intensity of light. Newly-hatched larvae appeared to be strongly attracted both to strong light (daylight) and to weak light (the faint light in surface waters at night). After absorption of the yolk sac, the attraction to strong light disappeared, and no heavy concentration of larvae was found in surface waters during the day. The fact that concentrations of larvae, comparable to those at the surface at night, were not found in the deep layers during the day, was attributed (a) to the greater ability of larvae to evade the sampling net during the day than at night, and (b) to the shallowness of the brood areas, which prevented the larvae from going sufficiently deep to reach the depth of preferred light intensity.

Study of the horizontal distribution showed heavy concentrations of larvae in the vicinity of the spawning grounds during the period that hatching was going on. After hatching ceased, the concentration of larvae in the inshore (or brood) areas progressively decreased at an approximately constant rate.

The extent of decrease of larvae noted in a brood area (Toquart Bay) appeared greater than would be expected on the basis of the average amount of larval mortality presumed to occur in the population. The fact that larvae were found in areas where no hatching had taken place indicated that a large part of the decrease was caused by movement of larvae away from the brood area.

The movement of larvae in the northern part of Barkley Sound (as shown by sampling) was interpreted on the basis of the pattern of water currents within the Sound (as determined by oceanographic survey). Large-scale movement of larvae took place along the northwest shore of the Sound (from the main spawning grounds in and near Toquart Bay, to the mouth of the Sound); this movement of larvae was related to the strong seaward-moving current along the northwest shore. The seaward transport of larvae was hastened by the fact that rate of flow was greater in the surface layers where the larvae were found to be heavily concentrated at night. Low concentration of larvae in another part of the Sound was shown to result from the presence there of a compensatory current flowing from the open sea into the Sound.

These facts suggest that few of the larvae carried to sea were returned to the Sound. Moreover, they led to the suggestion that herring larvae, carried offshore, do not survive, and that the larvae remaining in the Sound constitute the basis for the eventual abundance of the year-class in the fishery.

While direct evidence was lacking to indicate that larvae cannot survive in the open sea, several pieces of indirect evidence support the suggestion, including: (1) the fact that no larvae were taken in sampling in offshore waters, (2) the tremendous dispersal of the larvae that would presumably take place in the open sea, and the improbability that widely-isolated individuals could find their way back to the Sound, even if they could survive, (3) the lack of schools of newly-metamorphosed herring in bays and inlets near the mouth of the Sound, (4) the experimental evidence of Japanese workers that herring larvae after the yolk-sac stage show less survival in water of normal sea salinity than in water of less than normal salinity, and (5) the fact that herring larvae in European waters, although hatched in water of high salinity, show a marked tendency to seek coastal waters of low salinity. Further indirect support was gained from the lack of evidence that any mortality factor (predation, disease, limiting food supply, etc.) acting in inshore waters could cause the tremendous mortality (over 99%) known to occur during the larval period.

It was suggested that meteorological factors may affect year-class strength in herring through causing annual variations in rate of seaward flow of inshore currents during the critical larval period. The delayed effect of snowfall on river discharge was considered to be of greater importance than the more immediate effect of rainfall. It was obvious, however, that a number of interrelated meteorological factors (wind, rain, snow, and temperature) was operative. The conclusion was that no single meteorological factor was likely to provide a simple index for the survival of herring.

2. Studies on juvenile herring. A.S. Hourston

(A) Barkley Sound

A four-year study of the juvenile herring population in Barkley Sound was completed in 1954. The main purpose of the study was to establish and test a means of estimating year-class strength prior to recruitment. Estimates made during the egg and larval stages have failed to accomplish this because of the variable mortalities suffered at these stages, and the fish migrate offshore at the end of the first summer where they are not readily accessible until recruitment. Consequently the early juvenile stage seems to present the best opportunity for the early assessment of year-class strength.

For better interpretation of these assessments, studies were made of size groups, growth rates, and environmental conditions. The relationship of the juvenile population in an area to the adult spawning populations in that and other areas was investigated by tagging the older juveniles and recovering the tags in the adult fishery. Tag-recovery tests, along with tagging mortality experiments, provided the supplementary data necessary to interpret the results. In 1954 studies on the environment were also stressed in an effort to determine some of the causes of the distribution and survival noted.

(1) Size and growth

(a) Sampling. Samples of up to 100 fish were taken from each catch made and the standard length and weight of each fish were recorded. In 1954, 76 samples were taken as compared with 91, 65 and 56 in 1953, 1952 and 1951 respectively.

(b) Growth of juvenile herring during the summer of 1954. As in previous years, the growth of the 1954 year-class was expressed in terms of age-length, age-weight, and length-weight relationships. Age is given as the number of days after the estimated "average" hatching date of March 29. This date was arrived at by adding the incubation period (approximately 14 days in this region) to the "average spawning date" of March 15, representing the median of the period of major spawnings in this region (February 28 - March 29) and also the date of one of the two large spawnings that take place in this area.

(i) Age-length relationship. The 1954 fish of a given average age did not differ appreciably in size from either the 1951 or the 1953 fish, being slightly smaller than the former and larger than the latter. The 1952 fish were noticeably larger, possibly indicating unusually good feeding conditions that year. (The 1952 juvenile population was relatively ~~small.)~~

(ii) Age-weight relationship. Comparisons of the 1954 data with that of previous years yields results similar to those for the length-weight relationship.

(iii) Length-weight relationship. The logarithmic length-weight relationship for the 1954 fish indicated that these fish were slightly fatter than those in previous years, but this difference was of the same order as that between the 1951 fish and those of 1952 and 1953, and may represent random variation. The equations of the lines drawn by inspection were:

| | |
|---|---|
| 1954 | $\log W = 3.27 \log L - 5.44$ |
| 1953 | $\log W = 3.06 \log L - 5.07$ |
| 1952 | $\log W = 3.06 \log L - 5.02$ |
| 1951 | $\log W = 3.16 \log L - 5.22$ |

(c) Length groups within sub-populations. Again in 1954 the wide variation in length and weight of juveniles of comparable average age and the wide range in hatching dates of the various spawnings suggested the presence of several size-groups. This was borne out by the suggestion of four to six linear trends in both the age-length and age-weight relationships. The sampling data were, therefore, examined for the presence of more than one size-group, using a graphical analysis of polymodal frequency distributions by means of probability paper.

As in previous years all five length-groups found in Uchucklesit Inlet were also found in San Mateo Bay which also had an additional sixth size-group. The slopes of the trend lines in the two localities are also comparable. Thus migration from Uchucklesit Inlet to San Mateo Bay would be reasonable on this basis, with migration in the opposite direction almost equally feasible (but not indicated by the 1952 and 1953 data). Banfield Inlet and Kelp Bay each showed 12 size-groups all but one of which corresponded with those from the other locality, and probably contained a single stock of juveniles. Comparison of Uchucklesit and San Mateo stocks with the Banfield Inlet - Kelp Bay stock failed to show any marked resemblances. Their length-groups all fall within the range of those found in Banfield Inlet - Kelp Bay and some mixing, especially in the seaward direction, could occur, but would not appear to be as extensive as between Banfield Inlet and Kelp Bay or between Uchucklesit Inlet and San Mateo Bay. The seven size-groups found in Pipestem Inlet did not correspond closely with those in any of the other localities; the best fit was with the Uchucklesit and San Mateo fish with an occasional trend line corresponding and the slopes of the trend lines roughly comparable. The Ucluelet Inlet fish appear unique in that the growth curve showed greater slopes and 12 closely packed trend lines were indicated.

(2) Population estimates and extent of mixing

Assessment of the 1954 juvenile stocks in Barkley Sound was carried out mainly on the basis of scouting and marking programs. The size of each school found was roughly estimated, and more precise estimates were made from marking experiments on some of the major stocks. Data from the latter experiments, along with comparisons of length-groups found in the different stocks, were used to estimate mixing. Since coverage was not considered adequate in previous years, effort was increased to 106 boat-days in 1954 as compared with 79 in 1953 and 86 in 1952. Schools were found and estimated by visual observations, supplemented by echo-sounder tracings. Independent estimates by these two means showed good relative agreement. A total of 184,690 fish were marked in 1954 as compared with 192,821 in 1953, 83,170 in 1952 and 66,822 in 1951.

(a) Extent of mixing. As may be seen from the following tabulation, the conclusion from the previous three years' data that movement between localities in Barkley Sound involved less than one-third of the individual stocks is borne out by the 1954 data.

| Where marked | Mark | Number marked | Recoveries at: Banfield Inlet LV | Kelp Bay LVLP | Pipestem Inlet RP | San Mateo Bay BV | Uchucklesit Inlet RV | Ucluelet Inlet LP | Useless Inlet RVRP | All marks |
|---|---|---|---|---|---|---|---|---|---|---|
| Banfield Inlet | LV | 34,850 | 9 (64) | 2 (14.5) | | | 1 (7) | 2 (14.5) | | 14 |
| Kelp Bay | LVLP | 10,000 | | 4 (100) | | | | | | 4 |
| Pipestem Inlet | RP | 28,450 | | | 15 (100) | | | | | 15 |
| San Mateo Bay | BV | 28,450 | 1 (11) | | | 7 (78) | 1 (11) | | | 9 |
| Uchucklesit Inlet | RV | 29,090 | | | | | 5 (71) | 2 (29) | | 7 |
| Ucluelet Inlet | LP | 26,840 | | | | | | 9 (100) | | 9 |
| Useless Inlet | RVRP | 5,270 | | | | | | | 3 (100) | 3 |
| | | | 10 | 6 | 15 | 7 | 7 | 13 | 3 | 61 |

(LV - left pelvic (ventral) fin; RV - right pelvic (ventral) fin; BV - both pelvic (ventral fins); LP - left pectoral fin; RP - right pectoral fin; LVLP - left pelvic (ventral and left pectoral fins); RV - right pelvic (ventral and right pectoral fins).

Figures in parentheses represent the percentage of the recoveries of each type of mark made in the various localities in which marking was carried out. Indeed, three-quarters or more of the fish appear to have remained in the region of marking. The one apparent exception is Banfield Inlet where 36% of the recoveries were taken in other localities. However, all indications point to a single population in the Banfield Inlet - Kelp Bay region. The two localities were less than a mile apart and on more than one occasion, juveniles were observed more or less continuously along the shore between the two localities. Thus, if these two localities are considered to contain the same stock, emigration from this stock was only 17% (3/18). The length-group analysis of the sampling data tends to confirm this view.

On the basis of the recoveries made over the four years of the study the relative extent of migrations across the Sound and on one side of the Sound may be seen in the following tabulation:

| | 1951 | 1952 | 1953 | 1954 | 1951-1954 | 1952-1954 |
|---|---|---|---|---|---|---|
| Between localities SE side | 8 (2/24) | 33 (7/21) | 35 (21/60) | 15 (5/33) | 25 (35/138) | 29 (33/114) |
| Between localities NW side | 64 (7/11) | .. | 0 (0/2) | (0/24) | 19 (7/37) | 0 (0/26) |
| SE side to NW side of Sound | 23 (7/31) | 125 (3/24) | 12 (1/61) | 11 (4/37) | 10 (15/153) | 7 (8/122) |
| NW side to SE side of Sound | 59 (16/27) | 0 (0/3) | 0 (0/2) | 0 (0/24) | 29 (12/56) | 0 (0/29) |
| Net movement on one side of Sound | 26 (9/35) | 33 (7/21) | 34 (21/62) | 9 (5/57) | 24 (42/175) | 24 (33/140) |
| Net movement across Sound | 25 (23/58) | 11 (3/27) | 2 (2/63) | 7 (4/61) | 15 (31/209) | 5 (8/151) |

With the exception of the movement observed in 1951 from the Toquart Bay - Cigarette Cove region to the south-east shore, cross-sound migrations appear to be less extensive than those between localities along either side of the Sound. The 1951 migration may represent a late movement of juveniles into their natural rearing grounds as these fish appear from the Toquart Bay - Cigarette Cove region early in August and did not reappear. Thus, considering the results for the last three years only, the cross-sound migration is only about one-fifth that between localities on the same side of the Sound.

(b) Population estimates. A general estimate of the entire juvenile population in Barkley Sound in 1954 was made by means of a scouting survey. More precise estimates of the stocks in six localities were made by marking experiments and used to provide a correction factor to the general estimate. The latter is usually low, since all the fish in any locality are seldom observed during a single scouting.

(1) Estimates based on scouting. As a result of the greater stress laid on scouting in 1954, it was possible to scout the entire sound several times. This resulted in the location of stocks not observed in previous years and led to a two to threefold increase in the total estimate, as may be seen from the following tabulation. The numbers shown in the table represent the maximum estimate for any single scouting in the locality.

| Locality | Juveniles Estimated x $10^3$ | | | |
|---|---|---|---|---|
| | 1954 | 1953 | 1952 | 1951 |
| Alberni Inlet | .. | .. | 203 | .. |
| Assits Island to Congreve Island | 250 | .. | .. | .. |
| Banfield Inlet | 600 | 200 | 1150 | 1000 |
| Banfield Inlet to Kelp Bay | 200 | .. | .. | .. |
| Bernard Point to Assits Island | 250 | .. | .. | .. |
| Chrow Island | 50 | .. | .. | .. |
| Chup Point | 100 | .. | .. | .. |
| *Cigarette Cove | 150 | 0 | 5 | 50 |
| Coaster Channel | 10 | .. | .. | .. |
| David Channel | 50 | ** | ** | .. |
| Diana Island | 0 | .. | .. | .. |
| Dodger Channel | 50 | 10 | 1 | .. |
| *Dutch Harbour | 150 | 0 | 200 | .. |
| Ecoole Harbour | 500 | 0 | 300 | .. |
| Edward King Island | 0 | .. | .. | .. |
| Effingham Inlet | 600 | 1 | 3 | 5 |
| Effingham Island | 1600 | 5 | 200 | .. |
| Fleming Island | 75 | .. | .. | .. |
| Forbes Island | 0 | .. | .. | .. |
| *Georges Island | 250 | *** | *** | *** |
| Grappler Inlet | 200 | **** | **** | **** |
| *Hand Island Channel | 500 | .. | 100 | .. |
| Harris Point | 80 | 400 | 0 | 0 |
| Helby Island | 0 | .. | .. | .. |
| Island Harbour | 50 | 0 | 500 | .. |
| Island Harbour to Coaster Channel | 30 | .. | .. | .. |
| Jaques Island | 0 | .. | .. | .. |
| Jarvis Island | 0 | .. | .. | .. |
| *Kelp Bay | 2000 | .. | .. | .. |
| *Kelp Bay to Danvers Islet | 1000 | .. | .. | .. |
| Loudoun Channel | 2000 | .. | .. | .. |
| Macoah Passage | 1000 | .. | .. | .. |
| Mayne Bay | 2000 | 0 | 0 | 0 |
| Nanat Islet | 0 | .. | .. | .. |
| Nanat Islet to Danvers Islet | 30 | .. | .. | .. |
| *New York Point | 200 | *** | *** | *** |
| Numukamis Bay | 150 | .. | .. | .. |
| Chiat Island | 0 | .. | .. | .. |
| Peacock Channel | 300 | .. | .. | .. |
| Pipestem Inlet | 1500 | 1010 | 5 | 100 |
| Rainy Bay | 300 | 0 | 20 | .. |
| Rainy Bay to Vernon Bay | 0 | .. | .. | .. |
| Ritherdon Bay | 0 | .. | .. | .. |
| San Mateo Bay | 1000 | 300 | 1000 | .. |

| Locality | Juveniles Estimated x $10^3$ | | | |
|---|---|---|---|---|
| | 1954 | 1953 | 1952 | 1951 |
| *Sarita Bay | 1100 | 10 | .. | .. |
| Satellite Passage | 100 | 0 | 50 | .. |
| Sechart Channel | 1000 | 15 | 1000 | .. |
| Snowden Island | 500 | *** | *** | *** |
| Snug Basin | 30 | .. | .. | .. |
| Stopper Islands | 700 | 10 | 5 | 0 |
| Swaile Rock | 70 | ***** | ***** | ***** |
| Swaile Rock to Island Harbour | 50 | ***** | ***** | .. |
| Thiepval Channel | 1000 | .. | .. | .. |
| Toquart Bay | 250 | 0 | 0 | 10 |
| Turtle Island | 0 | .. | .. | .. |
| Tzartes Island (East side) | 1000 | 5000 | 0 | 2000 |
| Tzartes Island (West side) | 100 | ****** | ****** | .. |
| Uchucklesit Inlet | 900 | 300 | 5000 | 300 |
| Ucluelet Inlet | 1000 | 100 | 300 | .. |
| Useless Inlet | 300 | 200 | 1 | 10 |
| Vernon Bay | 250 | 30 | .. | .. |
| | 24,075 | 7,611 | 10,043 | 3,475 |

* Local names
** Included in Mayne Bay
***Included in Toquart Bay
****Included in Banfield Inlet
*****Included in Sechart Channel
******Included in Tzartes Island, east side

In 1954, 21 localities showed an increase in population over 1953, only 2 a decrease. The total estimate was 16,000 in 1954 as compared to 7,600 in 1953. In comparison with the 1952 estimates, 16 localities showed an increase in 1954, 5 showed a decrease and 2 remained the same; the total estimate for these 23 localities in 1954 was 16,000 fish, whereas in 1952 it was 10,000. However, the more thorough scouting in 1954 would be expected to result in higher estimates for that year and may be the major factor in this difference.

The most noteworthy individual features of the 1954 estimates were: (1) the discovery of a large population in Effingham Inlet where only an occasional school was observed before, (2) the finding of a large population in Mayne Bay for the first time, (3) the inclusion of a relatively large population in the general Toquart Bay area for the first time since 1952, (4) the tremendous increase in the Ucluelet Inlet stocks, (5) the return of the Sechart Channel, San Mateo Bay and Effingham Island stocks to the major level after a slump in 1953, (6) the sustained abundance of the Tzartes Island and Useless Inlet stocks after their tremendous increase in 1953 over the 1952 level.

(2) Estimates based on marking. A Schnabel-type marking experiment was again employed in 1954 to estimate the size of some of the larger stocks in Barkley Sound. The 1954 estimate for all localities marked is tabulated below along with similar estimates for previous years.

| Year | No. of localities covered | No. of fish marked | No. of recoveries | Population x $10^6$ Estimate | 95% Poisson Confidence Limits |
|---|---|---|---|---|---|
| 1954 | 7 | 163,350 | 59 | 189 | 147-240 |
| 1953 | 9 | 156,510 | 65 | 166 | 141-212 |
| 1952 | 6 | 62,112 | 30 | 62 | 47-100 |
| 1951 | 5 | 33,986 | 58 | 11 | 8-14 |

Since different stocks were marked in different years, these total estimates are not really comparable, with the possible exception of 1953 and 1954. (Three of the 1953 markings were not included in the 1954 program, while one of the 1954 markings was not carried out in 1953. In all cases these markings were relatively small.) The annual increase in population in the above tabulation no doubt reflects the expansion of the marking program rather than actual changes in abundance, as recoveries of marked fish have shown the Barkley Sound juvenile population is not homogeneous. However, on that basis, the 1953 estimate should be larger than the 1954 estimate for populations of comparable size, since it covers more of the total stock. The 1954 estimate is about the same as that of 1953, and thus the 1954 juvenile herring population in Barkley Sound may be slightly larger than the 1953 population on this basis. This is in accord with the estimates based on scouting.

A further indication of the relative strength of these year-classes may be derived from a comparison of local stocks studied more or less extensively during the four-year period. Estimates for all four years are available for Banfield Inlet while 1952-54 estimates are available for San Mateo Bay. The 1954 stocks in Uchucklesit Inlet, Ucluelet Inlet, and Useless Inlet may be compared with those in 1953, 1952, and 1951 respectively. These results are arranged in the following tabulation: (figures in parenthesis are the 95% confidence limits).

| Year | Banfield Inlet | San Mateo Bay | Uchucklesit Inlet | Ucluelet Inlet | Useless Inlet |
|---|---|---|---|---|---|
| 1951 | 4.3 (2.7-7.3) | | | | 4.6 (2.0-14.3) |
| 1952 | 26.0 (8.9-130.0) | 13.6 (6.9-32.0) | | 5.1 (1.8-25.7) | |
| 1953 | 41.3 (28.2-63.1) | 70.5 (34.2-176.2) | 41.1 (14.0-205.4) | | |
| 1954 | 43.5 (21.2-108.8) | 38.3 (18.6-95.9) | 37.7 (16.1-117.9) | 27.3 (14.4-61.4) | 10.6 (3.6-53.1) |

The 1951 markings were not sufficiently extensive to enable adequate estimates. In addition techniques were in the process of development and marking mortality was probably rather variable. The 1952 year-class appears to have been definitely weaker than the two succeeding ones in each of the three localities in which estimates could be made, while the 1953 year-class was approximately equal in strength to the 1954 year-class in Banfield and Uchucklesit Inlets, but stronger in San Mateo Bay.

(3) Discussion. An index of the extent to which a stock of juveniles is observed in a survey of the locality may be obtained by comparing the population estimates from the marking experiments with the scouting estimates for these localities. The latter are invariably smaller as even an extensive visual survey would not likely discover all the fish in a locality. Consequently the visual estimates for the entire sound must be low; the true level of abundance probably lies closer to that which could be obtained by marking extensively throughout the sound. Such a program is beyond the scope of this study but an approximation of this type of estimate may be obtained by calculating a "conversion factor" for the visual estimates in the localities included in the marking program and applying it to the scouting estimate for the Sound. This procedure has been applied in the following tabulation.

| Year | Estimate for localities marked (x $10^6$) | | Correction factor | Estimate for Barkley Sound (x $10^6$) | |
|---|---|---|---|---|---|
| | From marking | From scouting | | From scouting | Corrected |
| 1954 | 188.59 | 7.30 | 25.8 | 24.98 | 644.4 |
| 1953 | 166.50 | 1.97 | 84.5 | 7.61 | 643.0 |
| 1952 | 67.14 | 8.95 | 7.5 | 10.04 | 75.3 |
| 1951 | 10.93 | 1.07 | 10.2 | 3.48 | 35.4 |

Again the small estimates for 1951, and, to a lesser extent 1952, reflect the incomplete coverage of the Sound by the surveys of those years. Even considering this, the 1952 population appears to have been considerably smaller than those of the two subsequent years and was probably less than that of 1951. The 1953 and 1954 populations appear to have been about equal in size. Even the estimates listed above are probably slightly low as some stocks may have escaped detection. Thus the juvenile population in these years was probably at the order of 700 million fish. This agrees well with estimates of the number of eggs laid, reduced by known mortality rates up to the juvenile stage.

(3) Relationship to adult populations.

The relationship of the juvenile stocks in Barkley Sound to adult populations in this and other areas is being studied by means of the recovery in reduction plants of tags from mature fish which were inserted at the juvenile stage. A total of 22 tags were recovered in this manner during the 1954-55 fishing season, all from III-year fish. A total of 27,433 fish of this year-class were tagged as juveniles. These recoveries are tabulated below:

| Inserted | | | Recovered | | |
|---|---|---|---|---|---|
| Date | Place | Area | Date | Place | Area |
| (1952) | | | (1954-55) | | |
| Aug. 27 | San Mateo Bay | 23 | Oct. 19 | Swanson Channel | 18 |
| Aug. 6 | Uchucklesit Inlet | 23 | Oct. 19 | Swanson Channel | 18 |
| Aug. 17 | Banfield Inlet | 23 | Oct. 21 | Swanson Channel | 18 |
| Aug. 27 | San Mateo Bay | 23 | Oct. 22 | Swanson Channel | 18 |
| Aug. 17 | Banfield Inlet | 23 | Oct. 24 | Swanson Channel | 18 |
| Aug. 27 | San Mateo Bay | 23 | Nov. 2 | Swanson Channel | 18 |
| Aug. 15 | Uchucklesit Inlet | 23 | Nov. 3 | Swanson Channel | 18 |
| Aug. 13 | San Mateo Bay | 23 | Nov. 15 | Swanson Channel | 18 |
| Sep. 16 | Dixon Bay | 24 | Nov. 21 | Uchucklesit Inlet | 23 |
| Aug. 8 | Banfield Inlet | 23 | Nov. 22 | Uchucklesit Inlet | 23 |
| Aug. 13 | San Mateo Bay | 23 | Nov. 22 | Barkley Sound | 23 |
| Aug. 13 | San Mateo Bay | 23 | Nov. 23 | Barkley Sound | 23 |
| Aug. 15 | Uchucklesit Inlet | 23 | Nov. 24 | Uchucklesit Inlet | 23 |
| Aug. 15 | Uchucklesit Inlet | 23 | Nov. 29 | Barkley Sound | 23 |
| Sep. 25 | Effingham Island | 23 | Dec. 1 | Quatsino Sound | 27 |
| Aug. 6 | Uchucklesit Inlet | 23 | Dec. 1 | Barkley Sound | 23 |
| Aug. 8 | Banfield Inlet | 23 | Dec. 2 | Barkley Sound | 23 |
| Sep. 16 | Dixon Bay | 24 | Dec. 2 | Barkley Sound | 23 |
| Aug. 17 | Banfield Inlet | 23 | Jan. 5 | Barkley Sound | 23 |
| Aug. 8 | Banfield Inlet | 23 | Jan. 6 | Barkley Sound | 23 |
| Aug. 13 | San Mateo Bay | 23 | Jan. 25 | Deepwater Bay | 13 |
| Oct. 1 | Ecoole Cannery | 23 | | | |

The results of test runs of 10 tags put through the various plants in which tags are recovered, simultaneously with test runs of 50 adult tags, are summarized below along with similar results from the two other seasons. Figures in parentheses in the 1953-54 column include tests which were not carried out simultaneously with the adult tests but within two days thereafter.

| Plant | 1951-52 | | | 1953-54 | | | 1954-55 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Number of tests | Plant efficiency | Efficiency ratio | Number of tests | Plant efficiency | Efficiency ratio | Number of tests | Plant efficiency | Efficiency ratio |
| 1 Ceepeecee | 2 | 48 | .70 | .. | .. | .. | .. | .. | .. |
| 2 Colonial | 1 | 72 | .78 | 2(3) | 70(57) | .98(.85) | 2 | 85 | .96 |
| 3 Gulf of Georgia | 3 | 76 | .92 | 1 | 90 | .96 | 3 | 60 | .67 |
| 4 Imperial | 3 | 88 | .92 | 3(4) | 90(73) | .99(.80) | 2 | 70 | .80 |
| 5 Kildonan | .. | .. | .. | 1 | 84 | .89 | .. | .. | .. |
| 6 Nootka | 1 | 84 | 1.02 | .. | .. | .. | .. | .. | .. |
| 7 North Shore | .. | .. | .. | 3 | 87 | .90 | 2 | 40 | .57 |
| 8 Phoenix | 3 | 99 | 1.04 | 3 | 53 | .76 | 3 | 93 | .98 |
| 9 Port Albion | .. | .. | .. | 1 | 84 | .93 | 1 | 30 | .33 |
| All Plants | 13 | 80 | .93 | 16 | 75(73) | .86(.83) | 13 | 68 | .78 |
| Major Plants | 7 | 81 | .89 | 8 | 85(73) | .93(.83) | 7 | 70 | .80 |

Plant efficiency in juvenile tag recovery was poorer in 1954-55 than in the other two years, and the efficiency ratio (efficiency in recovering adult tags divided by efficiency in recovering juvenile tags) was down, even in the major plants. However, if the non-simultaneous tests are included, the 1953-54 results do compare well with those of 1954-55. The 1953-54 results may therefore present a closer indication of the true situation than was thought at the time and the magnet efficiency and the efficiency ratio may be closer to .70 and .80 respectively than the .80 and .90 considered in the 1953 report. The returns of tags indicate that a relatively large proportion of the Barkley Sound juveniles (about 55%) spawn in other areas, when mature, especially on the lower east coast of Vancouver Island. However, the catch on the lower and middle east coast (76,000 tons) was 6 times as large as that on the west coast (14,000 tons) and 10 times as large as that in Barkley Sound (7,500 tons), based on catch bulletins to February, 1955. If this difference represents a difference in the efficiency of the fishing rather than in actual abundance of the adult herring in these regions, then the indicated movement from Barkley Sound to the east coast is only about 10%. Although the lower-east-coast fish are more concentrated it seems improbable that the relative efficiency of the two fisheries could be so radically different.

It therefore appears that in some years at least, a considerable portion (perhaps half) of the herring spawned in Barkley Sound join the lower east-coast stocks of adults. Consequently assessment of the year-class strength at the juvenile stage for the lower-east-coast stocks would have to take the Barkley Sound juveniles into consideration as they could account for one-fifth of the stock. On the other hand, year-class strength in Barkley Sound would presumably be affected considerably by variations in this emigration. However, this loss may be cancelled out to a greater or less degree by immigration from other areas, including the lower east coast. No extensive taggings have been carried out in the latter area; however the two tags from Clayoquot Sound which were recovered in 1954-55 were recovered in Barkley Sound (one may have been from Quatsino Sound) indicating some immigration into Barkley Sound. A more extensive tagging program would seem to be in order to acquire this important information. No tags were inserted in 1954 as other aspects of the work were given a higher priority.

(4) Relationships of juvenile herring schools to their environment.

In 1954, the program of observations of environmental factors which might affect juvenile distribution and abundance was intensified and expanded. Direct observations of meteorological conditions were made and a survey of zooplankton abundance was added. Temperatures were again recorded by a shallow-water bathythermograph and surface salinities were taken. All these data were recorded once a week on a two-day synoptic survey of 34 stations throughout the Sound. Surface current measurements were taken over a 25-hour period by means of a drift pole at eight key stations in the Sound.

(a) Winds and current. The juvenile herring stocks in Barkley Sound are concentrated on the south-east side of the Sound, whereas the spawning occurs mainly along the north-west side. Since the prevailing winds in this region are westerly during the summer, it seemed possible that the migration of the young herring could be related to this factor, perhaps resulting from the transport of water or surface plankton on which juveniles feed, to the south-east side of the Sound. The fact that the fish found on the north-west side were practically all in inlets, sheltered channels and around islands, where the general eastward flow pattern would be disrupted, tends to support this view. If this is the case, then the juveniles should appear more concentrated and available in these regions after periods of prevailing westerlies and less so after periods of prevailing south-easterlies, the only other major wind observed. Wind forces at Pachena Lighthouse at the south-east tip of the Sound were therefore resolved into their cross-sound components, i.e., north-west and south-east and plotted on a daily time scale with observed juvenile abundance in the ten localities scouted most intensively. Four periods of prevailing north-westerlies were found, along with two periods of south-easterlies. The ratio of the areas enclosed by the curve for north-west winds to that of the curve for south-east winds was 1.3:1 (65-50) indicating a slightly greater influence was exerted on the surface water from north-west. Although there was some indication of an increase in observed abundance following periods of prevailing winds from the north-west, there was no indication of the opposite situation under conditions of prevailing south-easterlies. Similar but less detailed plots of juvenile abundance and wind direction in 1953 and 1952 also failed to show any correlation between the two. Apparent abundance does not, therefore, appear to bear an important relationship to wind conditions.

In order to obtain a general picture of the surface currents in Barkley Sound and the effect of wind on them, 25-hour stations of half-hour drift pole observations were made at eight stations in Barkley Sound. Three of the stations were repeated under different wind conditions. The drift pole was a 14-foot 2 x 4 in. timber weighted at one end with a light mounted on the other end; it floated with about 8 inches of the pole above the water surface. Direction of drift was obtained by sighting a compass on the after deck of an anchored vessel onto the pole. Distance drifted was measured by a small line (1/16-inch diameter) with corks tied on at intervals so that two corks in one minute represented a current of one knot (i.e., about every 50.7 ft.).

From frequency distributions of direction of flow using 20-degree intervals it appeared that the currents at four of the eight stations showed a more or less simple reversal along an axis of about 100° - 280° (i.e. across the Sound). The currents at these stations were therefore resolved into their components along this axis. The other four stations showed a sizeable in-and-out component along a 40° - 220° axis and both this component and the cross-sound component were plotted for these stations. The areas under the curve in each direction were determined by a planimeter. At five of the eight stations the flow was predominantly cross-sound but at all except the one in Loudoun Channel off Peacock Channel the flow was greater towards the north-west than towards the south-east side (easterly flow did predominate slightly at one of the Sechart Channel stations). Westerly winds predominated during five stations and south-easterly during two, whereas at four the wind did not blow consistently from either direction. Thus, wind could not have been the major factor in the movement of the surface water. An increase in the extent of south-east winds in Loudoun Channel did not appear to have appreciably affected the direction of flow, and an increase in the extent of westerly winds in Sechart Channel and Coaster Channel occurred at a period of increased, rather than decreased westerly flow. Thus, except for small variations in the current curves, wind does not seem to have had much effect on surface circulation. The winds involved were generally small (less than force 3) and would not blow strongly enough for a long enough time to have any major effect. It would therefore appear that winds were not important in the movement of the surface water.

Since the surface water appears to flow principally north-west, the possibility of a counter-flow at some other depth is immediately suggested. In April, 1950 a counter-flow was found at 3 fathoms off Harris Point and a north-easterly flow at 3, 5 and 10 fathoms in Sechart Channel. Since the south-east side of the Sound is rich in nutrients, a certain amount of upwelling could take place there supporting the view of a counter-current below the surface. While these currents were only about half the strength of the surface current, the plankton probably spend a much shorter time at the surface than at greater depths and could consequently be transported towards the eastern side of the Sound.

It is interesting to note that the single daily count cycle occurring with a twice daily tidal change which was described in this region by Doe in 1952 was again observed at 5 of the stations. Doe attributed this to a differential rate in tidal rise and fall on either side of the Sound or to a difference in the width of the tidal front. He considers runoff to be the dominant factor in the surface circulation in April. Since runoff in this region reaches its maximum in June, the effect of this factor would probably be at least equally great from mid-July to mid-September as in April and should thus be just as dominant in the summer as in April. This is borne out by the fact that surface flow throughout the Sound seems to be generally away from the principal fresh water source, the Somass River in Alberni Inlet. Indeed surface salinity west of the Broken Group indicates this water probably came through the Broken Group from Imperial Eagle Channel, rather than from the Toquart Bay - Loudoun Channel region.

(b) Salinity and temperature. Surface salinity samples were taken at each station on the synoptic surveys. Samples were taken from a bucket of sea water drawn up from about two feet below the surface. In localities where juveniles were consistently abundant average salinities varied from 17.23 (Uchucklesit Inlet) to 29.39 p.p.m. (Banfield Inlet) thus indicating a wide tolerance range. However, the salinities in most of these regions run from 23 to 27 p.p.m. Japanese herring fry survive best in 4/5 sea salinity, followed in order by 3/5, 2/5, 1/5, 1/10, and 5/5; in the latter they lasted only a few hours. Surface salinities in the ocean off Barkley Sound are about 31 p.p.m. and thus if the same situation applies in Barkley Sound, the young herring would be expected to survive best in salinities of about 25 p.p.m. This suggestion fits very well with the observed abundance of juvenile herring in Barkley Sound and the average salinities where juveniles were captured during 1954.

Surface temperature, observations and B.T. casts were made at each station during synoptic surveys of the Sound and after each tide change at anchor stations. Surface temperatures were mapped as were those at depths 10, 20, 40 and 60 feet.

From the data it was apparent that juveniles were abundant in localities of high (Pipestem Inlet, 17.14°C.) and low (Banfield Inlet, 13.88°C.) surface temperatures. Similar ranges of tolerance were shown at 10 feet (Pipestem Inlet, 15.80°C. and Banfield Inlet, 12.3°C.), 20 feet (Ucluelet Inlet, 14.16°C. and Banfield Inlet, 11.70°C.), 40 feet (Ucluelet Inlet, 13.35°C. and Banfield Inlet, 11.00°C.) and 60 feet (Useless Inlet, 12.66°C. and San Mateo Bay, 10.86°C.). Generally, the rearing grounds exhibited relatively low temperatures at 20 feet (12-13°C.), 40 feet (11-12°C.) and 60 feet (10.5-11.5°C.). However good and poor rearing grounds showed no significant differences in temperature or salinity, or in the range of these factors when tested statistically.

(c) Phosphate and oxygen. Determinations of the phosphate and oxygen of the surface waters at ten stations throughout the Sound were made on September 8 and these were also mapped. Stations on the east side of the Sound and in the outer part of the Broken Group showed a high phosphate and low oxygen content. Conditions of low phosphate and high oxygen prevailed where the main proportion of fish hatch (i.e., the north-west side). This indicates little decomposition has taken place here and thus the production is probably low and, therefore, feeding conditions poor. Using phosphate production and oxygen depletion as an index, production near Ucluelet is medium, and on the south-east side of the Sound it is quite high. Thus the abundance of juveniles corresponds quite well with productivity ratings based on this index.

(d) Plankton. Previous analysis of wind data suggested that the tendency for the juvenile herring to be concentrated on the south-east side of the Sound could be related to a possible concentration of planktonic food organisms on this side by the cross-sound movement of surface waters effected by the predominantely north-west winds found in Barkley Sound at this time of year. A survey of the amount of plankton present during the summer in various localities throughout the Sound was therefore included in the 1954 field program in order to test this hypothesis.

Samples of zooplankton were taken at each of the 34 stations employed in the B.T. synoptic surveys. A Hardy small plankton sampler was towed for a distance of approximately two miles through the water resulting in the straining of about one cubic meter of water. A high-speed plankton sampler was employed in order to permit maximum sampling in a short period (2 days).

Volumetric analysis was carried out on board ship on the sample as a whole, using Froelander's plankton volume displacement indicator. Any coelenterates, ctenophores or other large organisms were removed before the analysis, so that the volumes recorded were those for the smaller organisms only. Since young herring in southern British Columbia waters tend to feed on a considerable variety of organisms these samples are assumed to be fair representation of the amount of food available to the juveniles.

The results show relatively higher concentrations of plankton in Loudoun and Thiepval Channels and, to a lesser extent, on the north-west side of the former channel, (Macoah Passage and Ucluelet Inlet). A relatively high local concentration was also found in Inner Vernon Bay. Relatively low concentrations were found in Trevor Channel and Alberni Inlet and their adjoining bays (Aguillar Point, Kelp Bay, Sarita Bay, Chimmin Point near San Mateo Bay, Rainy Bay, Inner Tzartus Island and Alberni Inlet). Banfield Inlet showed average abundance. Abundance was also low in Effingham Inlet, Outer Pipestem Inlet, Swaile Rock and Outer Vernon Bay. Aside from a few local variations zooplankton abundance was relatively high in the south-west corner of the Sound and relatively low along the south-east side and in the larger inlets. Generally speaking, this is the opposite trend to that indicated by juvenile abundance. The only localities in which large populations of both zooplankton and juveniles were found were Trevor Channel, Ucluelet Inlet and Inner Vernon Bay.

This apparently inverse relationship between zooplankton and juvenile abundance could be the effect of grazing. Riley and Bumpus have established such a relationship for phytoplankton and their zooplankton predators; and a similar situation may apply to the zooplankton - herring relationship.

Aside from the relatively large concentrations of juveniles in the Inner Loudoun Channel - Thiepval Channel region, which were, indeed, somewhat sporadic, the juveniles did not show a tendency to collect in regions of highest food concentrations. Since juveniles were relatively abundant in all inlets, the good showing in Ucluelet Inlet and Inner Vernon Bay could not be attributable to the relatively abundant food supply there. However, plankton concentrations within the inlets were generally slightly greater than just outside the inlets, and thus could contribute to the tendency for the juveniles to be found inside the inlets and bays.

The relatively high productivity of the Sound as a whole combined with the relatively low rate of loss of water to the open ocean should tend to make conditions in Barkley Sound on the whole very good for the rearing of juvenile herring.

(e) Production in Barkley Sound. A rather crude and gross estimate was made of the total production in Barkley Sound during the spring and summer of 1954, on the basis of the following equation.

Zooplankton production = increase in standing crop + loss due to grazing + loss to bottom and bottom feeders

The first of these terms was estimated from the average density of plankton and the volume of the euphotic zone, the second from the food required for the estimated increase in biomass on the part of the young herring, salmon and other grazers, while the third was taken to be approximately equal to the second. On this basis,

$$\text{Zooplankton production} = 160 + 3290 + 3290 = 6{,}720 \text{ million grams}$$

or 19 grams per square meter of water surface. Phytoplankton production on this basis would be 108 grams per square meter. This estimate compares favourably with one of 140 grams per square meter determined by Waldichuk from oxygen depletion and phosphate liberation, especially since the former figure is minimal.

It is worthy of note that the 1954 juvenile herring population required about 3,290 million grams of dried plankton as food, or slightly less than half the estimated total zooplankton production. If these calculations are significant, an exceptionally large year-class, such as that of 1947, may depend mainly on a higher-than-average food supply during their first summer for their proportionately large survival to the stage of recruitment. It does not seem that Barkley Sound could support a much larger population (e.g., more than twice the size) of juvenile herring during 1954 than was found there. However, the 1954 year-class appears to be relatively good and may, therefore, be exceptional in the amount of food consumed. No comparable data are available for the 1947 year-class at this stage to permit comparisons.

(B) Juvenile herring in the Strait of Georgia

A preliminary survey of the juvenile herring stocks in the Strait of Georgia was conducted in 1955, employing techniques developed and tested during the similar study in Barkley Sound. Emphasis was placed on finding the juvenile stocks as a basis for future investigations. Conclusions concerning the habitats and habits of the juveniles in Barkley Sound were found to be generally applicable in the Strait of Georgia. The lower-east-coast sub-district was scouted once relatively thoroughly. Approximately 192 million fish were estimated to have been found. Studies in Barkley Sound indicated that about one-sixtieth of the population is observed in this manner and on this basis there were 12 billion juveniles in the lower east coast in 1955. However it would be unwise to consider this figure as quantitative since few localities were visited more than once and the Barkley Sound correction factor may not be applicable to these data.

The survey was extended to the middle-east-coast sub-district and into American waters around the San Juan Islands as time permitted. About 39 million juveniles were found in a survey that covered approximately half of the prospective rearing grounds in the middle-east-coast sub-district. About 68 million juveniles were found in the San Juan Islands.

These data in themselves give no indication of the relative abundance of the 1955 year-class, but will provide a basis for comparison with subsequent surveys. Temperatures and salinities were recorded at a series of depths in many of the localities scouted and will be compared with those of another year.

Tagging experiments in Barkley Sound indicated emigration of about 50% of the juvenile stocks to other major populations. Since the relationship between the juvenile and adult stocks in a sub-district is of vital importance in predicting year-class strength at maturity from juvenile abundance, a rather intensive tagging program was initiated in conjunction with the surveys. In 1955, 12,762 juveniles were tagged on the lower east coast and 7,291 on the middle east coast.

## EXPERIMENTAL DEVELOPMENT OF MID-WATER TRAWLS - W.E. Barraclough

With the material assistance of experienced fishermen a successful mid-water trawl for herring has been designed and tested as a project under the Industrial Development Vote of the Department of Fisheries. This trawl is successful in catching the densely schooled and relatively inactive herring found in British Columbia waters in late autumn and winter; it is operated from a well-powered vessel. Attempts are now underway (1) to develop trawls which will catch the more active and dispersed summer herring and other faster-swimming fish (including salmon), and (2) to develop a trawl suitable for smaller vessels such as are included, for example, in the halibut fleet. The potential value of such trawls lies in their use as tools for exploration as well as for actual commercial fishing. Preliminary trials of a modified version of the successful trawl were unsuccessful in catching young salmon and the trawl was lost; further attempts will be made in 1956. An important development in 1955-56 was the use of the mid-water trawl close to bottom by using conventional otter boards, a change which can be made and reversed quite quickly. Fishing just above the bottom, good catches were made and the trawl was used profitably by commercial fishermen.

### Demonstration of a successful mid-water trawl for herring

The first phase of the mid-water trawl project was completed in February, 1955, when the success of a trawl for catching schooled winter herring in mid-depths was demonstrated, using the chartered dragger Sea Pride II (length 60 ft.; 175 h.p.). The net was constructed almost entirely of nylon twine and rope instead of cotton, in order to reduce the resistance of the net in the water without losing too much strength. The otter boards used to spread the mouth were of new design and suspended in a new manner. The gear was most effective at night and numerous catches of 10 to 35 tons were made in 15- to 20-minute tows at depths from 15 to 35 fathoms. Catches in daylight were lighter, averaging one to two tons, but two daylight tows at between 40 and 50 fathoms took 15 and 35 tons. A description of the net and its operation has been distributed in Circular No. 36, "Progress Report on the development of the British Columbia mid-water trawl for herring". Widepsread interest exhausted supplies of the Circular very quickly but it is being reprinted as a Bulletin of the Fisheries Research Board.

## Adaptation of the mid-water trawl net for bottom herring trawling

A number of attempts to catch herring in British Columbia waters with bottom trawls have been made by the smaller trawlers within the past ten years. Some vessels met with moderate success but generally their attempts were not considered very successful. The nets were of conventional bottom trawl design, the cod ends were lined with heavy tarred herring netting and the gear was towed directly along the bottom. Little vertical opening to the mouth of the net was achieved even with additional floats attached to the headline. In European herring trawling operations kites are attached to the headline in order to give additional vertical opening to the mouth of the net. This method was not adopted by B.C. trawlers becase this meant additional cables from the kites to the headline and otter boards and the smaller vessels were not equipped to handle such gear.

During the course of experimental fishing in October and November 1955, a close contact was maintained with fishermen who were interested in mid-water and bottom-trawl herring fishing. As our efforts met with success a number of these fishermen quickly adopted the mid-water trawl net for bottom herring trawling. These vessels included the Santa Maria, Loretta B, Karmsund, Nadena, Lady Billie, Ruth Carlyle and Sea Pride II, which landed about 2000 tons of herring during the months of December, 1955, and January, 1956. This herring fishery for the trawlers provided a profitable alternative to the relatively poor fishery for graycod during the winter months.

A number of features in the design of the mid-water trawl net contributed to its success in bottom trawling for herring and some modifications for this purpose were developed during our fishing experiments.

1. Because the net was constructed entirely of nylon netting a great decrease in the weight of the net itself was achieved when compared to the previous cotton trawl nets. This finer and lighter twine results in a marked decrease in resistance of the net in the water.

2. The conical 4-sided shape of the net with 4 wings gave a larger vertical opening (35-45 feet) to the mouth of the net, than that which can be achieved by the conventional two wing bottom trawl and the addition of kites.

3. In addition to the trawl plane floats attached to the headline, hydroplane elevators were developed to provide additional lift. These were shackled freely on the upper sweep lines at the end of the two upper wing corners of the net. This eliminated the need for kites and additional cables from the kites to the otter boards. The hydroplane elevators assisted in floating the trawl clear off the bottom.

4. Changes in the attachment of the upper sweep lines to the upper wing corners provided an increase in the mouth opening of the net and assisted and

increased the efficiency of the hydroplane elevators and trawl plane floats in clearing the net off the bottom.

5. The net was fitted with conventional otter boards operating on the sea bottom with the net itself fishing about two fathoms above the bottom.

6. The gear can be quickly changed from mid-water to bottom use or vice versa.

A separate report, with detailed drawings, is being prepared on the development of this type of gear.

After the completion of the charter of the Sea Pride II its captain, Norman Sigmund, continued to fish with a net of this design. He used it on the bottom at depths from 35 to 55 f. in Satellite Channel and 45 to 55 f. in Swanson Channel--both off the lower east coast of Vancouver Island. The average catch per half-hour tow was 5 to 6 tons and about 5 to 6 tows were made each day. His catches were much below the twenty to seventy-five tons of herring caught in tows of twenty to thirty minutes' duration in the same areas during the experimental fishing of the charter period but were considered profitable. His total catch in December, 1955 (one week) was 85 tons and in January, 1956, was 537 tons. With a price of $26.00 per ton this resulted in a return of $3.00 per ton for each member of the 5-man crew.

## Demonstration of the mid-water trawl to fishermen at Prince Rupert

From February 15 to March 17, 1956, the trawler Aleutian Queen was chartered to demonstrate the mid-water trawl to the fishermen of the Prince Rupert area. This was suggested by a number of requests from fishermen and plant operators who wanted to see the operation and development of the gear. Before the demonstrations a day was spent in the waters near Seattle, Washington, calibrating the depth or position of the net in relation to varying amounts of towing warp at different towing speeds. This was done with the aid of a Sea Scanar by the Minneapolis-Honeywell Regulator Co. who gave their time and assistance gratis.

Considerable interest in the gear was shown by about eighty people including vessel skippers, crew members of trawlers and halibut vessels and fishing plant officials - all of whom witnessed phases of the operation of the trawl. Those halibut fishermen whose vessels are inactive during the winter months were well represented and many expressed the opinion that they would participate in the herring trawling fishery next season. The fishermen welcomed the versatility of the net when it was demonstrated that it could be converted to fish just off the bottom when equipped with ordinary otter boards.

Herring in the Prince Rupert area were well scattered and in small schools. The schools were found in vertical columns not as layered herring schools which were reported near the Queen Charlotte Islands. Demonstration tows were, therefore, very short and catches small. A typical example of the tows would be a catch of 1 1/2 tons of large herring when the net was towed through a column of herring for 15 seconds.

The vessel was disabled at Namu for a week in February with a broken crankshaft and cold and stormy weather accompanied by almost continuous snow storms hampered the demonstrations. Because of these handicaps the demonstration of the gear was not completely successful and further experimental fishing in this area should be considered because of the interest shown by the fishermen in the Prince Rupert area and on the Queen Charlotte Islands.

After many conversations with the fishermen it is our opinion that bottom trawling for herring with the mid-water trawl net will be the initial step to mid-water trawling for most fishermen. As each fisherman gains confidence from his experience in the operation of the net and gear, it will also be used for mid-water trawling.

## GROUNDFISH - K.S. Ketchen

During 1955 the Groundfish Investigation entered a period of stock-taking or consolidation in an effort to digest the large volume of data which has accumulated during the past decade, and to give critical consideration to the most profitable course of future investigation. This has involved relinquishing the use of the Investigator No. 1 and suspension of tagging, field sampling and survey projects. However, a watching brief is being maintained through the continued collection of trip interviews and samples from the commercial landings. Collection and processing of these data require the full time of three of the staff of six. In 1955 one of the three remaining staff members was involved throughout the year in the mid-water trawl (IDV) project, and this reduction in staff delayed the stock-taking.

(a) Activities in 1955. A great deal of effort is now being put into the project involving the analysis of catch statistics. Because the trip interview system of collecting catch records has not always provided complete coverage of landings we are working in close cooperation with the Department to obtain the complete picture of total landings. We in turn are supplying the Department with detailed records, without which the present sales-slip system of recording would be inadequate for population studies. To complete our understanding of the international aspects of the fishery we are exchanging data with biologists of the Washington State Fisheries Department.

In most cases revision of the catch statistics has now been completed as far back as possible, with the result that we now have on hand a reasonably complete record of catch by species and area for the past eleven years, and by country for the past eight. Considerable attention is being paid to the revision and interpretation of catch/effort statistics. This very difficult project should be completed by the summer of 1956, hence enabling a detailed assessment of the effects of fishing during the past decade.

The project on age and growth analysis is of vital importance, but unfortunately is slow to yield useful results in view of the limited personnel to handle the material. Nevertheless, the basic work for description of the age structure, growth and mortality of lemon sole, rock sole, butter sole and lingcod has been completed and is ready for use in interpretation of changes in catch/effort and in studies of equilibrium yield. There is a large accumulation of unanalysed material on the brill and gray cod, but it is expected that the former will be brought up to date within the next year.

Results of the various tagging projects have been summarized preliminary to analysis of the validity of the various tagging methods, mortality rates and growth rates. Unfortunately, field work was suspended before the groundwork could be laid for similar studies on the gray cod, a species which is now the dominant foodfish in the otter-trawl fishery.

(b) Immediate objectives. Aside from the long-term objective of assessing the dynamics of groundfish populations and accumulating a general background for management of the resource, there are a number of important problems which, for various reasons, require early solution. These are as follows:

(1) To assess in a quantitative way the relative importance of the effects of fishing and of environmental factors in the current decline in abundance of brill along the British Columbia coast; and to determine the optimum rate of removal from the "normal" stock.

(2) To determine the efficacy of recent restrictions on the otter-trawl fishery in the Strait of Georgia.

(3) To determine whether or not the exploitation of juvenile flatfish for mink food in the Strait of Georgia constitutes inefficient utilization.

(4) To determine the efficacy of regulations pertaining to the line fishery for lingcod in the Strait of Georgia.

(5) To assess the condition of the stocks of flatfish in Hecate Strait and determine the equilibrium yield for each species.

(6) To establish the basis for predicting changes in the availability of gray cod.

## Catch and availability

The port observers at Vancouver and Prince Rupert obtained 1382 trip interviews in 1955. Of this total 758 were from otter-trawlers, 437 from salmon trollers, 120 from crab and shrimp boats and 67 from long-liners. The coverage of trawler landings represents a very high proportion of the total landings of the province. Leaks in the system occur at Victoria, Sydney and Steveston but these are of minor importance. At any rate the Department's sales slip system provides a general indication of activities at these ports.

In 1955 the total British Columbia catch of groundfish (exclusive of halibut) was 22,450,000 pounds, or approximately 3,000,000 pounds more than that of the preceding year. However, this increase was entirely the result of greater landings of scrapfish for animal food, not of fish for human consumption. The otter-trawl catch in 1955 amounted to 18,660,000 or 83% of the total production. The remaining 3,790,000 pounds was taken by hand-line and long-line vessels and was mainly comprised of lingcod and blackcod.

In contrast to the Canadian trawl catch of 18,660,000 pounds, the United States catch from waters immediately off the British Columbia coast was 39,750,000 pounds. U.S. landings of all species but rock sole and "minkfeed" were higher than the Canadian landings. About one-quarter of the U.S. landings involves various species of rockfish, a group which attracts little attention in the Canadian fishery.

1. Tabulation of 1955 trawl landings in British Columbia (preliminary) — C.R. Forrester

The summary of trawl landings for British Columbia in 1955 is presented according to three major divisions: (1) Hecate Strait and Queen Charlotte Sound, (2) west coast of Vancouver Island, and (3) the Strait of Georgia. Weights given are in thousands of pounds.

Groundfish catches in Hecate Strait and Queen Charlotte Sound, 1955

| Month | Lemon sole | Rock sole | Brill | Butter sole | Dover sole | Rex sole | Fldr. | Gray cod | Ling cod | Rock fish | Mink feed |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan. | 60 | .. | .. | 66 | .. | 1 | 1 | 92 | 7 | 1 | 90 |
| Feb. | 29 | 1 | 2 | 319 | .. | .. | 7 | 176 | .. | 3 | 7 |
| Mar. | 178 | 2 | .. | 19 | .. | .. | 1 | 359 | 7 | 1 | 191 |
| Apr. | 322 | 63 | 4 | 1 | .. | 1 | 3 | 134 | 14 | 2 | 45 |
| May | 137 | 351 | 18 | .. | 3 | .. | 2 | 239 | 31 | 77 | 114 |
| June | 37 | 572 | 11 | .. | 45 | 3 | .. | 147 | 15 | 14 | 265 |
| July | 20 | 751 | 4 | .. | 26 | 8 | .. | 33 | 29 | 2 | 561 |
| Aug. | 128 | 717 | 6 | .. | 83 | 27 | .. | 21 | 1 | .. | 384 |
| Sept. | 34 | 243 | 2 | .. | 31 | 12 | .. | 70 | 2 | 1 | 546 |
| Oct. | 8 | 69 | 1 | .. | 4 | .. | .. | 6 | 1 | 5 | 270 |
| Nov. | 26 | 151 | 1 | .. | .. | .. | .. | 74 | 3 | 1 | 152 |
| Dec. | 28 | 13 | .. | 1 | .. | .. | .. | 108 | 3 | 4 | 252 |
| Total | 1007 | 2933 | 49 | 406 | 192 | 52 | 14 | 1459 | 113 | 111 | 2877 |

Total production of food fish from this division was approximately 13% higher than in 1954. There was, however, a noticeable decline in landings of brill and rockfish. The outlook for the brill is still gloomy with no evidence of recruitment to the fishery as yet. The mid Hecate Strait fishery for "ocean perch" was almost non-existent in 1955. Some reason for the lack of ocean perch landings may be evident in the increased demand for scrapfish species as mink food. Production for this market was almost three times that of 1954.

Groundfish catches off west coast of Vancouver Island, 1955

| Month | Lemon sole | Rock sole | Brill | Dover sole | Fldr. | Gray cod | Ling cod | Black cod | Rock fish | Skate | Dogfish liver | Mink feed |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan. | .. | 7 | .. | .. | 6 | 5 | 1 | .. | 6 | .. | 1 | 20 |
| Feb. | .. | 2 | .. | .. | 3 | 1 | .. | .. | 1 | .. | .. | 3 |
| Mar. | 5 | 33 | 2 | .. | 40 | 9 | 5 | .. | 7 | 2 | 1 | 1 |
| Apr. | 7 | 38 | 12 | .. | 43 | 107 | 16 | .. | 7 | 2 | 12 | 1 |
| May | 12 | 47 | 156 | 6 | 2 | 478 | 137 | .. | 21 | 4 | 9 | 76 |
| June | 7 | 74 | 78 | 15 | 13 | 263 | 230 | .. | 25 | 4 | 3 | 160 |
| July | 4 | 9 | 117 | 64 | .. | 84 | 321 | 1 | 7 | 3 | 4 | 141 |
| Aug. | 7 | 18 | 68 | 83 | 2 | 73 | 190 | 5 | 5 | 1 | 11 | 164 |
| Sept. | 7 | 1 | 52 | 5 | 1 | 115 | 113 | 9 | 2 | .. | 4 | 412 |
| Oct. | 4 | 7 | 52 | 34 | 3 | 29 | 60 | 3 | 2 | 1 | 1 | 145 |
| Nov. | 1 | 14 | 1 | .. | 31 | 4 | 1 | .. | 1 | .. | .. | 12 |
| Dec. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| Total | 54 | 250 | 538 | 207 | 144 | 1168 | 1074 | 18 | 84 | 17 | 46 | 1135 |

Here again the influence of the minkfeed market may have affected the interest in foodfish species. Foodfish production generally was down 13%, while the landing of scrap species was up 60%. The catch of brill off the west coast of Vancouver Island in 1955 was down to roughly half a million pounds, the lowest landing since 1945.

Groundfish catches in Strait of Georgia, 1955

| Month | Lemon sole | Rock sole | Brill | Fldr. | Gray cod | Ling cod | Rock fish | Skate | Dogfish liver | Crab | Mink feed |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan. | 35 | 11 | .. | 11 | 280 | .. | 6 | 8 | 67 | 4 | 388 |
| Feb. | 57 | 22 | .. | 50 | 344 | .. | 17 | 10 | 56 | 4 | 344 |
| Mar. | 45 | 14 | .. | 31 | 285 | 13 | 9 | 9 | 19 | 3 | 129 |
| Apr. | 34 | 8 | .. | 4 | 125 | 6 | 3 | 7 | 4 | 3 | 78 |
| May | 27 | 8 | .. | 2 | 32 | 6 | 1 | 5 | 13 | 3 | 170 |
| June | 22 | 2 | .. | 2 | 31 | 5 | 2 | 4 | 7 | 2 | 44 |
| July | 13 | 1 | .. | 3 | 5 | 2 | 1 | 2 | .. | 2 | 41 |
| Aug. | 15 | .. | .. | 4 | 37 | 2 | .. | 2 | 1 | 1 | 29 |
| Sep. | 5 | .. | .. | 1 | 4 | .. | .. | 1 | 1 | 1 | 14 |
| Oct. | 54 | 2 | .. | 3 | 90 | 6 | 3 | 4 | 8 | 1 | 117 |
| Nov. | 41 | 3 | .. | 2 | 137 | 12 | 6 | 5 | 18 | 1 | 239 |
| Dec. | 104 | 24 | .. | 13 | 84 | .. | 18 | 10 | 13 | 5 | 190 |
| Total | 452 | 95 | .. | 126 | 1454 | 52 | 66 | 67 | 207 | 30 | 1783 |

Landings of flatfish species in the Strait of Georgia continue to decline. Production of all foodfish for this area was down 25% from 1954 and again the increased minkfeed demands may have been chiefly responsible. However, the relatively poor fishery for gray cod was also a factor. Nearly two million pounds of scrap fish species were landed from this area in 1955, or roughly twice the landing for the same period in 1954.

2. Trends in availability — K.S. Ketchen and C.R. Forrester

Long series of data on availability (catch per unit of effort) are now on hand for those species of groundfish which are subjected individually to fisheries at fairly specific periods of the year and in specific areas. These catch/effort determinations are relatively simple in comparison with those required for interpretation of multiple-species fisheries, but nevertheless still require considerable revision and interpretation.

(a) Lemon sole in Hecate Strait. The average catch per unit of effort was 1030 pounds in the spring fishery of 1955. This was substantially greater than the 1945-55 average of 830 pounds and was exceeded in the past only in the fishery of 1945 when the catch/effort stood at 1220 pounds. There is no evidence of a sustained trend in catch/effort over the eleven-year period, even though the catch went through a period of increase between 1945 and 1950 and a period of decrease between 1950 and 1955. It is doubtful whether the data on catch/effort are a valid index of actual changes in abundance.

(b) Rock sole in Hecate Strait. Average catch/effort of rock sole was 1770 pounds in 1955 as opposed to the all-time high of 2550 pounds reached in the preceding year. This is still considerably greater than the 1945-55 average of 1420 pounds. Throughout this eleven-year period there has been a marked upward trend in catch/effort in spite of an upward trend in the annual removal by the fishery. The entrance of strong year-classes into the fishery in recent years is partly responsible for this increase in fishing success. It is reasonable to suppose that increased efficiency of fishing and improved knowledge of the behaviour of the rock sole has also been a contributing factor.

(c) Brill off west coast of Vancouver Island. The catch of brill per unit of effort continues to decline off the west coast of Vancouver Island, in keeping with earlier predictions. The average catch per trip in 1955 fell to 3750 pounds after a general decline from the peak year of 1948 (9700 pounds per trip). A long-term failure in recruitment is known to be an important factor in this decline.

(d) Gray cod in the Strait of Georgia. There are two specific gray cod fisheries of long standing in the Strait of Georgia, one in Swanson Channel and the other at Nanoose Bay. As pointed out in Progress Report No. 102 the trend in catch/effort on both fishing grounds was slightly upward during the late 1940's and early 1950's. Latest determinations show that while the catch/effort dropped below the mean at Nanoose Bay in the winter of 1954-55, it rose well above the mean in the winter of 1955-56. In Swanson Channel the catch/effort lay slightly above the mean value in 1954-55, and below in 1955-56. There is still no evidence of any sustained downward trend in catch/effort in either area, even though catch and effort in general have been on the increase over the past decade.

(e) Blackcod (all areas). A review of the catch/effort trends in the blackcod fishery was presented in Bulletin 3 of the Pacific Marine Fisheries Commission and covered the years up to 1953. The following comments deal with more recent years. Southeastern Alaska continues to be the most productive region of the Pacific coast and in 1954 and 1955 the catch/effort was 111 pounds and 116 pounds, respectively. This is in line with a general upward trend which began in 1951. Catch per skate off the west coast of Vancouver Island in 1954 and 1955 was 62 and 57 pounds, respectively. This is slightly below the average for the preceding six years. Off the west coast of the Queen Charlotte Islands the corresponding catches per skate were 92 and 67 pounds. In this area the catch/skate is given to considerable fluctuation from year to year and is probably not indicative of changes in abundance. In Queen Charlotte Sound the catch per skate was considerably below average (46 and 30 pounds). The fishery was, however, particularly light in this region in both years, and thus may not have provided adequate information for computing an index of abundance.

3. Total trawl landings in British Columbia in recent years. K.S. Ketchen

Revision of the total catch figures of Canadian trawlers operating along the British Columbia coast has been underway for two years. In that time we have managed to compute "best possible" estimates for the early years of the fishery (1945-47) on the basis of log-book records weighted to Department totals, and have revised the trip report totals for recent years through close cooperation with the Department. The latter work has consumed most of the time of one seasonal worker. Yearly totals by species are given in the following table for the period 1945-54.

| Year | Thousands of pounds | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lemon sole | Rock sole | Brill | Butter sole | Dover sole | Rex sole | Fldr. | Gray cod | Ling cod | Rock fish | Dogfish liver | Mink feed |
| 1945 | 2196 | 414 | 810 | 1451 | 514 | 91 | 246 | 1604 | 1390 | 1312 | 856 | 114 |
| 1946 | 2210 | 1085 | 2398 | 1540 | 1008 | 159 | 630 | 2861 | 1453 | 569 | 519 | 27 |
| 1947 | 950 | 2766 | 1762 | 252 | 417 | 64 | 187 | 930 | 533 | 87 | 399 | 41 |
| 1948 | 2045 | 2135 | 7721 | 651 | 157 | 119 | 149 | 1033 | 1027 | 85 | 667 | 35 |
| 1949 | 1689 | 1678 | 3215 | 29 | 171 | 160 | 183 | 1889 | 1901 | 134 | 587 | 59 |
| 1950 | 5271 | 2177 | 2039 | 8 | 694 | 235 | 326 | 3041 | 1348 | 236 | 126 | 37 |
| 1951 | 2162 | 3548 | 1585 | 1824 | 974 | 234 | 461 | 5678 | 1876 | 449 | 204 | 414 |
| 1952 | 2537 | 5955 | 1828 | 3716 | 941 | 180 | 495 | 4913 | 1113 | 589 | 229 | 1392 |
| 1953 | 2241 | 1851 | 1040 | 160 | 416 | 81 | 138 | 3196 | 585 | 456 | 245 | 2298 |
| 1954 | 1470 | 2588 | 941 | 216 | 402 | 23 | 277 | 5700 | 984 | 866 | 326 | 2843 |
| 10-year mean | 2277 | 2420 | 2334 | 985 | 569 | 135 | 309 | 3085 | 1221 | 478 | 416 | 726 |

In 1954, landings of all species were considerably below the mean production of the past decade, except in those of rock sole, gray cod and "mink feed". Except in the case of the brill, these lower-than-average productions can be attributed primarily to market conditions. The brill catch has been declining irregularly since 1948 and, as mentioned in other sections of these reports, is the result of decreasing abundance. Increased demand from the "fish stick" trade has resulted in a general upswing in the landings of gray cod, while the rapid increase in landings of whole fish for mink feed is indicative of the rapidly developing fur farm industry in British Columbia.

4. Comparison of the Canadian and United States trawler catches from banks adjacent to British Columbia, 1953-55. K.S. Ketchen

Through close cooperation with biologists of the Washington State Fisheries Department it has been possible to obtain total catch figures pertaining to the United States trawl fishery along the British Columbia coast. Before 1953 such records were somewhat lacking in detail, but recent introduction of a trip interview system in Washington has eliminated this problem. Accordingly, complete figures are now being compiled for individual fishing banks. For the purpose of the present report, however, the comparison of the U. S. and Canadian catches is given by two large areas--the west coast of Vancouver Island and the Hecate Strait - Queen Charlotte Sound area.

Because of poor market conditions in 1953, catches of the more important species were down from those of the preceding year. However, there appears to have been some improvement in markets in 1954 and 1955.

Over the period 1948-55, the total catch of brill from Hecate Strait has undergone a substantial decline, from about 7,000,000 pounds in 1948 to little more than 1,000,000 pounds in 1955. Off the west coast of Vancouver Island the trend is only slight but has been marked by increasing emphasis on the winter fishery off Estevan Point.

Another species which has shown a decline in this eight-year period is the lingcod. The decline has been noticeable both in Hecate Strait and off the west coast of Vancouver Island. However, there is evidence that the trend has been arrested and even reversed in the last two years. This is particularly noticeable off the west coast of Vancouver Island, where fishermen now report large numbers of young fish appearing on those grounds.

Noticeable upward trends in the catches of gray cod are occurring in both areas, and also of rock sole in Hecate Strait. In both 1954 and 1955 the total catch of gray cod was around 13,000,000 pounds and in both years this species dominated the trawl fishery. Heavy landings of rockfish, particularly of the so-called Pacific ocean "perch" (Sebastodes alutus) are being recorded by United States vessels, but as in previous years, the Canadian fishery for rockfish has been of minor importance, presumably because of poor market conditions.

Landings of lemon sole have followed no particular trend in the past eight years, in so far as Hecate Strait is concerned, but there is some suggestion of a decline off the lower west coast of Vancouver Island. Landings of dover sole and flounder remain at a very low level, but a slight increase has been occurring off the west coast of Vancouver Island.

Trawl catches from international waters adjacent to British Columbia, 1953-55 (millions of pounds)

| Species | Brill | Lemon sole | Rock sole | Fldr. | Dover sole | Ling cod | Gray cod | Black cod | Rock fish |
|---|---|---|---|---|---|---|---|---|---|
| **1953** | | | | | | | | | |
| West coast | | | | | | | | | |
| Canadian | 0.873 | 0.054 | 0.078 | 0.024 | 0.234 | 0.671 | 1.055 | 0.013 | 0.054 |
| American | 0.985 | 0.754 | 0.021 | 0.049 | 0.476 | 0.326 | 2.488 | 0.151 | 2.411 |
| Total | 1.858 | 0.808 | 0.099 | 0.073 | 0.710 | 0.997 | 3.543 | 0.164 | 2.465 |
| Hecate Strait* | | | | | | | | | |
| Canadian | 0.173 | 1.756 | 1.713 | 0.012 | 0.226 | 0.087 | 0.582 | 0.004 | 0.435 |
| American | 1.346 | 0.668 | 0.311 | 0.337 | 0.690 | 0.514 | 3.655 | 0.068 | 3.814 |
| Total | 1.519 | 2.424 | 2.024 | 0.349 | 0.916 | 0.601 | 4.237 | 0.072 | 4.249 |
| Grand Total | 3.377 | 3.232 | 2.123 | 0.422 | 1.626 | 1.598 | 7.780 | 0.236 | 6.714 |
| **1954** | | | | | | | | | |
| West coast | | | | | | | | | |
| Canadian | 0.838 | 0.044 | 0.248 | 0.062 | 0.076 | 0.734 | 1.971 | 0.041 | 0.133 |
| American | 2.360 | 0.230 | 0.001 | 0.004 | 0.656 | 1.010 | 2.565 | 0.180 | 3.825 |
| Total | 3.198 | 0.274 | 0.249 | 0.066 | 0.732 | 1.744 | 4.536 | 0.221 | 3.958 |
| Hecate Strait* | | | | | | | | | |
| Canadian | 0.091 | 0.838 | 2.229 | 0.004 | 0.227 | 0.143 | 1.685 | 0.004 | 0.271 |
| American | 1.070 | 0.886 | 0.424 | 0.029 | 0.272 | 0.532 | 7.250 | 0.070 | 6.850 |
| Total | 1.161 | 1.724 | 2.653 | 0.033 | 0.499 | 0.675 | 8.935 | 0.074 | 7.121 |
| Grand Total | 4.359 | 1.998 | 2.902 | 0.099 | 1.231 | 2.419 | 13.471 | 0.295 | 11.079 |
| **1955** | | | | | | | | | |
| West coast | | | | | | | | | |
| Canadian | 0.538 | 0.054 | 0.250 | 0.144 | 0.207 | 1.074 | 1.168 | 0.018 | 0.084 |
| American | 1.573 | 0.369 | .. | .. | 1.761 | 1.869 | 4.013 | 0.250 | 3.749 |
| Total | 2.111 | 0.423 | 0.250 | 0.144 | 1.968 | 2.943 | 5.181 | 0.268 | 3.833 |
| Hecate Strait* | | | | | | | | | |
| Canadian | 0.049 | 1.007 | 2.933 | 0.014 | 0.192 | 0.113 | 1.459 | .. | 0.111 |
| American | 1.189 | 1.131 | 1.032 | 0.080 | 0.164 | 0.958 | 6.190 | 0.021 | 3.825 |
| Total | 1.238 | 2.138 | 3.965 | 0.094 | 0.356 | 1.071 | 7.649 | 0.021 | 3.936 |
| Grand Total | 3.349 | 2.561 | 4.215 | 0.238 | 2.324 | 4.014 | 12.830 | 0.289 | 7.769 |

*Cape Scott to Dixon Entrance

## 5. The controlled trawl fishery in the Strait of Georgia.

A number of small areas in the Strait of Georgia were again opened to otter-trawlers for various periods during the winter of 1954-55. This practice began in a small way in 1948, but in the years since that time there has been a trend towards relaxation of the original restrictions on fishing. The original purpose of the closure was to curb what appeared to be excessive exploitation of lingcod and of certain stocks of spawning flatfish. Subsequent reopening of certain fishing areas and study of the trawl catches has shown that the trawl fishery, at least in its present form, takes relatively small quantities of lingcod and that there is no basis for the belief that it competes unfairly with the long-established hand-line fishery for lingcod. More difficult has been the problem of determining the best policy for the exploitation of flatfish and gray cod stocks. The regulations as they now stand are cumbersome and in some cases perhaps an obstacle to maximum utilization. However, some stocks are very small and appear still to be declining in size, in spite of the restriction on fishing. Until the cause of the decline can be assessed, it is probably unwise to consider further relaxation.

The results of the winter fishery of 1954-55 have appeared in Biological Station Circular No. 41. The following is a brief summary of that report:

The total catch of foodfish in the winter of 1954-55 was 893,000 pounds, or about 320,000 pounds less than that in the previous winter. This was a result mainly of the relatively poor fishery for gray cod, which appeared to be scarce on nearly all the fishing grounds. This was partially compensated for in increased landings of minkfeed and dogfish liver. A summary of the catch by species and areas is contained in the following table and fishing success in individual areas is summarized below.

The otter trawl catch from the experimental areas along the east coast of Vancouver Island, from October, 1954 to March, 1955 inclusive.

| | Catch in pounds | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Cape Lazo | Union Bay | Deep Bay | Yellow Rock | Qualicum Parks-ville | Nanoose Bay | Satel-lite | Total |
| Hours of fishing | 449 | 391 | 501 | 664 | 721 | 287 | 376 | 3,389 |
| Lemon sole | 34,663 | 102,377 | 24,480 | 16,375 | 23,465 | 690 | 14,718 | 216,768 |
| Rock sole | 7,170 | .. | 475 | 23,321 | 5,944 | 715 | 1,357 | 38,982 |
| Flounder | 690 | 44,675 | 34,435 | 39,649 | 50 | .. | 370 | 119,869 |
| Other flatfish | .. | 195 | 150 | .. | 4,655 | 25 | .. | 5,025 |
| Gray cod | 72,222 | 12,450 | 50,624 | 93,266 | 96,416 | 43,640 | 24,241 | 392,859 |
| Lingcod | 1,148 | 2,946 | 717 | 1,692 | 38,117 | 1,205 | 2,450 | 48,275 |
| Rockfish | 3,786 | 17,868 | 5,786 | 4,315 | 7,585 | 7,965 | 320 | 47,625 |
| Others | 3,088 | 6,876 | 4,680 | 3,088 | 4,703 | 509 | 821 | 23,765 |
| Dogfish liver | 11,413 | 3,110 | 4,255 | 18,658 | 22,580 | 3,620 | 65,803 | 129,439 |
| Carcasses | .. | .. | .. | .. | .. | .. | 242,000 | 242,000 |
| Minkfeed | 1,680 | 16,300 | 19,421 | 9,200 | 27,191 | 1,822 | 26,050 | 101,664 |
| Total foodfish | 122,767 | 187,387 | 121,347 | 181,706 | 180,935 | 54,749 | 44,277 | 893,168 |
| Total all species | 135,860 | 206,797 | 145,023 | 209,564 | 230,706 | 60,191 | 378,130 | 1,366,271 |

(a) Cape Lazo. This area is important in the production of lemon sole, gray cod and dogfish, but for the past two years the yield per unit of effort has been below average. Factors other than overfishing are believed responsible for this situation.

(b) Union Bay. The lemon sole is the main species exploited in this area, and the catch amounted to about 102,000 pounds during the open period (10 days, at one day per week). Despite the heavy restriction on fishing in this area, the catch per unit of effort is still declining. Further restriction may be necessary if it proves desirable to maintain the stock at its present level.

(c) Deep Bay and Yellow Rock. Catches of flatfish (lemon sole and rock sole) have declined sharply in this area in the last two winters. These areas have been opened only recently and hence some decline had to be expected as a result of the removal of the accumulated stock. It is still too early to say whether the stocks are being overfished.

(d) Qualicum to Parksville. Landings from this area increased sharply in the winter of 1954-55 because of increased fishing effort. They were composed mainly of gray cod, lingcod and dogfish. No noticeable trends in fishing success are evident as yet.

(e) Nanoose Bay. The fishery in this area depends almost entirely on gray cod, and in the winter of 1954-55, this species was in relatively low abundance. However the poor fishing success appears to be the result of natural factors rather than those connected with fishing.

(f) Satellite Channel. Landings of foodfish from this area were down considerably from those of the previous year. Reduced fishing effort accounted for part of the decline, but the fact that the grounds were over-run with dogfish throughout most of the open period, may have had some bearing on the success of fishing. Landings of dogfish liver were more than double those of the previous year and amounted to almost half of the total liver landing from the experimental areas.

## Tagging experiments

Projects involving the tagging of groundfish species were suspended early in April 1955, and as a consequence the releases were much fewer than in previous years. In the early months of 1955 over 2,000 gray cod were tagged on fishing grounds along the east coast of Vancouver Island. About 400 lingcod were tagged and released in the same area. In a joint operation with the Washington State Fisheries Department, 2,500 brill (petrale sole) were tagged and released on the deep-water spawning ground off Estevan Point and Cape Flattery.

Recaptures from earlier experiments continue to be received, and some progress has been made in summarizing results in Progress Reports.

### 1. Brill tagging

B.M. Chatwin

(a) Tagged brill recovered during 1955. A total of 102 Canadian tagged brill were recovered during 1955. Of this number, 52 were from fish tagged during the 1954 and 1955 cooperative tagging experiments on the Estevan-Deep and are discussed separately below. The remaining 50 recoveries were from tagging conducted in various trawling areas along the British Columbia coast since 1947. In summary: 37 of the 50 tagged brill recaptures were from north coast taggings (Hecate Strait, Goose Islands and Cape Scott), and 15 were from releases off the west coast of Vancouver Island. Twelve of the recaptures from tagging in northern waters showed a southerly migration from the tagging sites. Of this number, 2 were recaptured from the winter fishery off Estevan in the "deep", 1 was returned from SW of Cape Flattery on the "spit" in 100 fathoms, and 9 were recovered from various areas lying between Estevan and the areas of tag release in Queen Charlotte Sound and Hecate Strait. These recoveries provide further evidence of the southward spawning migration of north coast fish to deep offshore areas off the west coast of Vancouver Island. Only 2 of the 15 fish tagged off the west coast of Vancouver Island and recovered during 1955 indicated movements from the tagging sites. One tagged fish released off Sydney Inlet in 22 fathoms during September 1951 was recaptured off Estevan in 180 fathoms, and 1 released on the Big Bank in 1950 was recovered off Cape Scott.

In order to define the migrations of summer brill stocks occurring off the British Columbia coast, a complete analysis of all Canadian brill taggings is now underway.

(b) Estevan tagging. In 1954 and 1955, during the months of March and April, brill were tagged in the deep offshore waters 25 to 30 miles SSW of Estevan Point in cooperation with scientists from the Washington State Department of Fisheries. The purpose of these taggings was to determine where the brill move after spawning, thus revealing the relationship between this offshore spawning aggregation and other inshore stocks of brill which are exploited during the summer months.

During April 9 to 12, 1954, using the chartered American trawler Heather, 1,796 tagged brill were liberated, of which total 922 Canadian tags and 874 American tags were used. Subsequent recoveries during 1954 were few, and it was believed that a poor survival of tagged fish resulted from adverse conditions at the time of tagging. Accordingly, the experiment was repeated during the spawning season of 1955. In late March, 1955, using the U.S. Fish and Wildlife vessel John N. Cobb, 1,194 Canadian and 814 American tagged brill were liberated. In each year, male fish predominated in the tagged samples, thus the results may only apply to that segment of the stock. Average sizes of fish tagged (computed from total Canadian tagged fish released) for male and female fish respectively were; in 1954 41.4 cm. and 47.0 cm., and in 1955 41.2 cm. and 46.8 cm. The accompanying table shows the total number of tagged fish recovered from the 1955 tagging according to the various general areas of recovery.

Recoveries to March 31, 1956, of brill tagged and released in 1955 on the Estevan Deep

| Area of capture | Canadian | American | Total |
|---|---|---|---|
| Estevan (tagging area) | 17 | 4 | 21 |
| Off Sydney Inlet | 1 | 0 | 1 |
| La Perouse Bank | 2 | 0 | 2 |
| Off Nootka | 0 | 0 | 0 |
| Off Esperanza | 13 | 3 | 16 |
| Off Cape Cook | 5 | 1 | 6 |
| Off Cape Scott | 5 | 11 | 16 |
| Goose Island Grounds | 3 | 2 | 5 |
| Northern Hecate Strait | 0 | 1 | 1 |
| Area Unknown | 5 | 1 | 6 |
| Total | 51 | 23 | 74 |

Recaptures to March 13, 1956, show a general north-westerly dispersion to trawling grounds as far distant as Queen Charlotte Sound and northern Hecate Strait. Twenty-one or 28% of the total number recovered were recaptured on the Estevan-Deep; of this number 8 were taken soon after tagging during March and April 1955, and 13 during a period from November, 1955, to March 31, 1956, (it is suggested that the latter were captured on their return to the spawning area). Only 3 or 4% of total recaptures were made in trawling areas inshore and to the southeast of the Estevan tagging area (i.e., the southwest coast of Vancouver Island). Summer trawling in areas adjacent to the northwest coast of Vancouver Island (Nootka, Esperanza, and Cape Cook) accounted for 22 or 30% of the total number recaptured. Tagged brill recovered in areas off Cape Scott, on the Goose Island grounds, and in northern Hecate Strait totalled 22 or 30%. Six or 8% were unreported as to area of capture. These results show that the male portion of the Estevan spawning stock are vulnerable to exploitation on inshore banks adjacent to the northwest coast of Vancouver Island and on other north coast trawling grounds. That all or part of this spawning group migrate to the more northern areas is not known: however, recaptures of tagged fish suggest similar exploitation rates in each of the major recovery areas.

A cooperative publication covering the results of the Estevan tagging experiments is planned.

(c) Cape Flattery Spit tagging. On March 30, 1955, in conjunction with the Estevan-Deep tagging, a total of 436 brill were tagged and released 43 miles SW of Cape Flattery in 140-150 fathoms. Of the total number tagged, 266 Canadian and 170 American tags were used. Like the Estevan stock, these fish represented a spawning aggregation, and at this time consisted mainly of male fish in a spent condition. The average size of the Canadian tagged fish was: 41.1 cm. for males, and 47.7 cm. for females. Inclement weather, poor trawling bottom, and a high percentage of Sebastodes in the catch (70-80%) prevented further tagging on this ground. As of March 31, 1956, only 1 tagged brill has been recovered from this tagging. This was one of the four female fish tagged and was recaptured on July 23, 1955, in 36-42 fathoms, 1 1/2 miles E by N of Swiftsure light. Because fish selected for tagging were in extremely poor condition, additional recoveries are not anticipated.

2. Lingcod tagging

(a) Results from previous experiments. Tagging of lingcod (*Ophiodon elongatus*) was carried out annually between 1939 and 1943 aboard handline vessels in the Strait of Georgia. The results of these experiments were reported in Progress Reports, Nos. 56 and 57, 1943. Subsequent to 1943 further recoveries were obtained from these taggings, and additional tagging experiments were carried out. In the period 1939-54, 3,145 lingcod were liberated on banks in the Strait of Georgia and off the west coast of Vancouver Island. A report has been prepared concerning the movements of all previously unreported tagged lingcod, and deals also with the differences in the recoverability by hand-liners and otter-trawlers of all fish tagged and released after capture by these two types of gear. The report, "Further Results From Tagging Experiments on Lingcod" is to be published in the Pacific Progress Reports series.

In summary, the report confirmed earlier results in that there appears to be no well-defined migration pattern for lingcod. Results also showed that tagged fish which at the time of tagging were caught by hand-line are more likely to be recovered later by that type of gear, and fish tagged from trawls are more likely to be recaptured by trawls.

(b) Lingcod tagging during the closed season, 1954-55. During the months of December, 1954, to February, 1955, inclusive, 409 lingcod were tagged and released on banks in statistical Areas 14 and 17 in the Strait of Georgia. This work was carried out in order to obtain present-day rates for lingcod growth, mortality, and fishing intensity. In this report, a summary is given of tag recoveries received during the 1955 lingcod fishing year (March - November incl.) from fish tagged on deep banks, shallow banks, and on beach fishing areas. The average sizes of fish tagged are shown in Table I.

Table I. Number and average size of lingcod tagged December, 1954, to February, 1955.

| | December | | January | | February | |
|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female |
| Deep-bank No. | 5 | 89 | | 5 | | 2 |
| Av. L. cm. | 62.2 | 84.8 | | 82.0 | | 75.5 |
| Shallow-bank No. | 73 | 17 | | | | |
| Av. L. cm. | 65.8 | 72.5 | | | | |
| Beach No. | 103 | 28 | 9 | 1 | 50 | 11 |
| Av. L. cm. | 60.6 | 65.0 | 59.6 | 66.0 | 62.5 | 62.6 |

(1) Seasonal recoveries. Table II shows the number of recoveries obtained from the total number tagged at each location. In the early months of the season, the recovery of tagged fish was greatest, dropped to a low level during the spring and summer months and increased slightly during late-season fishing. Previous tagging results show that the seasonal recovery of tags is proportional to the total catch landed.

For fish tagged on deep-bank, March recoveries constitute 75% of all deep-bank recoveries, and approximately 25% of the total recoveries. Fish tagged in shallow-banks and beaches were recovered at a more constant seasonal rate than those tagged on deep-banks.

Table II. Numbers of tagged lingcod recovered during 1955, from previous closed-season tagging

| | No. tagged | Recovered | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Total |
| Deep-banks | 134 | 12 | 1 | .. | .. | 1 | .. | 1 | 1 | .. | 16 |
| Shallow-banks | 73 | 1 | 1 | .. | .. | 3 | 2 | .. | 2 | 2 | 11 |
| Beaches | 202 | 3 | 4 | 1 | 2 | 1 | 1 | 3 | 3 | 1 | 19 |
| | 409 | 16 | 6 | 1 | 2 | 5 | 3 | 4 | 6 | 3 | 46 |

(2) Recoveries by individual line fishermen and by other gear. For the recent tagging a chartered lingcod vessel was employed. In Table III, a tag-recovery schedule is presented in order to compare the tag recovery of the charter vessel (recoverer A), who had intimate knowledge of the tagging, with that of fishermen who were unaware of the tagging areas.

Table III. Recovery of tagged lingcod in 1955 according to individual line fishermen and by other gear

| Recoverer | Number recovered from | | | Total |
|---|---|---|---|---|
| | Deep-bank | Shallow-bank | Beach | |
| Area 17 | | | | |
| A(Charter party) | 6 | 9 | 3 | 18 |
| B(Fisherman) | 6 | .. | .. | 6 |
| C(Sport) | .. | 1 | 3 | 4 |
| D(Gillnet) | .. | 1 | .. | 1 |
| E(Fisherman) | 1 | .. | .. | 1 |
| F " | 1 | .. | .. | 1 |
| G " | .. | .. | 1 | 1 |
| H " | .. | .. | 1 | 1 |
| I " | .. | .. | 1 | 1 |
| J " | .. | .. | 1 | 1 |
| K " | 1 | .. | .. | 1 |
| Area 14 | | | | |
| L | .. | .. | 2 | 2 |
| M | .. | .. | 2 | 2 |
| N | .. | .. | 3 | 3 |
| O | .. | .. | 2 | 2 |
| P Trawl | 1 | .. | .. | 1 |
| Total | 16 | 11 | 19 | 46 |

Recoverer A returned 18 or 39% of the 46 lingcod recovered. Recoverer B accounted for 6 of the total recoveries. Both A and B fished exclusively for lingcod all season, the remainder (E to K) fished only part. Of the 16 deep-bank tagged fish recovered, A and B returned 6 each, and the remaining 4 were returned by separate individuals or gear. It is evident that the catchability of deep-bank tagged fish was no greater for fisherman A, the charter party, than it was for fisherman B. All areas where the deep-bank liberations were made are well known to the fishery.

For the shallow-bank taggings a total of 11 recaptures were made, 9 by A and two incidentally by other gear, C and D. These shallow-bank releases were made on two selected banks by charter party A and all but two of the subsequent recaptures were made by that party. In the absence of detailed information on the activity of other fishermen it is difficult to interpret fully this differential catchability. However, it is believed that fisherman A has an atypical interest in shallow-bank lingcod - and hence estimates of fishing rate on such fish are likely to be unrepresentative.

(3) Lingcod fishing rates. In tagging experiments, the ratio of marks recovered (R) to marks released (N) is taken as a measure of the rate of exploitation of the stock, provided that certain basic assumptions hold true. These fishing rates have been calculated for Strait of Georgia lingcod stocks (east coast of Vancouver Island) during 1955 and are presented in the table below.

| | R/N |
|---|---|
| Deep-bank stocks | 16/134 = .12 |
| Shallow-bank stocks | 11/73 = .15 |
| Beach stocks | 19/202 = .09 |
| Total | 46/409 = .112 |

The mean rate of fishing for 1955 was estimated as 11.2%. The calculated rate for shallow-bank lingcod in 1955 was 15.0%, and resulted from one vessel's effort. This slightly higher rate may be attributed to increased effort in fishing for a known abundance of tags. Within limits of sampling error, an approximate figure for the rate of removal of fish from the stock (excluding the shallow-banks) was 10.0% in the fishing year. This is fairly close to the estimates obtained from experiments in the period 1941-44 (a mean of 8.9%).

(4) Seasonal movement. Of the 46 tags recovered in 1955 only one showed movement from the tagging site. This was a 92-cm. female, tagged on the French Creek reef, December 2, 1954, and recovered by trawl on February 18, 1955, approximately 15 miles to the northwest near Yellow Rock (Chrome Island). At the time of tagging the size and shape of this fish's abdomen indicated spawn developing. On recovery, a running condition was reported. An off-reef spawning movement is suggested.

(5) Growth of tagged fish. Eight male recoveries (average size at time of tagging 61.2 cm.) grew on the average 5.6 cm. in length during an average time-free of 8.2 months. Growth determinations from vertebral rings show that male

lingcod at age 4 are 62.0 cm. and at age 5 are 67.5 cm. in length; an annual difference of 5.5 cm. It is likely, therefore, that the greater part of the annual growth occurs during eight months of the year, and little during the winter months.

(6) Shallow-bank experiment. A total of 63 lingcod were tagged in two separate days of fishing on a five-fathom bank off Newcastle Island. As shown in the following table there was a very noticeable difference in the results, even though the two fishing days were only one week apart.

| | Number tagged | Recoveries | | | | | |
|---|---|---|---|---|---|---|---|
| | | Apr | July | Aug | Oct | Nov | Total |
| 13 Dec 54 | 21 | 1 | 2 | 1 | 2 | 2 | 8 |
| 17 Dec 54 | 42 | .. | .. | 1 | .. | .. | 1 |

All recoveries, with the exception of one gill-net recovery in October, were made by one line fisherman (fisherman A - see Table III). The relatively high percentage of recaptures from the tagging on December 13, as compared with that from December 17 is striking. The reason for such a differential rate is unknown, but it serves to point out the complexity of lingcod movement and/or catchability on any one reef which must be accounted for in computation of fishing rates.

(7) Transplanting experiment. In an earlier tagging experiment a number of lingcod were captured at one fishing location, removed some distance from their original residence and then tagged and released. Subsequent recoveries from this tagging experiment have shown a homing tendency among lingcod. In order to obtain further results to test the validity of the observation, fifteen fish were captured by trawling gear on the Cape Lazo grounds in 45 to 50 fathoms, retained two days in a live tank, then tagged and released at Norris Rock in five fathoms of water (13 miles from the place of capture). On the same day as these releases occurred, 9 fish were captured with lines at Norris Rock, then tagged and released at that spot. Subsequently 2 of the line-tagged fish were recaptured at Norris Rock by line gear, and one of the trawl-tagged transplants was recovered by trawl gear back in the Cape Lazo area. The 9 line-tagged fish were males approximately three years in average age, and of the 15 trawl-tagged 11 were females and 4 males, all on the average 4 years of age. Further results are anticipated.

## 3. Graycod tagging

C.R. Forrester

Preliminary experiments showed that the gray cod could be successfully tagged with button-type tags attached with monofilament nylon.. Between November, 1954, and April, 1955, several tagging experiments were conducted using the button tags with various methods of attachment and a tag of red plastic tubing (the California "spaghetti" tag). Preliminary results of these experiments were published in Pacific Progress Reports No. 103. The present report summarizes this paper and includes recovery information to March, 1956.

Button or Petersen-type tags were attached with either light or heavy monofilament nylon (15 or 30-pound test), braided Dacron (80-pound test), braided nylon (150-pound test) or light stainless steel wire. These strands were threaded through the flesh between the first and second dorsal fins with the aid of a hypodermic needle. The "spaghetti" tag was attached in a similar manner.

(a) Swanson Channel. A total of 1,322 fish were tagged in this area between November, 1954, and January, 1955, of which 323 were subsequently recaptured. Only 14 (4.3%) were recaptured outside the general tagging area. Of these, 8 were taken by United States trawlers on American fishing grounds south and east of the tagging area. Five recoveries were made in fishing areas 65 to 80 miles north of the tagging area along the east coast of Vancouver Island and one was recovered off the mouth of the Fraser River. Of the 323 total recoveries, 280 had been made by May, 1955. Five recoveries were made during the summer from May to October, 1955, and 38 recoveries were made in the period October, 1955 to March, 1956.

(b) Nanoose Bay. Tagging was carried out in the last week of March, 1955, following the annual closing date for trawlers in this area. Up to the beginning of February 1956, 32 recaptures (out of 619 fish tagged) had been reported from areas not affected by closure. Of these, 16 were reported by Canadian vessels (12 from Swanson Channel and 4 from the Fraser River estuary). Sixteen recaptures were made by United States vessels. Fifteen of these were from fishing grounds bordering the lower Strait of Georgia and one from the west coast of Vancouver Island (about 200 miles from the tagging site). During the 1956 open period at Nanoose Bay (February 1 to March 20) 33 more recoveries were made from Nanoose Bay itself while one tag was recovered in Lambert Channel (60 miles to the north).

It is interesting to note that all of the Nanoose Bay tags recovered in Swanson Channel were recovered in or before November, 1955, and not during the peak of the main Swanson Channel fishery which occurs in January and February.

(c) Cape Lazo. Twenty-six recoveries have been received from the original 168 tags liberated in February, 1955. With two exceptions, all were recovered at or a short distance from the tagging site. One recovery was made in Nanoose Bay 25 miles to the south while another was made 100 miles from the tagging area, in United States waters near Orcas Island.

(d) Suitability of attachment. Examination of the wounds of captured fish suggests that the monofilament nylon attachment is superior. The stainless steel, plastic tubing and braided materials cause moderate to severe irritation and erosion of the flesh, whereas a high percentage of fish with monofilament attachment had shown firm fusion of flesh to the nylon. A greater return of dacron and braided nylon than monofilament nylon in the Swanson Channel experiments is believed directly due to the light weight (15 lb.) of the monofilament employed. Larger diameter monofilament was used in the Nanoose Bay experiment and results for this area to date (13.7%) are similar to those for the spaghetti tags with considerably less irritation to the flesh. Further returns should indicate clearly the best method of attachment.

4. Lemon sole tagging — K.S. Ketchen and C.R. Forrester

(a) Migrations of lemon sole in the Strait of Georgia. In Pacific Progress Report No. 104 a general summary was given of the results of lemon sole tagging in the Strait of Georgia over the past decade. The discussion was based on 3,390 recaptures from a total of 13,954 tagged fish.

Tagging has shown that the lemon sole stock of the Strait of Georgia is divisible into three main populations, one in the Baynes Sound - Cape Lazo area, another in the Gulf Islands and another around the estuary of the Fraser River. Only 1.4% of the total number recaptured had emigrated from their respective tagging areas and only 0.3% had moved entirely out of the Strait of Georgia.

There is a strong suggestion that a small highly migratory population enters the Strait from the open coast during the spring or summer and returns before the winter begins. This conclusion is based on the fact that the majority of emigrants from the Strait of Georgia were tagged during the summer and fall months. Relatively few outside recaptures were obtained from tagging conducted in the winter months.

(b) Lemon sole recaptures from tagging in Hecate Strait at Queen Charlotte Sound, and Queen Charlotte Strait.

Extensive tagging of lemon sole was conducted in Hecate Strait in 1950, 1951 and 1952. A few returns are still being made from these experiments. Two tags were obtained in 1955 from the 1950 experiment and both were taken in the tagging area. Only one recapture was obtained in 1955 from the 1951 tagging and this came from the Goose Island bank about 150 miles south of the tagging area. Eleven recoveries were made in 1955 from the 1952 experiment and all were from the tagging area.

Tagging was conducted on the Goose Island grounds in Queen Charlotte Sound in 1952, 1953 and 1954. Two recaptures were made in 1955 from the 1952 experiment and both were from the tagging area. Recaptures in 1955 from the 1953 tagging amounted to 17, of which 14 were from the tagging area, one was from Hecate Strait and 2 were from the coast of the United States (Columbia River and Umatilla Lightship). Recaptures from the 1954 experiment amounted to 20 in 1955 and all were from within the general tagging area.

Six recoveries were made from tagging conducted in 1952 and 1953 in one of the inlets bordering on Queen Charlotte Strait. However, all were from the tagging area.

In general it appears that the Hecate Strait stocks is separate from that of Queen Charlotte Sound. There is some evidence of mixing and lengthy migration, but this always constitutes a very small fraction of the total recapture from each tagging. The inlet populations appear to be independent of one another and also of those populations in adjacent exposed waters.

5. Pin corrosion studies — C.R. Forrester

It has been noted that the incidence of corrosion in metal tagging pins is often greatest in regions which have stagnant bottom conditions. To test the possibility that the chemical conditions in such areas might have a bearing on the corrosion problem, a laboratory experiment was initiated early in 1955. Separate batches of 12 nickel pins and stainless steel pins were placed on cellulose acetate sheets and sealed in jars containing the following solutions:

| Jar no. | Pin type | Solution |
|---|---|---|
| 1 | Nickel | "Normal" sea water |
| 2 | Nickel | "Normal" sea water + $H_2S$ |
| 3 | Nickel | "Normal" sea water + $P_2O_5$ |
| 4 | Nickel | "Normal" sea water + $H_2S$ + $P_2O_5$ |
| 5 | Stainless steel | "Normal" sea water |
| 6 | Stainless steel | "Normal" sea water + $H_2S$ |
| 7 | Stainless steel | "Normal" sea water + $P_2O_5$ |
| 8 | Stainless steel | "Normal" sea water + $H_2S$ + $P_2O_5$ |

The "normal" sea water was obtained from the end of the Station wharf. The strengths of hydrogen-sulphide and phosphorous-pentoxide added to the sea water were four times the strength given for these components in stagnant fjords by Sverdrup et al in "The Oceans". The strength of the additives was quadrupled in the hope of accelerating any reaction which might take place. At the end of one year the pins in each jar were examined for signs of corrosion.

It is significant that there was evidence of corrosion in only one of the series. This corrosion was apparent on 10 of the 12 nickel pins examined from the jar containing the combination of $H_2S$ + $P_2O_5$. There was no corrosion in the corresponding jar containing the stainless steel pins. The corrosion of the nickel was similar to that which has occurred on tagging pins used on fish in the wild, and in the jar was accompanied by a precipitation of irridescent grayish material. Analysis of the precipitate is still to be carried out and it is hoped that this will provide a precise explanation of the reaction involved.

## Age and growth studies

During 1955, collections of flatfish otoliths from samples of the commercial landings were maintained as in previous years with emphasis on lemon sole, rock sole, brill and butter sole. In all a total of 27,012 otoliths were collected, along with 10,640 length measurements of gray cod and 5,038 measurements of black cod.

Otolith readings on lemon sole, rock sole and butter sole are keeping pace with the collections and are virtually up to date. Readings of brill otoliths are being increased in order to overcome the backlog in that material. No progress has been made on the study of gray cod otoliths but it is believed that use of length-frequency data will give sufficient information for general appraisal.

A substantial advance has been made in estimating the age and growth of lingcod from vertebrae.

### 1. Brill

(a) Average size of brill off the west coast of Vancouver Island (B.M. Chatwin). Samples of brill have been taken since 1945 from stocks of fish occurring off the west coast of Vancouver Island. Length data obtained have been compiled to date and are summarized in the accompanying table. Since trawlers usually confine their fishing to one general area during any one trip, the sampling has been treated according to three major areas: (1) San Juan to Cape Beale (statistical Areas 20, 21), (2) Cape Beale to Estevan Point (statistical Areas 23, 24), and (3) Estevan Point to Cape Cook (statistical Areas 25, 26).

Average length (mm.) of west coast of Vancouver Island brill.

| | 1945 | 1946 | 1947 | 1948 | 1949 | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | 11-year mean size |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) San Juan to Cape Beale | | | | | | | | | | | | |
| males | 389 | 387 | 343 | 372 | 386 | 386 | 404 | 405 | 407 | 408 | 428 | 394 |
| females | 432 | 429 | 377 | 401 | 422 | 438 | 445 | 439 | 464 | 464 | 490 | 444 |
| (2) Cape Beale to Estevan | | | | | | | | | | | | |
| males | 369 | 385 | 362 | 373 | 390 | 382 | 395 | 393 | 411 | 407 | 405 | 390 |
| females | 439 | 428 | 411 | 414 | 433 | 431 | 453 | 453 | 468 | 463 | 462 | 441 |
| (3) Estevan to Cape Cook | | | | | | | | | | | | |
| males | 407 | 405 | 378 | - | 383 | 388 | 389 | 388 | 425 | 393 | 398 | 388 |
| females | 478 | 472 | 443 | - | 435 | 427 | 469 | 497 | 487 | 485 | 473 | 461 |
| (4) San Juan to Estevan (areas 1 and 2) | | | | | | | | | | | | |
| males | 382 | 385 | 359 | 372 | 389 | 382 | 396 | 398 | 409 | 407 | 408 | 391 |
| females | 436 | 428 | 405 | 413 | 431 | 433 | 452 | 450 | 467 | 463 | 470 | 442 |
| (5) San Juan to Cape Cook (areas 1, 2 and 3) | | | | | | | | | | | | |
| males | 385 | 388 | 372 | 372 | 388 | 384 | 395 | 397 | 410 | 406 | 404 | 390 |
| females | 446 | 441 | 425 | 413 | 431 | 432 | 455 | 462 | 469 | 468 | 470 | 445 |

A general upward trend in the average size of brill is evident for each general area in recent years. Previous reports have shown that the increase in average size of all west-coast brill since 1948 (No. 5 above) was related to a continuing failure in recruitment. The mean sizes of brill in each area, computed for the 11-year period, show that females from the Estevan-Cape Cook area (No. 3), are larger by almost 2 cm. than female fish from the more southern areas (Nos. 1 and 2). The size-composition characteristics of the stock in the Estevan-Cape Cook area may be complicated by the fact that some Hecate Strait fish (which are of larger size than west-coast fish) contribute to a winter fishery in the deep water off Estevan and are also taken in inshore waters (Areas 25 and 26) during the spring and summer months. However, brill in the southern Vancouver Island areas (Nos. 1 and 2) show great similarity in size composition, and samples for these areas have been combined in No. 4 above. Preliminary tagging results indicate that intermingling of stocks north or south of Estevan Point is negligible. Population studies will be considerably simplified by the division of the west-coast sampling into two main regions: north of Estevan Point (Areas 25 and 26), and south of Estevan Point (Areas 20 to 24 inclusive).

(b) Age composition of brill, Cape Beale to Estevan Point (C.R. Forrester and W.E. Barraclough). The decline in recruitment of brill on the west coast of Vancouver Island has been described in previous summary reports and in Progress Report No. 98 of the Pacific Coast Stations.

| Year-class | Percent frequency 1950 male | 1950 female | 1951 male | 1951 female |
|---|---|---|---|---|
| 1948 | .. | .. | 0.4 | 0.1 |
| 1947 | 0.2 | 0.3 | 2.5 | 1.4 |
| 1946 | 3.9 | 3.1 | 8.1 | 4.9 |
| 1945 | 19.7 | 15.8 | 17.5 | 9.0 |
| 1944 | 13.6 | 10.2 | 17.3 | 11.1 |
| 1943 | 20.0 | 20.6 | 20.5 | 13.8 |
| 1942 | 17.1 | 16.9 | 14.8 | 14.7 |
| 1941 | 11.1 | 11.7 | 8.6 | 13.4 |
| 1940 | 7.0 | 8.0 | 3.3 | 11.8 |
| 1939 | 3.0 | 4.0 | 3.6 | 5.2 |
| 1938 | 1.7 | 2.8 | 1.9 | 4.7 |
| 1937 | 1.5 | 2.0 | 0.8 | 3.3 |
| 1936 | 0.7 | 1.4 | 0.4 | 2.5 |
| 1935 | 0.3 | 1.3 | 0.4 | 1.9 |
| 1934 | 0.1 | 1.0 | .. | 1.1 |
| 1933 | 0.1 | 0.3 | .. | 0.8 |
| 1932 | .. | 0.2 | .. | 0.3 |
| 1931 | .. | 0.2 | .. | 0.1 |
| 1930 | .. | .. | .. | 0.2 |
| Total number | 2111 | 2828 | 521 | 1601 |
| Average length | 382 mm. | 426 mm. | 395 mm. | 459 mm. |
| Average age | 7.3 years | 7.9 years | 7.9 years | 9.5 years |

Age determinations for 1950 and 1951 for the Cape Beale-Estevan Point region, which supports the main west-coast fishery for brill, confirm the conclusions reached in the length-frequency studies. Year-classes since 1943 are entering the fishery in below-average strength. Age studies of the brill are continuing and should be up to date in the coming year.

(c) Change in size composition of brill in terms of catch per unit of effort (K.S. Ketchen). In order to get a quantitative evaluation of the effects of the decline in recruitment of young to the stock of brill off the west coast of Vancouver Island, the trend in size composition has been examined in terms of the catch per unit of effort (catch per trip). Of course, age-composition data would be more useful for such a study but these are not as yet available in their entirety.

By reference to length-weight charts, it was possible to obtain from each year's length-frequency sample the percentage by weight of each size-group in the sample. This enables computation of the poundage of each size-group in the annual catch, or, as was done here, the catch per unit of effort for each length-group. In the accompanying table a summary is given of the calculated catch per trip by arbitrarily-grouped size classes (4-cm. groups) of female fish.

Average number of pounds of female brill per trip, by size-groups

| Length group (cm.) | 1948 | 1949 | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | Average |
|---|---|---|---|---|---|---|---|---|---|
| 28-31 | 24 | 14 | 15 | 4 | 5 | 0 | 0 | 2 | 8 |
| 32-35 | 361 | 136 | 197 | 37 | 57 | 12 | 38 | 25 | 108 |
| 36-39 | 1602 | 484 | 421 | 203 | 200 | 91 | 119 | 104 | 403 |
| 40-43 | 2316 | 1133 | 1028 | 647 | 743 | 401 | 342 | 246 | 857 |
| 44-47 | 1814 | 1279 | 1589 | 1184 | 1504 | 1290 | 953 | 639 | 1282 |
| 48-51 | 1021 | 903 | 1039 | 1159 | 1540 | 1356 | 1254 | 909 | 1148 |
| 52-55 | 542 | 578 | 592 | 648 | 1040 | 748 | 833 | 635 | 702 |
| 56-59 | 126 | 146 | 239 | 258 | 561 | 207 | 272 | 231 | 255 |
| 60-63 | 47 | 28 | 78 | 12 | 68 | 29 | 29 | 72 | 45 |
| 64-67 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 3 |
| Total catch per trip | 7853 | 4701 | 5198 | 4152 | 5718 | 4134 | 3840 | 2886 | 4811 |
| Average weight per fish (lbs.) | 2.1 | 2.5 | 2.6 | 2.9 | 3.1 | 3.2 | 3.3 | 3.3 | 2.9 |

It will be noted that the catch per trip of fish in the size range 28-47 cm. is now (1955) very much below the average for the 1948-55 period. Catch per trip of size groups 52-55 and 56-59 are now fairly close to the eight-year mean, while the catches of size groups containing the largest fish are above the mean.

There is as yet no indication of improvement in recruitment, which now appears to be merely about one-fourteenth of its value in 1948. As a result the fishery is each year dependent on older and older fish in fewer and fewer numbers. The fact that the average weight per fish is stabilizing near three pounds, while the catch per unit of effort continues to decline, suggests that increase in weight through growth is now far outweighed by removals through natural death and fishing.

2. Lingcod B.M. Chatwin

(a) Age and growth. Studies on the use of vertebrae as a means of determining age of young lingcod were carried out in 1954 (Pacific Progress Reports No. 99, July 1954). In 1955 the method was applied to lingcod of commercial size and the results were presented in Progress Report No. 105 along with a comparison with growth rates obtained from tagging.

It was shown therein that: (1) female lingcod may attain an average size of 42 inches or 107 cm. by the time they reach age 15, whereas males may reach 36 inches or 91 cm. after 13 years, (2) the commercial size limit, 3 lbs. dressed head-off, selects lingcod of not less than three years of age, and (3) lingcod captured commercially range in total length from 50 cm. to at least 114 cm. and include twelve or more age-groups.

It was also noted that the vertebrae age-determination method would not be sufficiently practical to permit routine sampling of commercial catches for age composition. However, the present study has yielded growth information heretofore lacking, which will now permit a study of the problem of minimum size limits in relation to maximum yield.

(b) Sampling of commercial lingcod landings, 1955. Sampling of trawl lingcod landings initiated for the first time during the summer of 1954 provided information on the size and dressed weight of lingcod taken by trawling gear off the west coast of Vancouver Island. Historically, the line fishery for lingcod in British Columbia has accounted for the greater part of the total catch landed, but sampling of this fishery has proved difficult because catches from various areas are usually accumulated in live-ponds, then landed en masse for marketing. However, through personal contact with line fishermen and by careful check on line-landings by Vancouver port observers, 952 line-caught as well as 2,238 trawl-caught lingcod from specific areas have been examined since September 1954. All samples, with the exception of one, are comprised of mixed sexes and dressed head-off fish. The results, which are classified according to three major fishing areas, are shown in the accompanying table.

| Area and gear | | Number | Average total length(cm.)* | Range of sample length(cm.)* | Average dressed wt.(lbs.) | Est. av. age (years) | % wt. of lingcod in total catch |
|---|---|---|---|---|---|---|---|
| West coast of Van. Is. | | | | | | | |
| Trawl | | 1848 | 72.65 | 53 - 113 | 7.2 | 6 | 52% |
| Line | | 111 | 61.78 | 53 - 84 | .. | 3+ | 4% |
| Strait of Georgia | | | | | | | |
| Trawl | | 266 | 66.74 | 58 - 101 | 5.8 | 4+ | 79% |
| Line | male | 105 | 67.2 | 52 - 88 | .. | 4+ | 100% |
| | female | 95 | 79.5 | 58 - 108 | .. | 8 | 100% |
| | female | 52 | 103.9 | 84 - 117 | 21.5 | 13+ | 100% |
| North coast | | | | | | | |
| Trawl | | 124 | 85.45 | 63 - 111 | .. | 8+ | 20% |
| Line | | 589 | 101.85 | 70 - 123 | 17.4 | 15 | 93% |

*Converted from dressed measure.

(c) Mortality rates. In order to estimate mortality rates for Strait of Georgia lingcod, tagging data from experiments performed during the period 1939-1944 have been analyzed. In 1939-40, strap tags were attached to the operculum, and during 1941-44 ring tags were placed around the upper jaw-bone of each fish tagged. Because two different types of tags were used, separate analyses were performed on each set of data to obtain average estimates of mortality. On the basis of the rate of decline in the return of tagged fish, instantaneous rates of mortality were computed for Strait of Georgia lingcod and are shown in the accompanying table.

| Period | Type of tag | Instantaneous mortality rates | | |
|---|---|---|---|---|
| | | Total "i" | Fishing "p" | Natural "q" |
| 1939-40 | Strap | .7321 | .0427 | .6894 |
| 1941-44 | Jaw | .4723 | .1019 | .3704 |

Corresponding rates of total mortality on an annual basis for the periods 1939-40 and 1941-44 are, a = 51.8% and 37.5% respectively. The difference of 14.3% between these values obtained has been ascribed to the types of tag used in the two experiments--in that a high loss of tags occurred in the experiment involving the opercular strap tags. This loss would cause the estimated mortality rate to be too high.

As a means of checking the tagging data mortalities, catch curves were constructed from length-frequency data of all fish tagged during each period. From representative parts of each curve, estimates of seasonal mortality for the 1939-40 period of 32.7%, and for the 1941-44 period of 35.1% were obtained. The best estimate for the total rate of mortality is taken from the 1941-44 tag recovery data; i = .4723 or a = 37.5%. For the same period, the seasonal rates of fishing (m) and natural mortality (n) were computed, and were on the average, 9.5% and 30.9% respectively.

A paper concerning mortality rates in Strait of Georgia lingcod is being prepared.

3. Age composition of butter sole

The British Columbia trawl fishery exploits a winter spawning stock of butter sole in Skidegate Inlet on the east coast of the Queen Charlotte Islands. The commercial catch has been sampled since 1946, and all otolith samples have been read up to 1955, with the exception of those of 1952, and reported in previous summary reports. The table below shows the percent frequency of age-groups in the 1955 fishery which took approximately 615,000 pounds of fish from the inlet.

| 1955 | Percent frequency | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | Total number |
| Female | 0.3 | 6.9 | 31.5 | 40.9 | 15.5 | 3.8 | 1.0 | .. | 581 |
| Male | 0.2 | 13.1 | 39.2 | 37.6 | 8.1 | 1.4 | 0.2 | .. | 561 |

The age composition of Skidegate Inlet butter sole since the inception of sampling has been characterized by dominance of age-groups 5 to 7. The butter sole has an apparent high natural mortality, and dominance by a particular year-class for more than two years is exceptional. The fishery has fluctuated greatly in the years since 1946, from zero catch to as high as 3.5 million pounds. As these fluctuations have had little, if any, effect on the age structure of the Skidegate Inlet stock it is believed that natural factors have the dominant effect in changes in abundance and catch/effort.

4. Age and growth of lemon sole — C.R. Forrester

(a) Hecate Strait. Approximately 4500 otoliths have been examined from samples of the 1954 and 1955 catch of lemon sole in Hecate Strait. The age composition is given in the following table.

| | Percent frequency | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13+ | Total |
| Female | | | | | | | | | | | | |
| 1954 | .. | 3.5 | 27.8 | 29.1 | 19.4 | 9.8 | 4.4 | 2.7 | 1.8 | 0.8 | 1.4 | 2234 |
| 1955 | 0.1 | 8.8 | 31.4 | 22.8 | 17.4 | 10.5 | 5.8 | 1.6 | 1.1 | 0.2 | 0.2 | 811 |
| Male | | | | | | | | | | | | |
| 1954 | .. | 4.6 | 29.8 | 29.8 | 20.6 | 7.0 | 4.1 | 2.9 | 0.7 | 0.3 | 0.2 | 1099 |
| 1955 | .. | 11.8 | 31.2 | 28.7 | 16.2 | 6.4 | 3.5 | 1.9 | 0.3 | .. | .. | 314 |

Samples from this area continue to be dominated by young fish. This situation confirms predictions of year-class strength made by Ketchen on the basis of water temperatures. His predictions were for stronger than usual year-classes from brood years of 1949, and 1950.

(b) Union Bay. Considerable difficulty has been experienced in age determination of the lemon sole in the Union Bay area. Comparisons of growth as indicated by otoliths with that indicated by tag returns have shown discrepancies in larger older fish. This is believed to be due to overcrowding in the dense stock of fish which accumulated after the closure to commercial trawling in 1947. A re-reading of otoliths and a comparison with readings from inter-opercular bones has thrown some light on the problem. It is apparent that overcrowding resulted in a cessation or great reduction in growth of older fish. This complicates otolith reading in that checks added to the margin of the otolith of an old fish may be overlooked. The percentage frequency of age-groups in female fish as has been determined by re-readings is presented in the following table.

| | Percent frequency | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Age | | | | | | | | | | | | |
| Year | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 16 | Number |
| 1951 | .. | 1.4 | 9.8 | 37.2 | 43.8 | 6.8 | 0.7 | 0.2 | .. | .. | .. | .. | 1113 |
| 1952 | .. | .. | 1.8 | 10.1 | 28.8 | 35.8 | 16.5 | 4.7 | 1.5 | 0.7 | .. | 0.1 | 716 |
| 1953 | 0.5 | 5.6 | 11.5 | 9.4 | 17.1 | 26.5 | 18.6 | 7.4 | 2.8 | 0.3 | 0.3 | .. | 392 |
| 1954 | 0.4 | 3.3 | 18.6 | 18.5 | 14.5 | 19.4 | 18.4 | 6.0 | 0.9 | 0.1 | .. | .. | 806 |
| 1955 | 0.3 | 4.9 | 26.7 | 21.8 | 16.4 | 7.3 | 6.7 | 7.3 | 5.9 | 2.2 | 0.5 | .. | 371 |

Lack of exploitation after the closure was evident in the marked difference in percentage frequency of 7- and 8-year-old fish in 1951. This difference has carried through to 1955 where it may still be seen between 11- and 12-year-old fish. There is evidence of some recruitment of 4- and 5-year-old's in 1953. By 1955 the bulk of the accumulated stock had been removed and the fishery was again dependent on young fish.

Average length and age of Union Bay lemon sole increased steadily until 1952, when the largest commercial fishery took place. Since that time there has been a decrease in average length and a corresponding decrease in average age.

5. Age composition of rock sole in Hecate Strait

Samples continued to be taken from the northern Hecate Strait rock sole fishery. The table below shows the age composition as determined by otolith readings for the years 1953-55.

| | Percent frequency | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Number |
| **Female** | | | | | | | | | | | | |
| 1953 | 3.2 | 20.7 | 43.1 | 19.9 | 7.2 | 3.5 | 1.5 | 0.8 | 0.1 | .. | .. | 2093 |
| 1954 | 9.8 | 43.3 | 30.6 | 10.8 | 3.2 | 1.2 | 0.4 | 0.5 | 0.1 | .. | 0.1 | 2002 |
| 1955 | 1.7 | 21.5 | 35.5 | 22.8 | 10.4 | 4.0 | 2.3 | 1.1 | 0.5 | 0.3 | .. | 1131 |
| **Male** | | | | | | | | | | | | |
| 1953 | 7.2 | 37.8 | 32.7 | 14.4 | 5.8 | 1.6 | 0.2 | 0.2 | .. | .. | .. | 1230 |
| 1954 | 14.1 | 54.0 | 23.9 | 5.9 | 1.8 | 0.3 | .. | .. | .. | .. | .. | 1164 |
| 1955 | 4.0 | 31.4 | 37.7 | 20.9 | 4.0 | 1.9 | .. | 0.2 | .. | .. | .. | 430 |

The relationship of brood strength to water temperatures is more clearly defined in the rock sole than in the lemon sole, particularly in female fish. The 1947 year-class was particularly strong as 6-year-old fish in 1953, but was supplanted by the 1949 year-class (appearing as 5-year-olds) in 1954. This 1949 year-class carried through to dominate as 6-year-old fish in 1955.

In male fish, the 1949 year-class can be seen distinctly as the strong 5-year-olds and 6-year-olds of 1954 and 1955, respectively. However, the 1947 year-class seems to have been overshadowed slightly by the 1948 year-class. Male fish are considerably smaller at the same age than female fish - so that apparent year-class strength in younger fish may be complicated by net selection or culling by the fishermen. The Hecate Strait rock sole fishery continues to be dependent on or dominated by younger age-groups of fish.

6. Growth of gray cod in the Strait of Georgia.

Gray cod tagging in the Swanson Channel and Nanoose Bay areas has provided some indication of the growth of that species in the Strait of Georgia. Though returns for a complete year have been sparse, it is already evident that there are differences in growth between the two areas.

Returns from immature Swanson Channel fish free for a period of twelve months have shown average growth increments of 15 cm., whereas fish of comparable size tagged and recovered at Nanoose Bay have shown growth of only 10 cm. for a similar period. Mature fish (greater than 54 cm. when tagged) tagged on the Nanoose Bay grounds and recovered one year later have increased only 5 cm. in length.

Measurement of tagged fish shows that the growth rate is rapid in the winter months. In Swanson Channel, immature fish ranging in length from 40 cm. to 53 cm. and tagged between November and January, were found to grow an average of 2.7 cm. (1.1 inches) in an eight-week period. In the same interval mature fish ranging in length from 53 cm. to 80 cm. grew an average of 1.7 cm. (0.7 inches). Growth for the eight-week period in Swanson Channel when extended at the same rate for a period of one year, agrees remarkably well with the actual growth for the year. From this an assumption of constant growth throughout the year might be made, but more returns are required before a firm conclusion can be drawn.

7. Growth of blackcod in captivity

C.R. Forrester and
K.S. Ketchen

In March, 1955, an experimental tagging of blackcod was conducted at this Station to determine the efficacy of various types of tags. Fish were tagged and released in the outdoor concrete tanks and fed a diet of chopped herring. Unfortunately a high concentration of amphipods present in the tank played havoc with the tagging wounds of fish with the result that information on the relative merits of the various tags was lost. However, identification of the fish by tags did permit comparisons of growth during the term of the experiment. The fish were fed at regular intervals and at each feeding were fed to the point where they no longer displayed interest in the herring. Growth increments have been plotted below for the period of the test when most recoveries were made. After that time warm weather and low tides made water control in the tanks uncertain and the experiment was terminated.

| | Size groups at time of tagging (cm.) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 34-37 | 38-41 | 42-45 | 46-49 | 50-53 | 54-57 | 58-61 |
| No. of fish | 4 | 9 | 6 | 6 | 4 | .. | 1 |
| Av. growth increment(mm.) | 93 | 90 | 84 | 58 | 47 | .. | 35 |

The growth shown by these fish is considerably greater than has been revealed by investigations of age and growth of wild fish. Comparisons of growth rates with those known for wild fish suggest that if the phenomenal tank growth could be maintained it might be possible to raise juvenile blackcod (2-year-olds) to commercial size in approximately one-quarter of the time required in the wild, namely, in little more than one year instead of the usual four or five. There is therefore some basis for investigating further the commercial feasibility of such an operation.

## W H A L E - G.C. Pike

### The 1955 whale catch

A catch of 629 whales consisting of 122 fin, 37 humpback, 11 blue, 36 sei, 320 sperm and 3 *Berardius*, was taken by 6 catcher boats operating from the Coal Harbour station from April 2 to September 25, 1955.

The success of the season as measured by catch per catcher's day's work, a unit of effort which considers the number of catchers, the length of the season and time lost due to repairs and weather, was good compared to 1954 and 1953. For the first year since the operation began in 1948 the total catch failed to show an increase over the previous year. This was partly the result of poor weather. In 1955, 34% of the possible whaling days were lost because of poor weather as compared to 29% in 1952, and 25% in 1953 and 1954. Without the loss of these additional whaling days the catch would no doubt have been much better in 1955.

| Year | No. of whales caught | No. of catcher's day's work | Catch per catcher's day's work | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Blue | Fin | Hump | Sei | Sperm | Blue whale units | All species |
| 1952 | 465 | 444 | 0.04 | 0.54 | 0.14 | 0.05 | 0.28 | 0.35 | 1.05 |
| 1953 | 539 | 611 | 0.01 | 0.30 | 0.08 | 0.02 | 0.45 | 0.23 | 0.88 |
| 1954 | 630 | 750 | 0.01 | 0.20 | 0.14 | 0.18 | 0.31 | 0.20 | 0.86 |
| 1955 | 629 | 691 | 0.02 | 0.18 | 0.05 | 0.20 | 0.46 | 0.18 | 0.90 |

The species, the size, and the fatness of whales caught must be considered when judging the success of a whaling season. Sperm whales must be considered independently of the baleen whales because they yield a different type of oil. Species of baleen whales vary in their yields of oil in the approximate proportions of: 1 blue = 2 fins = 2 1/2 humpbacks = 6 seis. The 1955 season shows an exceptionally good catch of sperm whales whose average size and fatness was similar to previous years. The catch of baleen whales, expressed in "blue whale units", was smaller per unit of effort in 1955 than in the previous three years, chiefly as a result of a larger proportion of sei whales relative to the more valuable fin and humpback whales. The catch of fin and humpback whales in 1955 was smaller per unit of effort than in any previous year. The average size of baleen whales varies little from year to year. The thickness of the blubber covering, however, varies considerably. Feeding conditions for baleen whales were poor in 1955 as indicated by the relatively thin blubber and the high incidence of stomachs which were empty or nearly empty. The average thickness of blubber on fin whales, expressed as a proportion of body length, was 0.34% in 1955 as compared to 0.38% in 1952.

## Age, growth and maturity of fin whales

Data pertaining to age, growth and maturity have been collected from 823 fin whales taken during the years 1949 to 1953 inclusive. These whales comprised 448 females, of which 46% were immature, and 375 males, of which 52% were immature. The mature females comprised 55% pregnant whales, 30% resting and 15% lactating. These proportions are representative of the entire catch of 892 fin whales taken during the period and they vary little from year to year. The catch itself, however, is not representative of the entire population. The 50-foot legal length limit excludes most fin whales in their first year and a large proportion of fin whales in their second year. Fin whales entering British Columbia waters are transients and include mostly immature or young mature whales.

Periods in the baleen plates and length-frequency groups have been used to study age and growth of immature fin whales. Tentative conclusions are that sexual maturity is attained usually at an age of 4 years and less often at ages 3 years, 5 years or more. These ages correspond to average lengths of 60 feet for the females and 58 feet for the males.

Periods in the baleen plates and length-frequency groups are of little use in the determination of age in mature fin whales. Following the first few years of rapid growth, wear at the tip of the baleen obscures early growth periods and length groups overlap, losing their identity.

Corpora lutea persist in the ovaries of fin whales throughout life and a count of their numbers gives information on relative age. Translation of corpora lutea counts in terms of absolute age requires additional knowledge of the age at first maturity, the interval between pregnancies and the number of ovulations per breeding season (since the species is polyoestrus). Previous attempts to estimate values for these factors have given a variety of results and none have proven entirely acceptable. Important results of the study of ovaries from 203 mature females are summarized below. The method of study involves a recognition of corpora lutea of recent origin as distinct from corpora in various stages of regression.

The interval between breeding periods is usually two years, seldom less, but may sometimes be three or more years. Of 58 females which had ovulated in their first season as mature whales, 83% were impregnated with an average of 1.7 corpora lutea and 17% had ovulated unsuccessfully with an average of 1.4 corpora lutea. An average of 2.4 corpora lutea accumulate prior to subsequent pregnancies. The increment is greater in older whales.

An age schedule based upon a frequency tally of corpora lutea numbers in the ovaries of 203 mature female fin whales is presented below. The increments have been arbitrarily adjusted to compensate for the occurrence of unsuccessful ovulatory periods which result in intervals of 3 instead of the usual 2 years between successive pregnancies, and for larger increments in older whales. The calculations assume that sexual maturity is attained at an age of 4 years.

| Age in years | Number of whales | Percent of all mature females |
|---|---|---|
| 4, 5 | 82 | 40.5 |
| 6, 7 | 57 | 28.0 |
| 8, 9 | 27 | 13.5 |
| 10, 11 | 17 | 8.0 |
| 12, 13 | 8 | 4.0 |
| 14, 15 | 3 | 1.5 |
| 16, 17 | 4 | 2.0 |
| 18, 19 | 1 | 0.5 |
| 20, 21 | 3 | 1.5 |
| 22, 23 | 1 | 0.5 |

A significant feature of this age schedule is that the stock of fin whales serving the British Columbia industry consists mostly of young animals. Forty-six percent of all the females were immature and these comprised mostly whales in their 2nd and 3rd years. An additional 18% were taken during the first breeding season and most of these (those pregnant and those which had ovulated unsuccessfully) had not yet reproduced. Approximately 65% of all females taken were less than 6 years of age.

A similar approach to the problems of age, growth and maturity is being used in studying the other species of baleen whales.

## Gray whale

Ten California gray whales (Eschrichtius glaucus) were captured and processed under special government permit in April, 1953. Data recorded during the examination of these whales include measurements of body parts, and notes on external characters, colour, baleen, food, parasites, condition of the reproductive organs and physical maturity. The material provides the first comprehensive description of the external form of the species from the north-east Pacific and a comparison of external features with gray whales taken in the northwest Pacific. It provides information on age, growth and maturity which has not been hitherto reported on. The broad aims of the study are to provide terms of reference on breeding, growth and age as a point of departure for future studies on the species.

Publication of the results of the examination of these 10 specimens has been withheld pending the accumulation of information on migration by means of questionnaires sent to lightstations located at vantage points on the coast. The full report will be submitted for publication in 1956.

Some important results of the study are as follows:

(1) There are no specific or racial differences between the gray whales from the eastern and western North Pacific in body form and colour. Body proportions vary with total length; head parts become relatively larger and tail parts relatively shorter as length increases.

(2) The average length at birth is near to 17 feet. Gestation lasts almost one year and is followed by a resting period. Average lengths of approximately 27, 32 and 35 feet are attained by females at the end of the 1st, 2nd and 3rd years, respectively. In females, sexual maturity is usually attained at the end of the 3rd year but the age may vary. Growth ceases at an average length of 45 feet for females and 42 feet for males.

(3) Northward migrating gray whales pass along the coast of British Columbia close to shore from the middle of February to the end of April and in some years the middle of May. The peak run is in March. During this migration the blubber is extremely thin. The oil yield of non-pregnant adults taken in April averages only about 800 gallons per whale.

(4) Southward migrants pass the coast of British Columbia from October to January but few gray whales are seen at this time, suggesting that the main run occurs offshore.

## C R A B   A N D   S H R I M P   I N V E S T I G A T I O N S - T.H. Butler

### Crab

The crab fishery of the Queen Charlotte Islands has been studied since 1947 to discover and explain fluctuations in the fishery and assess the need for regulation. At present the fishery is restricted, by a size limit, to the taking of large male crabs. The research program is divided into three phases: tagging, sampling, and life-history studies.

1. The 1955 Queen Charlotte Islands crab fishery

A record British Columbia crab catch of 4,514,300 pounds was made in 1955. The catch from the Queen Charlotte Islands (not including U.S. landings) accounted for 2,676,600 pounds or 59.3% of the total production of the province. In the following summary the success of fishing is given for each of the separate geographic fishing areas.

(a) Naden Harbour. This is the smallest of the fishing areas. Fishing is carried out during the spring and fall seasons by a fleet of small vessels. During 1955, 23,123 pounds were taken from April 9 to 30, and 20,080 pounds from October 4 to 27 for a total of 43,203 pounds. The 1954 catch was 111,730 pounds.

(b) McIntyre Bay. The season during 1955 extended from April 1 to October 27. The total catch was 1,383,397 pounds, compared to the 1954 catch of 1,167,770 pounds. Crabs were abundant at the start of the season and continued to be until

August, when the incidence of soft crabs in the traps resulted in uneconomical fishing. A voluntary closure by the industry was put into effect from September 1 to 20. The condition of the crabs at the end of the closure was fairly satisfactory but it is believed that with a further extension until October 1 the crabs would have been completely usable. In the 1954 Annual Report, a closure from August 1 to October 1 was recommended.

(c) Hecate Strait. Fishing in this area was carried on from April 15 to October 28. The total catch was 1,926,940 pounds; in 1954 the catch was 1,628,536 pounds. This area is exploited jointly by Canadian and United States vessels. In 1955, Canadian fishermen caught 1,250,067 pounds or 64.9% of the total landings. The catches of Canadian and United States vessels from 1950 to 1955 are shown below:

| Year | Canadian catch | U.S. catch | Total catch |
|---|---|---|---|
| 1950 | 354,986 lbs.(28.7%) | 880,292 lbs.(71.3%) | 1,235,278 lbs. |
| 1951 | 489,486 lbs.(33.8%) | 960,749 lbs.(66.2%) | 1,450,235 lbs. |
| 1952 | 699,400 lbs.(37.4%) | 1,169,062 lbs.(62.6%) | 1,868,462 lbs. |
| 1953 | 659,605 lbs.(32.1%) | 1,396,320 lbs.(67.9%) | 2,055,925 lbs. |
| 1954 | 679,100 lbs.(58.3%) | 949,436 lbs.(41.7%) | 1,628,536 lbs. |
| 1955 | 1,250,067 lbs.(64.9%) | 676,873 lbs.(35.1%) | 1,926,940 lbs. |

2. The 1955 tagging experiment

In 1955, crabs were marked using a type of tag not lost during the moulting. This tag, developed for the Blue Crab (Callinectes) on the Atlantic coast of the United States, was first used for the Pacific crab in 1952. At that time, 92 were male crabs, mostly below legal size, were tagged in Naden Harbour; eleven of the tags were recovered from 1952 to 1954. The objective of the 1955 tagging was to obtain information regarding movements of sub-legal-size crabs, growth, and natural mortality.

A total of 2094 crabs was tagged in the three fishing areas of Hecate Strait, McIntyre Bay, and Naden Harbour. Tagging in the two former areas was carried out from commercial crab boats, while in the latter area a chartered boat Atta Boy was used. There was a total of 423 recovered tags from all areas. The following table shows the numbers of tags released and the recoveries according to fishing areas.

| | Tagging area | | |
|---|---|---|---|
| | Hecate Strait | McIntyre Bay | Naden Harbour |
| No. tagged | | | |
| Legal size | 241 | 279 | 112 |
| Sub-legal size | 662 | 640 | 160 |
| No. recovered | | | |
| Legal size | 100 (41.5%) | 100 (35.8%) | 5 (4.5%) |
| Sub-legal size | 122 (18.4%) | 93 (14.5%) | 3 (1.8%) |

(a) Hecate Strait. Of the 122 recoveries of sub-legal-size tagged crabs, 61 showed evidence of movement. The most significant direction of movement was offshore (west to east); 36 recoveries showed average movement of about 6 miles. An inshore movement (east to west) was shown by 10 recoveries, moving an average distance of about 3 miles. A northward movement was shown by 9 recoveries, and the average distance moved was about 4 miles. Movement to the south was indicated by 6 recoveries, and the average movement was about 3 miles. Eight recovered tags showed movement across Hecate Strait (15-19 miles) during course of fishing season.

There were 100 recoveries of legal size crabs; 38 gave information regarding movement. Offshore movement was shown by 21 with an average movement of about 7.5 miles. An inshore movement was shown by 12 with an average distance of about 2.5 miles. Movement to the north was indicated by 4 recoveries, with an average movement of 4 miles. One recovered tagged crab had moved an indefinite distance from Hecate Strait to McIntyre Bay. Three recovered tags showed movement across Hecate Strait (13-22 miles) during the summer fishing season.

(b) McIntyre Bay. Of the 93 recoveries of sub-legal size, 24 showed evidence of movement. An eastward movement (towards Rose Spit) was shown by 10 of the recoveries, with an average distance of about 5 miles. The westward movement was indicated by 7 recovered tags, and the average movement about 3 miles. There were 5 recoveries which showed a movement around Rose Spit into Hecate Strait, a distance of about 19 miles.

Recoveries of legal-size crabs totalled 100 tags; 24 gave evidence of movement. The most significant movement was eastward with 15% of recoveries, showing an average movement of about 4 miles. A westward movement was shown by 5 recoveries, and the distance moved was about 3 miles. One recovery showed an inshore movement of less than a mile; and one recovered tag showed an offshore movement of about 1.5 miles. Two recoveries were made in Hecate, and the tagged crabs had moved an average distance of 17 miles.

(c) Naden Harbour. No information regarding movements of tagged crabs was obtained from the few 1955 recoveries. No explanation is available for the relatively few recoveries of tagged crabs in Naden Harbour.

The objective of the 1955 tagging experiment was accomplished in part. Tag recoveries showed that the small male crabs move about in much the same way as crabs of commercial size. Three unconfirmed reports of the moulting of tagged crabs were obtained from fishermen; in one case the reported growth was in line with available information from moulting records. However, more data on growth is expected from recoveries during the 1956 season.

3. Sampling for post-larval crabs

Experimental fishing to determine the abundance of post-larval crabs was continued during 1955. A chartered troller **Atta Boy** carried out the work during September in Naden Harbour and McIntyre Bay. The results from 1953 to 1955 are summarized in the following table:

| | McIntyre Bay | | | Naden Harbour | | |
|---|---|---|---|---|---|---|
| | 1953 | 1954 | 1955 | 1953 | 1954 | 1955 |
| Number of tows | 68 | 25 | 43 | 40 | 28 | 35 |
| Tows with crabs | 48 | 5 | 13 | 22 | 7 | 4 |
| Crabs per tow | 25.8 | 2.2 | 4.1 | 66.5 | 11.7 | 1.5 |
| Total crabs | 1240 | 11 | 54 | 1464 | 82 | 6 |

In both areas, post-larval crabs were most abundant in 1953, with 25.8 and 66.5 crabs per tow in McIntyre Bay and Naden Harbour, respectively. In Naden Harbour young crabs were 44.3 times more abundant in 1953 than in 1955; and in McIntyre Bay 11.7 times more abundant in 1953 than in 1954. No definite explanation for these fluctuations is available but they are believed to be due to the effect of environmental factors on larval crabs, rather than differences in the abundance of parent crabs. Further experimental fishing is planned during the 1956 season.

A progress report outlining the results of this work to date has been prepared.

4. Life-history studies

(a) Breeding of male crabs. As reported in earlier Annual Reports, it is possible to recognize breeding male crabs by the presence of "mating marks" on the large claws. During 1953 and 1954, 5,059 male crabs were examined, and 1,521 or 30.1% had mating marks. Annual and regional differences were found in the occurrence of mating marks; from 16.2 to 51.9% of crabs in the various samples had marks. There were also variations in the numbers of sub-legal males with mating marks; from 3.7 to 20.0% of small males in different samples had the marks. The carapace width of male crabs with marks was from 10.7 to 21.8 cms.

In 1953, a sample of 353 legal sized males from Naden Harbour was examined for the presence of mating marks, and also to determine shell condition. The degree of hardness of the shell and presence of fouling permitted separation into recently-moulted and unmoulted (for a year or longer) crabs. In this sample, about 65% of the unmoulted crabs had mating marks, and about 74% of the recently moulted males showed no marks. Therefore marks were found less frequently on newly-moulted crabs of the legal size group. It is likely that these males mated before moulted or would mate after the shells were hardened.

A close examination of mating marks has revealed that there are differences in the distinctness of marks. The marks vary from a few sharp scratches to a wide deeply-worn band (in some cases, the chitin is worn through completely). It was also noted that the degree of wearing varies directly with the hardness or fouling of the shell. There seem to be three possible explanations in cases of heavy wearing; (1) that the male has carried a single female for a long period, (2) that the male has mated with a single female in each of several seasons, (3) that the male is polygamous, i.e. it mates with several females during one season.

There does not seem to be sufficient evidence at the present to determine definitely whether the effect is due to one or a combination of the above factors. The fact that male crabs are polygamous in captivity lends support to the last explanation.

An article describing mating marks and their use in determining the size range, shell condition and behaviour of breeding males has been prepared for publication.

(b) Growth from moulting records. Little information is available on the growth of crabs in the commercial size range. Further information is needed on the increment at moulting, and the frequency of moulting. From 1953 to 1955, 66 moulting male crabs from Hecate Strait and McIntyre Bay have been measured. The size-range of these crabs was from 12.9 to 18.6 cms. Moulting crabs were taken from traps, and the increments are believed to be representative of natural moulting. A summary of the moulting records is presented below:

| Size range (old shell) | Number records | Range of increases | Average increase | Range of % increases | Average % increase |
|---|---|---|---|---|---|
| 12.9-14.0 cm. | 11 | 2.7-3.4 cm. | 2.9 cm. | 19.6-24.6% | 22.1% |
| 14.1-15.0 cm. | 17 | 2.3-3.5 cm. | 3.0 cm. | 16.3-23.8% | 20.8% |
| 15.1-16.0 cm. | 17 | 1.8-3.4 cm. | 2.9 cm. | 11.5-22.1% | 18.8% |
| 16.1-17.0 cm. | 12 | 2.2-3.8 cm. | 3.1 cm. | 13.2-22.6% | 18.7% |
| 17.1-18.0 cm. | 5 | 2.2-3.5 cm. | 3.1 cm. | 12.7-19.6% | 17.4% |
| 18.1-18.6 cm. | 4 | 2.5-3.5 cm. | 3.0 cm. | 13.6-19.3% | 16.5% |

These moulting records show that the growth increments of male crabs of legal size in the Queen Charlotte Islandsare greater than reported by Dr. D.C.G. MacKay from Boundary Bay, B.C., and also greater than increments reported by Mr. F.C. Cleaver from State of Washington. The records also show a gradual decline in the percentage increase in size at moulting. This reduction in growth of the larger male crabs is not sufficient to make their conservation impractical. The larger crabs are more valuable (about 25% more as frozen products) but natural mortality has not been considered here and at the present time no estimate of natural mortality is available.

## Explorations for shrimp

Exploratory fishing to locate new shrimp grounds commenced in 1953 at the request of the industry. Since that time most of the inshore and offshore regions of British Columbia coast have been explored. Five new grounds of different size and potential have been located; two of these are being exploited. The work has been carried out under the Industrial Development Vote of the Department of Fisheries.

A summary of 1954 results appeared in last year's Annual Report, and a detailed report was released in a multigraphed circular (No. 35).

In 1955, the offshore region of the coast was explored. It has been decided to discontinue shrimp explorations for the time being.

### 1. Results of the 1955 explorations — T.H. Butler and G.V. Dubokovic

The program was carried out from June 16 to August 11, using the charter vessel Glendale V. One hundred and fifty trawl tows were completed, from 48 to 112 fathoms; and 8 prawn traps set from 40 to 80 fathoms.

Although shrimps were caught in all parts of the offshore region, the present prospects for a commercial fishery are not good. In several areas the abundance is similar to that in established inshore fisheries for small boats. Larger, more seaworthy trawlers are required for offshore fishing, and the operation of such vessels is uneconomical with the rate of fishing found during 1955. The size of the shrimps offshore (about 200 to the pound) also makes them less valuable than the larger inshore shrimps (80-100 to the pound).

The best fishing of the offshore project was found west of Estevan, on the west coast of Vancouver Island. In the most productive tow "smooth pink" shrimps (*Pandalus jordani*) were taken at the rate of 324 pounds per hour. The trap catches of prawns were very poor. Several inshore regions were surveyed. In Smith Sound, seven exploratory trawl tows gave promising results, but further work is necessary to determine the possibilities for fishing in this region.

A multigraphed circular (No. 39) on the results of the offshore exploration has been prepared.

## INVESTIGATIONS ON MARINE BORERS - F.H.C. Taylor

### Testing of wood preservatives

In March, 1953, in cooperation with the Forest Products Laboratory of the Forestry Branch, Department of Resources and Development, an experiment to test the efficacy of certain substances in preserving plywood against the attack of marine borers was begun. This experiment is still in progress and will continue until all blocks disintegrate or are lost. The Forest Products Laboratory is responsible for all details concerning the treatment of the blocks, the Biological Station, Nanaimo, B.C. for the assessment of the degree of infestation by marine borers.

In this experiment, one-foot-square 3/4" plywood panels are mounted on three racks. Each rack contains 3 control (untreated) panels and 12 test panels, one of each treatment. Panels are arranged randomly in the racks except that a control panel occurs in each third of each rack and each treatment occurs once in the third, second or first third of a rack. The racks are suspended below zero tide line, a foot off the bottom and are examined at intervals.

The panels were placed in the water on March 17, 1953, and examined on August 11-12, 1953, were returned to the water on September 10, 1953, and re-examined on June 24 and 25, 1954. A long delay during which the blocks were kept in cold storage, ensued before they were returned to the water on April 15, 1955. On each examination the blocks were photographed for qualitative estimation of a record of fouling by encrusting organisms, scraped clean and examined for a qualitative estimate of surface damage by the isopod

Limnoria and X-rayed so that counts could be made of shipworms (Bankia). The treatments used and the number of shipworms found in two examinations are shown in the accompanying table. The blanks indicate that the panels were lost in winter storms during the second immersion period.

| Treatment | Immersion time | 1st Examination Rack A | Rack B | Rack C | Mean | Immersion time | 2nd Examination Rack A | Rack B | Rack C | Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| **Pressure Treatments** | Immersion Time: 148 days March, 1953 to August, 1953. | | | | | Total Immersion Time: 436 days Immersion time since last examination: 288 days September, 1953 to June, 1954 | | | | |
| Creosote: 12 lb./cu.ft. | | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 |
| 18 lb./cu.ft. | | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 |
| 24 lb./cu.ft. | | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 |
| Pentachlorophenol | | | | | | | | | | |
| 5% penta: 0.5 lb./cu.ft. | | 0 | 0 | 0 | 0 | | 68 | .. | 31 | 50 |
| 1.0 lb./cu.ft. | | 0 | 0 | 0 | 0 | | 64 | .. | 0 | 32 |
| **Cold Immersion Treatments** | | | | | | | | | | |
| Copper naphthenate: | | | | | | | | | | |
| 3% Cu 24-hr. immersion | | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 |
| 3% Cu 48-hr. immersion | | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 |
| 3¼% Cu 24-hr. immersion | | 0 | 0 | 0 | 0 | | 0 | .. | 0 | 0 |
| 3¼% Cu 48-hr. immersion | | 0 | 0 | 0 | 0 | | 0 | .. | 0 | 0 |
| **Brush Treatments** | | | | | | | | | | |
| Osmo-creo: 1 lb. per 15-18 sq. ft. | | 0 | 1 | 0 | 0.3 | | >600 | .. | >600 | >600 |
| Pentox dark green: 1 gal. to 400 sq. ft. (2 coats) | | 0 | 0 | 0 | 0 | | 19 | 56 | 33 | 36 |
| Cop-R-Nap: 1 gal. to 400 sq. ft. (2 coats) | | 0 | 0 | 0 | 0 | | 447 | 301 | 47 | 265 |
| Control | | 13 | 16 | 5 | 11.3 | | >600 | >600 | >600 | >600 |
| Control | | 9 | 32 | 20 | 20.3 | | >600 | .. | >600 | >600 |
| Control | | 9 | 5 | 29 | 14.3 | | .. | .. | .. | .. |

During the first immersion period (March to August, 1953) small numbers of shipworms were found in the control panels and one in an osmo-creo panel. During the second immersion period (September, 1953, to June, 1954) the control panels were completely riddled. Counts exceeded 600 to the square foot, the maximum that it was found could be counted accurately. The osmo-creo panels were also completely riddled. Of the remaining two brush treatments Cop-R-Nap showed a high degree of infestation and Pentox dark green medium infestation. The pressure treatment with pentachlorophenol was not very effective and infestation was medium. All creosote and copper naphthenate treated blocks remained completely free of shipworms.

On the first examination it was found that all treatments had been effective in materially reducing or eliminating attacks by Limnoria. Pentachlorophenol 1/2 lbs. per cu. ft. was least effective, pentachlorophenol 1 lbs. per cu. ft. and osmo-creo slightly more so, Pentox dark green and Cop-R-Nap still more so, while all creosote and copper naphthenate treatments were completely effective. On the second examination it appeared that very little additional damage had been caused by Limnoria. Possibly this crustacean is not as active during winter and spring as it is in late summer. The destruction of the surface of the panels by Limnoria may be a factor in permitting infestation by Bankia, particularly in those panels with brushed on non-penetrating treatments.

None of the preservatives were effective in materially reducing fouling by encrusting organisms such as barnacles and mussels.

## Shipworm Investigations in the Steveston Harbor Basin

R.J. LeBrasseur

In the fall of 1954 the Department of Public Works requested the assistance of the Biological Station, Nanaimo, B. C. for an oceanographic survey of the Steveston Harbor Basin and approaches. The survey, conducted by S. Tabata, Pacific Oceanographic Group, revealed that there was sufficient salt water entering the Basin for the shipworm, Bankia setacea Tryon, to survive. A subsequent survey described the mechanism for the entry of the larvae of Bankia into the Basin. Essentially, this is a tidal phenomena. As the tide rises a layer of salt water moves along the river bed under the overlying fresh water, carrying the planktonic Bankia larvae with it. In the Harbor Basin the salt water is retained approximately 5 hours longer than in the river depending on the tidal height and the fresh-water discharge. In addition it becomes entrapped in depressions in the floor of the Basin which further assists larval settlement. In December, 1954, five sites for test-block sampling for larval settlement at different depths, i.e., 2, 4, 6, 8 and 12 feet above the bottom, were established. Examinations of these, and subsequent blocks revealed that Bankia larvae were settling in the area.

Following the discovery of Bankia a routine joint program by the Department of Public Works, Biological Station, Nanaimo and the Pacific Oceanographic Group, was undertaken. Weekly observations of temperature and salinity were made by means of a Solu Bridge. The number of sampling sites was doubled and the test blocks examined at monthly intervals. In addition it was suggested that blocks containing living Bankia be placed at each sampling site to determine their survival under the various conditions of salinity and cannery effluents.

It was found that infestation occurs in all months, except June and July, but only at depths greater than 15 feet below-zero tide datum, the mean depth of the Basin. Infestation was, therefore, limited to those depressions extending below the floor of the Basin. It was particularly heavy at the head of the Basin, where salt water in excess of 20 $^{0}/oo$ was retained, even during the freshet period. At the other sites where infestation was observed the salt water was kept out of the Basin for nearly five weeks during the freshet period, May to July.

Judging from the salinity observations the larvae which settled in December, 1954, are probably alive. Since August, 1955, the larval settlement has risen from 500 to 900 per square foot per month at the bottom test block. This gives a cumulative total of 2,700 shipworms per square foot. The very large increase suggests that mature Bankia are established in the Basin and are reproducing. Examination of the test blocks for larval settlement and growth indicated that the larvae are quite susceptible to relatively small changes in salinity. Larvae were observed to settle in salinities as low as 15 $^{0}/oo$ but they failed to survive. Only where the salinity was 20 $^{0}/oo$ and greater did they show any growth. These observations are in contrast to those reported for adult Bankia which have been reported as active in salinities as low as 5 $^{0}/oo$.

As a result of the investigation it was concluded that all pilings which extend more than 15 feet below the zero-tide datum need immediate protection. It was recommended that the depressions in the Basin be filled to the level of the main floor in order to prevent any further retention of salt water.

## POLLUTION - M. Waldichuk

Pollution studies have concentrated on effluent disposal from proposed new pulp mills and expansion of existing ones. The work has been closely coordinated with the administrative branch of the Department of Fisheries, from which the industry obtains authority for allowing wastes to enter waters supporting fish. The policy that "prevention is more effective than abatement" has been continued in dealing with pollution problems.

### Assessment of pulp-mill pollution in British Columbia

1. Present status of pulp mills

Old pulp mills in existence in British Columbia today produce a variety of pulp and paper products by processes which create a greater pollution hazard in their effluent disposal than modern techniques. In most such mills, sulphite chemical digestion is employed where all products excepting the pulp are discharged into the sea or other receiving waters. An economical recovery process for reclamation of the salts in sulphite waste liquors has not yet been perfected for wide use. Most new mills are installing the sulphate (Kraft) chemical process for their pulp production. This method permits reclamation of the salts by evaporation and burning of the organic material for heating. In general, effluent from a given tonnage of sulphite pulp produces about 10 times as great a pollution hazard as that from an equal tonnage of Kraft pulp. The present state of pulp mill production and pollution therefrom in British Columbia is shown in the accompanying table.

2. Type pollution conditions in British Columbia

There has been a sufficiently large diversity of type situations examined in pulp-mill pollution of marine areas to make some generalizations. The regions will be classified according to geographical types.

(a) Fiord type. Numerous pulp mills along the British Columbia coast are located at the head of an inlet, often adjacent to an estuary. The choice of such a locality stems from the availability of good forests nearby, ease of transportation of logs from inlet logging regions, fresh-water supply, power, and favourable harbour facilities. These mills may discharge their effluent

Present status of pulp mills in British Columbia

| Pulp mill | Location | Production status | Neighbouring fisheries |
|---|---|---|---|
| Port Alice | On Neroutsos Inlet at head of Quatsino Sound. | Sulphite pulp 220 tons per day. Expanding. | Sport fishing for salmon. |
| Ocean Falls | On Cousins Inlet off Dean Channel. | Sulphite, groundwood and kraft pulp. | Commercial herring fishery in Dean Channel. |
| Powell River | On Strait of Georgia - north-east side. | Sulphite and groundwood. | Sport fishing. |
| Woodfibre | On Howe Sound - north-west side. | Sulphite and groundwood. | Some commercial salmon fishery; sport fishing. |
| Duncan Bay | On Discovery Passage just north of Campbell River. | Groundwood 300 tons/day. Expanding. | Sport fishing for coho and spring salmon. |
| Port Alberni | At head of Alberni Inlet | Kraft pulp 230 tons/day. Expanding. | Small commercial salmon and herring fishery; sport fishing. |
| Harmac | On Northumberland Channel. just south of Nanaimo | Kraft pulp 600 tons/day. | Commercial herring fishery; sport fishing. |
| Crofton | On Osborn Bay off Stuart Channel. | Proposed new kraft pulp mill. | Oysters; troll salmon; sport fishing. |
| Port Edward | In Chatham Sound, on Watson Island. | Sulphite pulp. | Salmon fishery off Skeena River. |

into the path of migrating salmon and other anadromous fishes. Thus precautions are necessary, where a valuable fishery is at stake, to prevent any serious condition of pollution.

Fresh water draining into these inlets permits a mechanism of flushing the effluent rapidly and effectively. Being of about the same density as fresh water, pulp-mill effluent mixes only in the surface brackish layer undergoing a continuous seaward displacement. Thus the most effective control on the extent of pollution in an inlet-type condition is (1) controlled discharge of fresh water above a certain minimum flow, (2) release of effluent at the surface, and (3) maintenance of the effluent in the jet stream of the surface flow.

In almost all cases of Kraft mill effluent discharge, the major pollution problem lies in the reduction of available oxygen in the water. Where dilution is sufficient to overcome the oxygen demand, direct toxicity of the effluent to the fish becomes insignificant. The problem of pulp-mill effluent discharge in volumes above the level of natural receiving waters was met in the expansion plans of the Port Alberni pulp mill. The effluent from the existing mill producing 230 tons of Kraft pulp daily can be effectively flushed from the inlet by natural conditions of river flow. But the expansion to roughly 500 tons of Kraft pulp and about 500 tons of newsprint per day would impose an oxygen demand on the inlet system in excess of the natural supply. This is particularly true with the reduced flow during late summer. Thus, in order to satisfy the increased oxygen demand, the flow of fresh water must be controlled above a certain minimum.

Other inlet-type systems, where pulp mills are found, are Port Alice on Neroutsos Inlet, Ocean Falls on Cousins Inlet, and Woodfibre in Howe Sound.

(b) Coastal seaway type. In this type of location, the effluent is discharged directly into the seaway, use being made of the tidal mixing to remove the pollutant. There is seldom any estuary adjacent to such pulp-mill locations so that fisheries for salmon are not likely to be endangered. Substantial tidal mixing in the channel receiving the effluent provides rapid dilution and dispersion. At the Harmac (Nanaimo) pulp mill, the effluent discharges into Northumberland Channel, where currents reach a knot on certain stages of the tide. In the case of Powell River, effluent from the mill is rapidly carried away by the waters of Malaspina Strait and Algerine Passage. Discovery Passage currents may reach 7 knots off Duncan Bay, site of a proposed pulp-mill expansion, and the water is almost completely mixed from top to bottom. Dilution here is rapid and extensive.

Fisheries, which can be affected in this type of effluent discharge, are those which inhabit the inshore regions of spawn there. The spawning of herring near shore or the migration of juvenile salmon can be especially affected. In certain cases, shellfish may be located in the path of outflowing effluent. The location of a pulp mill or other industrial establishment on a coastal seaway, however, presents the least dangerous type of effluent disposal as far as fisheries are concerned.

(c) Restricted embayment type. This type of region receiving industrial effluent exists only rarely along the British Columbia coast, but is common in the U.S. Pacific Northwest (Washington and Oregon States). Being intermediate between the inlet-type condition and the coastal seaway, the restricted embayment by virtue of its openness does permit some flushing of its waters to an adjoining channel. Generally, however, it possesses a circulation all its own separate from that of the adjoining channels. Hence a certain amount of stagnation results.

The proposed pulp mill at Crofton is an example of this type of situation. Osborn Bay into which the effluent would be normally discharged is relatively sheltered from Stuart Channel and its flushing and circulation are sluggish. Similar conditions exist in Departure Bay and Nanaimo Harbour as observed in earlier surveys.

## Specific pollution problems

### 1. Osborn Bay effluent disposal problem

The proposal to establish a new pulp mill in Crofton was submitted to the Department of Fisheries in October, 1954. Subsequently, a survey was conducted in Osborn Bay during November, 1954 to determine what pollution problems, if any, would be encountered in the event that pulp-mill wastes are discharged into the inner harbour. Data from this survey were examined to determine if currents and water characteristics would be favourable for rapid removal of the effluent. It was concluded that surface currents in Osborn Bay are sluggish and largely controlled by winds. A general counterclockwise circulation exists there, which would tend to restrain the pulp-mill effluent within the bay. Tidal currents do not play a very vital role in the flushing of waters from this sheltered region.

Osborn Bay is fringed, particularly at the northern end, by oyster-growing areas. Living primarily in the intertidal zone, oysters are vulnerable to any harmful wastes found in the surface waters. It has been observed in cases of pollution of American oyster-farming regions that a certain detrimental effect does accrue in oysters subjected to Kraft mill effluent for prolonged periods.

Recommendations were made to the Department of Fisheries that a pipeline be extended out of Osborn Bay and beyond the Shoal Islands to effect a release of effluent in deep water well removed from oyster-growing grounds.

Additional observations made in Osborn Bay during late summer (September, 1955) give further support to the inadvisability of releasing effluent into the inner bay. Near shore, during periods of flood tide, the surface current sets into the bay. Moreover, the prevailing southeast winds direct the water shoreward. At some distance from shore, however, there is a predominant northwest-southeast flow of the surface current in a line parallel to the shoreline. This would prevent effluent discharge at a depth of 10 fathoms from returning into shore.

2. Duncan Bay pulp-mill expansion

Plans for expansion of the existing Elk Falls Co. pulp mill, located at Duncan Bay just north of Campbell River, were submitted to the Department of Fisheries in January, 1956. It has been proposed to expand the present 300-ton newsprint mill to 500 tons per day and, in addition, to install facilities for a 500-ton Kraft mill with a capacity of 175 tons per day for full-bleach Kraft pulp.

Duncan Bay has been examined for any possibility that pollution might occur following the increase in production and the increased effluent output. Located on Discovery Passage, where tidal currents may exceed 5 knots, Duncan Bay is subjected to rapid flushing. The pulp-mill effluent will discharge from a pipeline extending from a point of land jutting into Discovery Passage. This will permit rapid mixing and dispersal of effluent. The outfall point does not lie adjacently to any estuarial region supporting salmon runs. Adult salmon migrating from the Pacific Ocean to streams tributary to the Strait of Georgia navigate Discovery Passage, but are sufficiently far removed from the outfall region in their course. However, juvenile salmon in their seaward trek hug the coastline, seeking the shelter of small bays and inlets along the way. These young salmon would be of major concern if any pollution developed, inasmuch as they may spend some time in the less exposed regions such as Duncan Bay.

It is not anticipated that a serious case of pollution will occur as a result of the new pulp-mill installations. Recommendations have been submitted, however, that careful observations be made on the effects of effluent during the first summer of operation of the new mill.

# O C E A N O G R A P H Y - M. Waldichuk

## Fisheries oceanography

Work has been commenced on the relationship of environmental conditions to the fisheries. Much of the preliminary research has been directed toward a study of existing data on long-term oceanographic and meteorological observations and the relationship of these to the year-to-year trends in fisheries. Certain salient features in the environmental trends appear to bear a relation to the growth and size of stocks of certain fish.

Emphasis in future work will be on the study of the chemical constituents in order to determine their relationship to the fisheries. The chemical studies will be coordinated with plankton studies and fisheries exploration so that any relationships which may exist will be observed.

### 1. Environmental conditions and the fisheries

Meteorological data for certain stations along the coast of British Columbia are available since the year 1900. Fisheries data of various sorts date back to 1910. Daily sea-water observations provide a continuous record of sea surface conditions at numerous stations along the coast as far back as 1914. Oceanographic survey data in varying degrees of coverage have been recorded since 1926. Mean monthly sea-level fluctuations at tide-measuring stations along the coast are available to 1918. All these data show certain relationships with one another. A large incidence of northwest winds off the west coast of Vancouver Island, for example, during a particular month is associated with lower mean monthly sea level than usual. This, in turn, reflects a state of upwelling in certain regions where deep, saline, cold water is brought toward the surface. With this water come the nutrients that are so necessary in plankton growth.

Although certain measured factors may not be in themselves the controlling variables in fish growth and abundance, they may be useful indicators of a changing state. As an example, air temperature appears to show year-to-year trends which are related in their gross features to growth of salmon. Air temperature is always closely related to the amount of sunshine. If light is the limiting factor in plankton production, which might very well be true in the northeast Pacific, then air temperature is a reasonable index of changes in the environment associated with plankton growth.

There is speculation that it is the seasonal and year-to-year shifts in the West Wind Drift which cause the major fluctuations in oceanographic conditions and the fisheries in the northeast Pacific. These shifts are undoubtedly related to the variations in the pressure systems of the northeast Pacific from year to year. As found off the coast of Japan, it may be possible to relate the positions and strengths of pressure systems to the climatic changes in the sea and air. This approach is being followed at present.

The years 1950 to 1955 have witnessed very large fluctuations in the fisheries, both in size of individual fish and in catch. In 1951 there was an exceptionally large growth in herring on the British Columbia coast, particularly along the northern coast. The year 1952 exhibited an especially poor growth in herring along the lower east coast. Growth in spring and coho salmon was at a low in 1953. This was also true for whales. The year 1954 produced a Fraser

River run of sockeye that was outstandingly large. However, sockeye runs nearly everywhere along the coast dropped in 1955. For a salmon that spends, on the average, 27 months at sea, the catches suggest that the sockeye were favoured by a good growing year in 1952 and a poor growing year in 1953. This hypothesis is based on the premise that the first year at sea is the most important for growth and survival of the sockeye. Pink salmon provided large catches in 1953 and 1955 and an extremely small catch in the intervening year. Even with the odd-even cycles of large-small catches the variations encountered here were extraordinary. Being invariably 2-year fish, pinks suggest that 1952 and 1954 offered favourable conditions for growth in the sea, whereas 1953 was a poor year. This corresponds to the growth fluctuations in the other fisheries examined except the herring. There may be a 1-year phase lag in growth of herring and other fish for various reasons. Primarily, it may be attributed to the fact that herring are on a lower link of the food chain than the other food fish and exclusively plankton feeders. A second consideration is that herring probably feed closer to shore than salmon, so that they are less likely to be influenced by oceanic conditions.

The years, 1950 to 1955, were widely different meteorologically and oceanographically. Summers of 1950 and 1951 were warm with little precipitation, especially in 1951. The year 1952 had a delay in the seasons with a late summer and a dry, warm autumn. The years following have been relatively cool, wet and unsettled. Oceanographic surveys conducted during spring and summer, 1950-1952, revealed wide changes from year to year in both surface and deep water conditions.

A report on the analysis of various environmental factors and their relationship to the fisheries is in preparation.

2. Basic productivity

Preliminary work has been completed in setting up methods and equipment for chemical studies on nutrients. Total phosphates will be determined in samples taken by the Pacific Oceanographic Group during the North Pacific surveys in the summer of 1956. It is planned to obtain sea-water samples in surveys during the summer of 1956 for additional chemical analyses. More stress will be laid on analyses for the trace constituents such as manganese, iron and copper than has been the case in the past. The general feeling among other investigators has been that there is sufficient evidence at present to indicate that certain trace constituents may be limiting factors in plankton growth rather than the classical nutrients such as phosphates and nitrates.

### North Pacific plankton studies — R.J. LeBrasseur

Zooplankton samples were taken at each oceanographic station by towing a series of nets vertically through discrete depth intervals. Samples were obtained for each of the 85 stations from 0-100, 100-200, 200-300 and the 300-400-meter depth intervals simultaneously. Additional samples through 50-meter depth intervals were obtained during the first part of the cruise but these were discontinued because the volumes of plankton taken were too small.

The volumes of each sample and the proportion of the major constituents have been determined. The average volume was approximately 0.03 cc./cubic meter or about one-tenth that found in the coastal waters of British Columbia.

Plankton commonly make marked vertical migrations during each 24-hour period. They tend to move up towards the surface during the night and to sink with approaching daylight. Since the samples were taken without regard to daylight or darkness they had to be examined for evidences of diurnal movement. Only in the 200-300-meter depth interval was no variation found between the day and night samples. However, the variations were too small to be considered important. Accordingly, the samples have all been treated in the same manner.

Since the zooplankton is commonly made up of a variety of organisms it was necessary to determine the more important constituent members. Copepods were the dominant form taken in the samples. This was true for each depth interval as well as for the whole area. The copepods, together with the euphausiids, chaetognaths and amphipods, form the bulk of the food of pelagic plankton-feeding fish, such as salmon. Therefore, their distribution is of special interest as it may indicate where these fish are concentrated.

The plankton volumes were plotted for the survey area and the high and low concentrations (0.05 and 0.01 cc./cubic meter) noted. The highest concentrations (greater than 0.1 cc./cubic meter) were found in the coastal waters of Alaska. In the offshore waters the regions of high and low concentrations appeared to be randomly distributed. This suggests that the offshore surface water is fairly homogeneous, i.e., its physical and chemical characteristics (temperature and salinity) change very slowly. If such is the case, the concentration and distribution of zooplankton may be expected to vary both seasonally and yearly, since there is no environmental factor sufficiently persistent and dominant to make its presence felt by the plankton community.

Considered as food available to plankton-feeding fish the distribution of the zooplankton suggests: (a) plankters would not be responsible for concentrations of fish in mid-ocean, and (b) plankton-feeding fish can be expected to concentrate themselves in the more coastal waters of Alaska where a persistent high concentration of zooplankton is apparent over a wide area.

## Plankton collections of the Western Arctic expedition, 1954

R.J. LeBrasseur

The 1954 joint Canadian-United States Beaufort Sea expedition surveyed the area adjacent to Banks Island. Wherever possible, vertical plankton tows were made in conjunction with the oceanographic stations. The displacement volume, together with identifications of the various plankton constituents taken in the samples, are available in a data report.

Comparison of the samples with the physical-chemical features of the area failed to show a correlation between the animals and their environment. Crustaceans, particularly copepods, formed the bulk of the samples. The copepods were mainly made up of one species, *Calanus tonsus*. The other forms included coelenterates, gastropods, tunicates and chaetognaths of which the latter were the most abundant. The chaetognaths have been identified by R. Bieri at Scripps Institution of Oceanography as *Sagitta elegans* and *Eukronia hamata*, typical Arctic forms.

The plankton showed a marked seasonal change during the survey. The first samples taken just after the ice broke up, August 9, consisted of copepods, many of which exceeded 1 cm. in length, and two or three other groups of organisms. The last samples taken one month later, as the new ice was starting to form, were made up of larvae from a wide variety of organisms.

Compared to the central Pacific Ocean or the coastal waters of British Columbia, the Arctic appears to be quite productive. In the central Pacific plankton volumes vary about 0.01 - 0.05 cc./cubic meter, in the local coastal water they range from 0.1 to 1.0 cc./cubic meter, while in the Arctic the volumes ranged from 0.06 to 1.3 cc./cubic meter with an average of about 0.4 cc./cubic meter. Hence, at least for the six to eight weeks of the growing season, there is an abundance of planktonic food.