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FISHERIES RESEARCH BOARD OF CANADA

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BIOLOGICAL STATION

NANAIMO, B.C.

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A. W. H. NEEDLER, DIRECTOR

(WITH INVESTIGATORS' SUMMARIES AS APPENDICES)

FISHERIES RESEARCH BOARD OF CANADA

Report for 1960-61 of the Biological Station, Nanaimo, B. C.

The Nanaimo Biological Station carries out research on a broad range of problems associated with the development and maintenance of Canada's marine fisheries in the Pacific area. Subjects of its research include exploration of the fisheries resource to bring new stocks into use, biology and population dynamics of commercial species to provide the scientific basis for domestic or international regulation of fisheries, development of artificial means of increasing the production of fish and shellfish, problems of maintaining fisheries with increasing industrialization and population growth, and many others. Although all the Station's research is aimed at eventual application to fisheries problems, it is necessarily also concerned with the fundamental scientific knowledge on which the best solutions depend. Expansion of the Station's resources is needed if the growing demands for research from fisheries administration and fishing industry are to be met.

In 1960-61 a building with 2,500 square feet of net loft and 825 of laboratory space was constructed to house research on fishing gear. To extend experiments in artificial propagation of salmon two trailers were acquired, one with hatchery facilities and the other with living quarters, and preparations were begun for their use on sockeye salmon at Lakelse Lake. A small laboratory and cold-storage room were built on the Station's wharf to facilitate sampling and other work closely associated with vessels. Field facilities for studies at Babine Lake were improved. An experimental flume, constructed jointly by the Fish Culture Branch and the Station, came into use for studies of the swimming performance of salmon.

The Station again operated four vessels in 1960-61. The 78-foot general-purpose fishing vessel A.P. Knight was used mainly in herring and groundfish research but also in work on pollution and marine invertebrates. The 54-foot dragger Investigator No. 1 was used on groundfish, herring, crab, pollution and shellfish research, the 39-foot Alta on salmon and shellfish research, and the 30-foot Noctiluca mainly as a tender for the Port John field station but also to assist in prediction of oyster spatfall.

Two vessels were again chartered for studies of salmon on the high seas - the 84-foot Key West to seine salmon for tagging near the British Columbia coast and the 114-foot packer Fort Ross to study the vertical distribution of salmon south of Kodiak using special gill-nets. The 72-foot general-purpose steel fishing vessel Pacific Ocean was again chartered to collect fur seals in the open sea from Oregon to Alaska to meet Canada's research commitments under a treaty with Japan, U.S.S.R. and U.S.A. The chartered gill-netters Shirley D. (33 feet) and Lady Luck 1 (34 feet) again fished salmon systematically just above the upper limit of commercial fishing on the Skeena River to get immediate information on the numbers of salmon getting through the fishery. The Station supervised the work of the 81-foot fishing vessel Western Crusader chartered by the Industrial Development Service of the Department of Fisheries for deep-water clam explorations in the Queen Charlotte Islands area.

DISTRIBUTION OF SALMON STOCKS IN THE NORTH PACIFIC

Research on the distribution of salmon stocks on the high seas commenced in 1955 to carry out Canada's share of a joint program formulated by the International North Pacific Fisheries Commission in 1954. In the Protocol to the Convention between Canada, Japan and the United States which established the Commission, the three countries undertook to discover as soon as possible whether salmon of North American and Asian origin intermingle on the high seas and, if so, whether another line than the provisional eastward limit of Japanese salmon fishing, at 175°W, could be shown to divide the salmon from the two continents more equitably. To answer these questions the three countries have carried out one of the greatest co-operative fisheries investigations ever attempted.

The research program adopted by the Commission in 1954 included: (1) study of the distribution of salmon on the high seas through fishing by research vessels and statistics of commercial fisheries, (2) study of samples of salmon from both high-seas and inshore waters to recognize stocks of various origins on the high seas, (3) tagging and (4) study of the oceanographic background for salmon distribution and movements. To make as rapid progress as possible the program adopted by the Commission in 1954 included every method of recognizing salmon stocks which offered promise and some lines of research proved ineffective and were discontinued while others were productive. Canada's participation, through this Station, has included active field work in the eastern North Pacific and examination of material from all sources. It has included fishing to study salmon distribution, collection of samples both inshore and on the high seas, studies of samples as to their parasites, scale patterns and osteology, limited tagging and a leading part in oceanographic research.

In six years (1955 to 1960) this program has gone a long way towards answering the questions raised by the Protocol. It has shown that salmon are distributed very broadly throughout the North Pacific and Bering Sea and that salmon from the two continents intermingle over more than 25° of longitude in the Aleutian area, crossing the provisional line in both directions in large numbers. Because of the vastness and complexity of the distribution of many stocks intermingling over such a great area and because of variations in conditions with place and time, it has not been possible to obtain a reliable quantitative picture with the resources available. Nevertheless, the major features of the distribution and movements of a number of important stocks have been brought to light. Most important, it has been shown that, although stocks spawned in various areas occur together on the high seas, all or almost all salmon return as spawners to the fresh waters where they originated.

Reporting and re-orientation of the North Pacific salmon research. Having in mind the great advances already made and the doubt whether present resources and lines of attack could go much farther, the Canadian representatives on the Commission have pressed for reporting of the work already done and for review and modification of the research program. In 1960 the Commission took active steps towards the preparation of a comprehensive joint report on the results of its salmon research to date, as well as the publication of substantial individual papers. These efforts, especially the drafting of a joint report, involve much work by the staff of this Station and will continue to do so for another two years. It is, however, important to obtain as full reporting and as great a measure of scientific agreement as possible.

The Commission's research program has quite properly concentrated on the distribution and movements of salmon in the Aleutian area where Asian and American salmon intermingle and move in either direction across the provisional eastward limit of Japanese salmon fishing (175°W). Collection and analysis of material regarding salmon in other areas have received less attention and less has been learned of their distribution and movements. Furthermore, much remains to be learned of the factors responsible for salmon distribution and movements and for year-to-year variations in growth and survival. Prediction of the migration routes and sizes of salmon runs returning from the high seas is very important to regulation of the fishery so as to catch as many as possible while still allowing enough through to spawn. The Commission is reconsidering its program in relation to these broader objectives.

In the meanwhile the direction of Canadian research effort is being modified to give increased attention to the distribution and movements of salmon in the waters closer to our shores and to the oceanographic factors (including primary productivity) influencing distribution, movements, growth and survival. The work by the Pacific Oceanographic Group is reported elsewhere; an account of the biological work in 1960 follows.

Vertical distribution of salmon. Because of its importance to interpretation of the catches made by the shallow floating gill-nets used almost exclusively in the Commission's research program, further investigation of the vertical distribution of salmon in the open ocean was carried out by a chartered vessel in the western Gulf of Alaska (Latitude 55°N, Longitude 152° to 155°W), using a gill-net which could be set at various levels from the surface to a maximum depth of 160 to 200 feet. Daytime fishing in May and early June showed sockeye to be distributed throughout this vertical range. Night-time fishing indicated some upward shift in distribution, no fish being caught below 160 feet and more being present in the top 80 feet than in the daytime. In late June and July sockeye appeared to be restricted to depths of not more than 80 feet and some again shifted upward at night. The lower limit at which sockeye were caught coincided closely with the thermocline which had not yet developed during the early period. Chum salmon were also caught at all levels investigated by daytime fishing in May and early June and also showed a tendency to move upward at night. Restriction to surface waters with progress of the season appeared to be somewhat less pronounced than for the sockeye. Both species consistently occurred in numbers at depths much below the reach of conventional floating gill-nets.

Plankton and salmon feeding. Examination of stomachs showed that the most important food organisms for sockeye and chums in this area were amphipods and euphausians which together probably constituted 80% or more of the food consumed. Sockeye consumed more euphausians, chums more amphipods. Fish (mainly larval forms) appeared in about 50% of sockeye and 29% of chum stomachs but did not rank high in volume.

Plankton samples were taken in the fishing area by means of a standard plankton net (45 cm diameter) and an Isaacs-Kidd mid-water trawl with 6-foot aperture. Various depths from the surface to 440 feet were investigated. From the composition of these samples it was concluded that the salmon fed selectively, taking more amphipods and euphausians and fewer copepods and chaetognaths than would be expected from the relative abundance of these types of organisms. The finding of considerable concentrations of euphausians at depths of 80 and 130 feet in early June coincided with relatively large catches of sockeye at or near these levels.

Tagging. In order to learn more of the high-seas distribution of salmon spawned in Canadian rivers, tagging was started in 1960 in the eastern part of the Gulf of Alaska using a chartered seiner. The main effort was concentrated between 54°N and 56°N from the coast westward to 145°W, and along the west coast of the Queen Charlotte Islands. Persistent bad weather and a widespread scarcity of fish greatly restricted catches in these northern areas. Very few salmon were caught in areas far from land and the results indicated that seining is unsuitable for capture of salmon dispersed in the high seas. Of the 256 salmon caught (21 sockeye, 149 pink, 65 chum, 9 coho and 12 chinook) 5.7% were recaptured - sockeye, pinks and chums in southeast Alaska and northern and central British Columbia, chinooks on the Washington coast and in the Fraser River, and a coho in central British Columbia. None were recaptured to the westward. A short final cruise near the southwest coast of Vancouver Island tagged about a thousand salmon, 28.6% of which were recaptured in neighbouring waters.

Distribution of sockeye originating in Rivers and Smith Inlets. An investigation, begun in 1959, of the ocean distribution of sockeye originating in Rivers and Smith Inlets was continued. These fish can be distinguished from all other known stocks by characteristics of the scale pattern. Examination of more than 5,500 scales from sockeye caught on the high seas in 1957, 1958 and 1959 by Canadian, United States and Japanese research vessels yielded 45 showing the typical Rivers or Smith Inlets pattern. This more extensive material supported previous findings which showed ocean distribution extending westward to the Aleutians (170°W). Adults in the summer occurred from 155°W to the coast and immatures from 153°W to 170°W. The latter area is one in which immature sockeye from various sources are relatively abundant, and which may be an important rearing area for sockeye from other British Columbia rivers.

High-seas distribution of sockeye stocks as revealed by parasites. In 1960, samples of sockeye collected in 1959 were examined - the most extensive samples to date and the last planned for this study. As in 1958, effort was concentrated on detecting two parasites acquired by sockeye in fresh water and carried throughout their lives - the cestode *Triaenophorus crassus* found only in stocks originating in western Alaska (mainly Bristol Bay) and the nematode *Dacnitis truttae* found only in some stocks originating in Kamchatka. *Triaenophorus* is by far the more valuable of the two, being much more abundant in Bristol Bay sockeye than is Dacnitis in those from Kamchatka.

In all, 4,960 sockeye were examined - 299 smolts and 617 adults from North American areas, 144 adults from Kamchatka and 3,900 from the high seas of which about two-thirds were maturing in 1959. *Triaenophorus* was found in 270 specimens and *Dacnitis* in only 10.

The use of *Triaenophorus* as a natural biological marker for Bristol Bay and other western Alaskan sockeye has proved one of the most effective means of discovering their distribution and movements on the high seas. The results of examination of 1959 samples, noted below, confirm and extend the conclusions from the less extensive collections of the preceding four years.

All but three of the 150 mature sockeye infected with *Triaenophorus* found in high-seas samples were taken in May and June in an area extending from 145°W in the Gulf of Alaska to 175°E just south of the Aleutians, and from 170°W to 171°E in the Bering Sea. It appears that almost all mature Bristol Bay sockeye left the open ocean by the end of June, the three stragglers being taken in July or August.

The incidence of Triaenophorus in the returning runs in Bristol Bay was estimated to be between 10% and 13%. In the Bering Sea from 180° eastward the incidence in 16 samples comprising 869 maturing fish was quite uniform and averaged just over 10%. On the apparently reasonable assumption that the various Bristol Bay stocks are well mixed during their last two months in the sea, these results indicate that the Bering Sea samples from 180° eastward were largely of Bristol Bay origin. Samples taken in the Bering Sea from 180° westward to 171°E were inadequate for quantitative interpretation but at the latter longitude only 2% of 96 maturing sockeye had Triaenophorus, indicating a marked reduction in the proportion of Bristol Bay fish, the remainder probably originating in Asia.

South, but within 60 miles, of the Aleutians 8% of 349 maturing sockeye taken in 7 samples in May and June were infected, again indicating that most were of Bristol Bay origin although perhaps a lower proportion than in the Bering Sea. No Triaenophorus were found in 338 maturing sockeye in 11 samples taken in May and June farther south of the Aleutians at 175°E and westward. It appears that few maturing Bristol Bay sockeye were present there and the great majority were probably of Asian origin, as confirmed by the presence of two maturing sockeye with Dacnitis.

In the northern part of the Gulf of Alaska, samples of maturing sockeye taken at 55°N 155°W, 55°N 150°W and 58°N 145°W in late May and early June had 11%, 10% and 8% respectively with Triaenophorus, indicating a high proportion of Bristol Bay fish. Farther east and south at 55°N 145°W and 55°N 141°W in May the infection dropped to 3° and 0° indicating a lower proportion, presumably due to the presence of sockeye from North American areas east and south of the Alaskan peninsula. Migration of mature Bristol Bay sockeye out of the Gulf of Alaska about the end of May is suggested by a decrease from 10% with Triaenophorus in a sample taken May 25 to 28 at 55°N 150°W to none in a sample taken at the same place June 10 to 11.

The 49 immature sockeye found to be infected with Triaenophorus were taken from 50°N 145°W in the Gulf of Alaska to 175°E south of the Aleutians and from 175°W to 170°E in the Bering Sea, 13 in May and June and 36 in July and August.

Of the 8 immature sockeye infected with Dacnitis and therefore of Asian origin, 7 were taken in late May and early July west of about 170°E. One, taken in July at about 51°N 170°W south of the Aleutians, extends the eastward distribution of immature Asian sockeye identified by presence of Dacnitis. In 1956 two were found at 175°W, one in the Bering Sea and the other south of the Aleutians.

The outstanding result of the use of parasites to identify salmon stocks is demonstration of the occurrence of Bristol Bay sockeye over 45 degrees of longitude (145°W to 170°E) and 10 degrees of latitude (50°N to 60°N). In spite of this broad distribution on the high seas, sockeye with Triaenophorus have been found in spawning runs only in the western Alaskan area, although sampled extensively elsewhere. In other words they returned from the high seas only to the area where they acquired this infection in their early freshwater life, the only area where sockeye occur in fresh water with the pike (Esox) in which this parasite matures.

Study of chum salmon scales to distinguish stocks. The width and number of the rings or "circuli" on salmon scales reflect differences in the growth of the fish and, as a result, various scale patterns are characteristic of various areas. These characteristic patterns have been studied by examining samples of scales taken from chum salmon in inlets or river systems in North America, Siberia and Japan in 1956 and 1957 and have been used in attempts to recognize the origin of chum salmon taken in the same year on the high seas.

Almost two-thirds of the chum salmon examined from rivers in British Columbia and southeastern Alaska had scale patterns distinct enough to identify them in samples taken on the high seas. Similarly about one-third of those originating in northern Alaska and northern Asia had sufficiently distinctive scales to show that they came from that broad region. Scales of chum salmon in samples from southern Asia (mainly Hokkaido) were of an intermediate type which prevented identification of more than about 5%.

Examination of the scales from some 3,000 adult chum salmon sampled on the high seas in 1956 and 1957 revealed that mature North American and Asian chums intermingled extensively between 165°W and 175°E. The zone of intermingling tended to be widest near the Aleutians and narrower farther north in the Bering Sea. The approximate dividing line between areas in which one or the other predominated appeared to be in the vicinity of 170°W both north and south of the Aleutians. Chum salmon originating in British Columbia and southeastern Alaska were found throughout the Gulf of Alaska and westward to at least 170°W.

STUDIES RELATED TO REGULATION OF SALMON FISHERIES

Salmon contribute well over half of the value of the British Columbia fisheries and the salmon stocks are subject to increasingly heavy fishing. The large, efficient and mobile fleet is capable of catching such a high proportion of the salmon as they approach their spawning streams that, were it not for severe restrictions, the stocks would soon be reduced to a very low level. Regulation of fishing is, therefore, the most important tool for maintaining the yield at its optimum level. It will remain essential even if effective positive measures can be developed for increasing salmon stocks. Because fishing is becoming more intensive and because many salmon stocks have already been over-fished, improvement of the basis for regulation is a most urgent need.

For the most effective regulation it is necessary to know how many spawners are needed for maximum yields from the various stocks and how to restrict fishing enough to let those numbers through without reducing the catch unnecessarily. This involves basic studies of salmon and their environment to determine optimum levels of escapements and causes of fluctuations in abundance. Special studies are carried out on the sockeye and pink salmon of the Fraser River by the International Pacific Salmon Fisheries Commission and on those of the Skeena River by this Station for the Skeena Salmon Management Committee. The knowledge on which to base management of these important stocks is well advanced and steadily improving but for most of the remaining stocks, using over 1,500 rivers and streams, the information required for precise management is lacking. Intensive study of each stock is obviously impossible within any reasonable expenditure of effort, but more general investigations can be helpful.

In close co-operation with the Area Director of Fisheries, who is responsible for regulation, the Station (1) compiles and analyzes data on catch, fishing effort and escapement and (2) samples catches and escapements to obtain information on composition of the runs as to age, size and sex. In addition to their value to domestic fishery regulation these studies are used extensively in connection with the work of the International North Pacific Fisheries Commission and the Conference on Co-ordination of Fishery Regulations between the United States and Canada. Some of the current results of these studies are reported below; special studies on salmon management in the Skeena area, on the production of young sockeye in lakes and on Fraser River pink salmon are reported in later sections although also closely related to fishery regulation.

<u>British Columbia salmon catches in 1960</u>. The total commercial catch of salmon in 1960 (77,590,000 pounds round weight) was the lowest since such records were started in 1910, and the total catches of all species were lower than those in the previous generation.

The catch of 4,098,000 pink salmon was the lowest since 1946. Although good catches were made in the central part of the coast the total was 40% below the catch in the parent year, 1958. A similar decrease occurred from 1957 to 1959. The unusually warm and dry summers of 1957 and 1958 may have been responsible for a low survival. The pink salmon of 1960 also averaged small in size suggesting unfavourable oceanic conditions for growth and perhaps survival.

The catches of coho salmon (2,030,000 fish) and of spring salmon (742,000) were both the lowest since these two species were first recorded separately in 1945. Coho virtually all spend their first year in fresh water and mature at three years of age and the exceptionally dry summer of 1958 may have lowered their survival in fresh water. The catches of springs seem to have been affected by low levels of Columbia River stocks.

The catch of chums (1,837,000 fish) was the second lowest on record as was that of sockeye (2,858,000). For both species only the 1955 stock was lower.

<u>Sampling of catches for size, age and sex</u>. Pink salmon all mature at two years of age and virtually all cohos at three. On the other hand the ages at which sockeye, chum and spring salmon mature vary considerably. For these species it is therefore necessary to learn the age composition of the catches if we are to discover what returns have resulted from parent runs of various sizes or under various conditions. Catches of sockeye have been sampled in the major producing areas since 1912 but only in 1957 was sampling of catches of chum salmon for age, size and sex started. In 1960, for the first time, representative samples were obtained for all five species from all substantial fisheries throughout British Columbia. Almost 66,000 salmon were examined - 17,087

sockeye, 25,736 chums, 8,002 pinks, 7,253 cohos and 7,837 springs. As this program continues, more and more information will become available on the variations in the numbers and sizes of various broods and on the factors responsible.

<u>Sockeye of Rivers and Smith Inlets</u>. Among the information already emerging from this program it is noteworthy that the stocks present in these inlets in recent years have seldom produced as large a catch in the next generation as in the parent year. When the catches in the years 1950 to 1955 are compared with the total catches which resulted from those runs in the next generation, only the brood years 1951 and 1954 in Rivers Inlet and that of 1951 in Smith Inlet produced as large a resultant catch as that taken in the parent year. Whether the declines from generation to generation in most recent years have been caused by fishing or by natural factors cannot be said but there has been a downward trend.

<u>Age of chum salmon</u>. The sampling started in 1957 is already showing interesting results: (a) Chum salmon in northern British Columbia tend to be older, with 4-year-olds dominant, than in southern areas where both 3- and 4-year-olds are important. (b) There are very great changes in age composition from year to year which to a considerable degree reflect variations in the strength of broods or year-classes. Catch samples have contained from 3 to 91% of 3-year-olds, 8 to 95% of 4-year-olds and 0 to 21% of 5-year-olds. It is obvious that sampling for age is necessary if the success of various broods is to be understood. The brood year of 1955 produced relatively few 3-year-olds in 1958, 4-year-olds in 1959 or 5-year-olds in 1960. The brood year of 1956 was also a poor producer. The dominant feature of the 1960 catch was a high proportion of 3-year-olds which, it is hoped, presages a better run for 1961.

<u>Variations in the size and growth of coho salmon</u>. The average size of coho in troll catches in 1960 was higher outside Vancouver Island than in the Strait of Georgia as has been true since sampling started in 1952, and detailed

study of their scales indicates that this difference was present throughout the life of the fish. In 1960, however, the difference was smaller than in other years, especially in June and July. This suggests that coho which usually remain to feed in outside waters migrated into the Strait of Georgia earlier than usual. This would also explain the exceptionally good coho fishing there in 1960, which was the only year since 1951 when the troll catch was bigger in the Strait than outside.

Red and white spring salmon of the Fraser River. The red-fleshed spring salmon of the Fraser River system migrate early and spawn mainly in the upper tributaries at four years of age; the white-fleshed springs migrate later and spawn mainly closer to the sea, also mostly when four years old. There are, however, substantial numbers of younger and older fish in the runs of both species. Sampling of the catches for age has shown that the catches of the progeny of the red springs of 1953 to 1955 were greater than the catches of their parents and that, when the 1961 catch of 5-year-olds is added, the catches of the progeny of the 1956 run will be about equal that of their parents. In the case of white springs the catches of progeny equalled the catch of their parents only for the brood years 1952 and 1955, and were poorer for those of 1953 and 1954 and probably will be for 1956. Thus the red springs have been reproducing better than the white in spite of drastic closures in the autumn designed to protect escapements of both chum and spring salmon.

SALMON MANAGEMENT IN THE SKEENA AREA

In 1954 the Area Director of Fisheries and the Director of this Station were named as a committee responsible for the management of the important salmon fisheries of the Skeena River. As part of a large-scale co-operative program to improve the yield, this Station has carried out a research program to answer the two important questions in the regulation of salmon fisheries: How many spawners are needed to give the maximum catch over the long term? How can the fishery be regulated to let the right number of spawners through? To answer the first question, spawning escapements of sockeye and pink salmon have been studied in relation to the numbers of young fish or returning adults they produce. To answer the second, studies have been carried out on the intensity of the fishery and on the times when various components of the runs pass through, using special statistics of the fishery, tagging and special fishing at the up-river boundary of the fishery. The results of these investigations are used by the Committee in the formulation of regulations, in their adjustment as runs develop and in the assessment of their effects. The research in this area has also produced much of broader value. The work directed particularly to satisfy the needs of management has had to be based on as broad and thorough knowledge as possible of the biology of the salmon and of the Skeena River system as an environment for their reproduction. The work in recent years profits greatly from an initial program of research from 1944 to 1948, certain elements of which have been continued to the present time. The Station's most intensive research in salmon management is carried out in this area and affords opportunities for the study of many related problems of practical and scientific importance.

Improvement of sockeye production in the Babine Lake system. The sockeye runs to the Babine system, which average over 80% of the Skeena total, were badly damaged by a rock slide on the Babine River in 1951. In spite of very prompt action by the Department of Fisheries Fish Culture Branch to clear the river, the numbers of effective spawners getting through were reduced by about two-thirds in both 1951 and 1952. Stringent restriction of fishing on their progeny in 1955, 1956 and 1957 was necessary in order to restore these runs to their former levels. Achievement of the Committee's ultimate objective, the greatest possible sustained yield, requires still larger escapements. Analysis of the relationship between size of spawning stock and resultant production of Skeena sockeye in the next generation indicates that, on the average, the greatest yield to the fishery is obtained by a total escapement of about 900,000 spawners, considerably more than the average of recent years.

The distribution of the escapement within the system is also important. Investigations commenced in 1955 have shown that young sockeye do not disperse far from the spawning grounds where they are produced. Important spawning areas in the outlet contribute young sockeye to be reared in small northern basins of the system comprising only about 10% of the total lake area. The numbers here are usually adequate to make good use of the rearing capacity and high enough for crowding to affect growth. The spawning grounds tributary to the main basins of the lake are limited but even their relatively low capacity to produce sockeye fry was not being fully used by the small runs reaching them, leaving 90% of the system's rearing area greatly under-utilized. Fortunately the sockeye bound for the under-utilized part of the system were found to pass through the fishery earlier than those bound for the already well-utilized outlet areas. By special restriction of the fishing of these early runs the Committee has achieved a better distribution of the escapements and a gratifying increase in the numbers and size of young sockeye ("smolts") migrating to sea from the Babine system.

Disregarding the small precocious males or "jacks", the numbers of adult sockeye passing a counting fence at the outlet of the Babine system averaged about 450,000 from 1946 to 1954 excluding 1951 and 1952 when the run was blocked by the slide. In spite of the special restriction of the fishery the progeny of the blocked runs passed the fence in relatively small numbers - 71,000 in 1955 (the lowest escapement on record), 355,000 in 1956 and 433,000 in 1957. Well-distributed escapements of about optimum size entered the system in 1958 (842,000) and 1959 (783,000). The spawnings of 1956, 1957 and 1958 produced smolt runs of 22,000,000, 39,000,000 and 45,000,000 in the springs of 1958, 1959 and 1960. The latter was the largest yet estimated from the Babine system, although survival from egg to smolt was lower (2.9%) than with the smaller spawnings in 1956 (4.2%) and 1957 (5.9%). It will be most interesting to observe the size of the smolt run produced in 1961 by the second large spawning in 1959. The ultimate test of the effectiveness of the Committee's efforts to improve the Babine sockeye production lies, of course, in the numbers of adults which can be made available to the fishery in 1962 and subsequent years.

Capacity of Babine Lake to produce young sockeye. The systematic observation of the size, abundance and food of young sockeye in the various basins of the Babine Lake system were continued in 1960. They indicated that the population of young sockeye in the late summer of 1960, resulting from the large spawning run of 1959, was closely similar to that resulting in the summer of 1959 from the large spawning of 1958. There was no indication that the first large egg deposition had reduced the survival rate of the second. The questions remain of what is the ultimate capacity of the lake system to produce sockeye smolts and how best to approach it.

The investigations on young sockeye in the Babine Lake system since 1955 have shown that their growth begins to be affected by crowding at a density of about 2,600 per acre and decreases as crowding increases past that level. Investigations of the effects of smolt size on survival are at an early stage but their results, combined with the known relationship of growth to crowding at Babine Lake, suggest that the maximum return of adults per unit of lake area would be produced by a late summer density of about 4,000 young sockeye per acre. At this density Babine Lake would produce about 200,000,000 smolts, or about four times as many as the largest run yet estimated, that of 1960 from the 1958 spawning. While these figures are, of course, speculative, they do emphasize the under-utilization of the main basins of the lake as rearing grounds. The possibility is being explored of increasing the production of fry by artificial means as well as by regulation to assure the best numbers and distributions of escapements.

In 1960 the vertical distribution and diurnal migrations of other species, possible enemies or competitors, were studied using special monofilament gill-nets. The catches confirmed the vertical movements of young sockeye already indicated by echo-sounding equipment. They are distributed throughout the top 20 feet during daylight with maximum concentration about 10 feet, concentrate close to the surface in early moments of darkness and disperse over a greater depth range until daylight comes again. The closely related kokanee (land-locked sockeye) had a similar distribution pattern. Rainbow trout were caught mainly in the top 15 feet both by day and by night. Lake trout were caught in day-time from 50 feet down to 170 but were caught closer to the surface (especially 10 to 50 feet) at night. Ling were caught mainly from 70 to 180 feet. Whitefish were caught in the top 50 feet at night and from 50 to 100 feet by day. Peamouth and squawfish were caught mainly in the shallow parts of the lake system, only at night and nearly always in the top 30 feet.

<u>Skeena sockeye catch and escapement in 1960</u>. The 1960 sockeye run was expected to number only about 750,000, including less than 200,000 5-year-olds from the lowest spawning on record (1955) and about 500,000 4-year-olds from the moderate run in 1956. Although the whole expected run would barely provide an adequate escapement, regulation was designed to permit a small fishery while continuing the special protection of the early part of the run bound for the under-utilized part of Babine Lake. As fishing progressed it became apparent that the run was even smaller than expected and some further restriction of fishing became necessary. The fishery took 186,000 and about 320,000 spawners passed through, 263,000 (plus 49,000 "jacks") entering the Babine fishery. The reduced run (only two-thirds of expectations) and the small size of the fish

were shared with neighbouring areas and suggested poor oceanic conditions for survival and growth.

Estimation of escapements by special "test" fishing. An outstanding feature of the Skeena salmon investigations has been special standardized gill-netting carried out just above the up-river boundary of commercial fishing throughout each salmon season. Its primary purpose has been to provide prompt information on the numbers of salmon passing up the river, i.e. the total "escapement" to the Skeena system, although it also throws light on other subjects such as the proportions caught commercially in weekly fishing periods of various lengths. Detailed analysis of the data on the test fishing reveals many sources of variation in its catches. Two boats have been chartered each year and the efficiency of their skippers may differ consistently as much as 30%. Of environmental factors examined (wind, clouds, time of day, debris, seals, tide-levels etc.) only the stage of tide had a consistent effect, catches being higher when low tides confine the run to a narrower channel. An important factor is the effect of the number of fish in the net or its effectiveness in catching more, each fish in the net apparently frightening away a set proportion of those approaching it. In spite of these sources of error the test fishing has proved its validity as a preliminary measure of escapement which is extremely valuable in adjusting regulations to salmon runs as they develop.

Growth and age of return in Skeena sockeye. A major difficulty in predicting the size of sockeye runs lies in the fact that the proportions returning as 4-year-olds and as 5-year-olds vary greatly from year to year. Recently two promising leads have appeared which relate age of return to early growth.

The small 3-year-olds or "jacks", almost exclusively male, pass through commercial nets but are counted at the Babine counting fence. Comparison of their average size with the proportions returning as 4- and 5-year-olds in the same brood indicates that when the jacks are small the proportion returning as

4-year-olds tends to be small. In other words good early growth leads to early maturity and vice versa. This offers a means of predicting a year in advance the likely proportions of the run that will return as 4- and 5-year-olds.

Similarly good growth in fresh water tends to lead to early maturity. The size of smolts leaving Babine Lake has been found to be very closely correlated with the number of rings or circuli on their scales. Using the number of circuli in the freshwater growth as an indication of their size as smolts, it has been found that 4-year-old returning adults tended in general to have been larger as smolts than 5-year-olds. Thus the sizes of smolts may have some value in predicting age of return two years or more in advance. Both methods are being given further study.

Basis for management of Skeena pink salmon. An important objective of the Committee is to restore the catches of Skeena River pink salmon to their former much higher levels. Analysis of catch statistics shows that spawnings in years of abundance more often resulted in large returns than did spawnings in years of scarcity. The high catches of former years apparently depended on much larger spawning runs than we now have. This evidence of the need for larger escapements is supported by recent investigations which show that the number of fry produced is roughly proportional to the size of the spawning run and, therefore, that it is the number of spawners which is limiting production rather than the capacity of the streams.

Commencing in 1956 the annual estimates of escapements by officers of the Department of Fisheries have been supplemented by ground and air surveys, tagging and recovery procedures and fence counts, by Station personnel. During this period the odd-year escapements (1,058,000 in 1955, 970,000 in 1957, 1,478,000 in 1959) have averaged about three times as large as those in the even-numbered years (278,000 in 1956, 672,000 in 1958, 261,000 in 1960). The most important spawning grounds are in the Kispiox, Kitwanga and Lakelse tributary rivers averaging 290,000, 125,000 and 160,000 spawners respectively, together more than two-thirds of the total Skeena escapement. Tagging showed that the runs to the up-river tributaries pass through the fishery earlier than that to the Lakelse.

Estimates of the abundance of fry have been made at the three major tributaries since 1956. At first standard trap-netting was used which sampled only the surface waters but investigations in 1958 and 1959 showed that many fry moved downstream at greater depths and that the vertical distribution was quite variable. In 1960 nets were used which sampled the entire river from side to side and top to bottom. These indicated fry outputs from the Kispiox, Kitwanga and Lakelse Rivers of about 132,000,000, 34,000,000 and 30,000,000 and survivals from egg to fry of about 23%, 15% and 18% respectively. These generally good survivals, taken in conjunction with the earlier less complete data on fry produced by various numbers of spawners, support the view that production is limited by the size of the spawning run rather than the capacity of the streams and that the yield of the fishery would be improved by larger escapements.

Skeena pink salmon catch and escapement in 1960. The pink salmon returning to the Skeena as a result of the moderate spawning (672,000) in 1958 were expected to number about 2,000,000. Actually the run numbered little more than 500,000, one of the poorest on record, and considerably less than the number of spawners which produced it. The fishery took only about 270,000 and the total escapement was only about 261,000, similar in size to that two generations (four years) earlier but less than half the parent escapement. Special restriction of the fishery, because of the small size of the run, gave more protection to the late-running pinks of the Lakelse River which were therefore not as badly reduced as the runs to the Kispiox and Kitwanga.

A marked reduction in the return of pink salmon occurred in most areas in British Columbia and southeastern Alaska in 1960. It was associated with small average size of the fish. Unfavourable conditions for survival and growth in the sea are strongly indicated.

FRASER RIVER PINK SALMON

By a Protocol, ratified in 1957, to the Convention between Canada and the United States for the Protection, Preservation and Extension of the Sockeye Salmon Fisheries of the Fraser River System, the two countries agreed to conduct a co-ordinated investigation of the migratory movements of pink salmon entering Convention waters. A joint program was carried out in 1959 under a co-ordinating committee with representatives of the International Pacific Salmon Fisheries Commission, the Washington State Department of Fisheries (for United States) and the Canadian fisheries ministry (the Area Director of Fisheries and the Director of this Station). The work was done by the Commission in Convention waters and by the agencies of the two countries outside them. This Station carried out the major part of the Canadian share of the program with the close and valuable co-operation of the Fish Culture Branch and the Economic Services under the Area Director.

The program, the largest of its kind ever undertaken on Pacific salmon, involved the tagging of over 53,152 pink salmon in the northern and southern approaches to the Fraser. Over 32,000 tags (61%) were recovered in the fishery and 1,328 (2.5%) in fresh water. Intensive surveys, to recover tags and estimate spawning populations, were made in all major spawning areas from Puget Sound to Johnstone Strait. In the more important streams numbers of spawners were estimated by means of counting fences or by tagging and recovery programs. In Canadian streams north of Convention waters 29,520 tags were applied and 217,150 carcasses examined. Detailed analyses and preparation of a joint report have continued through 1960-61 into 1961-62 but valuable results have already emerged.

Out of a total stock of close to 10,000,000 the fishery took a catch of

7,375,393. Preliminary estimates of escapements are 540,000 for United States streams, 1,077,000 to the Fraser River system and 1,025,000 to Canadian streams north of the Fraser. Of the latter, 89% were in the 10 most important streams and 77% in the Skwakwa, Indian, Glendale and Squamish systems.

In 1959 almost all pink salmon using the Johnstone Strait approach were bound for Canadian streams north of the Fraser up to August 20 and 45% of the Johnstone Strait catch was taken in this period. During the remainder of August appreciable numbers of Fraser River fish were also present and about 17% of the catch was made in this period. From September 1 practically all pinks passing through Johnstone Strait were destined for the Fraser. At no time did pinks of United States origin appear in any numbers along the northern approach.

STUDIES OF SALMON REPRODUCTION AND PROPAGATION

Although regulation of the fishery is now the most important tool for obtaining the best yield from the salmon resource, the great long-term potential of positive, artificial measures for increasing salmon production must not be neglected. To develop effective techniques a great deal more must be learned about the biology, the capacities and the behaviour of salmon and, especially, their environmental requirements. The Station has been active in this field for some time. Studies on the conditions for the incubation of salmon eggs, and associated development of techniques for measuring those conditions in the gravel, have had wide application, including use in the design of artificial spawning grounds. Experiments have been conducted in an attempt to develop techniques of releasing hatchery fry with normal behaviour and good prospects for survival and return. Many facets of salmon biology have been studied which are applicable to artificial propagation. In addition, in 1960-61 initial steps were taken in a study of the capacities of streams to rear coho and in a study of the survival and growth of young salmon when they first enter the sea. Work in the general field of artificial propagation of salmon is being increased to meet the growing need for techniques of introducing runs to new areas, restoring depleted runs, or even maintaining new or larger runs in areas now lacking adequate natural spawning grounds.

Experimental hatchery investigations. The survival from egg to fry in modern hatcheries is from 5 to 10 times that in nature but survival from egg to returning adult is seldom greater and often much poorer. Work by Dr. W. S. Hoar at the Port John field station in 1955 suggested that hatchery fry might suffer greater mortalities because of distortion of their behaviour by the unnatural conditions under which they are incubated and released. In 1957 an experimental hatchery with a capacity of about 10,000,000 eggs was built on Kleanza Creek, a tributary of the Skeena, to determine the effects of incubating pink salmon eggs under natural conditions of temperature, darkness and water quality, and permitting the eggs to release themselves from darkened troughs with up-welling water.

These experiments have met with a number of difficulties and are not yet conclusive. A most serious factor has been the failure of the pink salmon runs to Kleanza Creek to meet expectations based on records of earlier escapements. This has made it necessary to supplement them with eggs from neighbouring areas with somewhat different conditions, thus introducing doubts as to the tendency of the fry to return to Kleanza as well as the progeny of native fish, and at the same time increasing the technical difficulties.

Returns of adults have, in fact, been disappointing. From the 1957 spawning, 345,000 fry from Kleanza eggs and 325,000 really abnormal fry from Lakelse River eggs were released; only 1,200 adults returned to Kleanza in 1959, a survival (of the Kleanza fry alone) of only 0.35%, about one-third of the estimated survival in major Skeena pink salmon broods in the same year. From the 1958 spawning 1,400,000 Kleanza and apparently normal Lakelse fry were released; only 600 adults returned in 1960, a survival from fry to adult of only one-fifth of that in other Skeena runs in that brood.

In 1959 only 400,000 eggs were obtained from the small Kleanza run, and were supplemented with 8,800,000 eggs from Kitwanga River which proved extremely sensitive to handling. About 6,000,000 fry were released in 1960 and the resulting return of adults will be observed in 1961. All the eggs from the Kleanza run of 1960 were shipped to Nanaimo or Robertson Creek, so that any return to Kleanza in 1962 will be a measure of straying of salmon produced in other areas.

The experimental hatchery operations have shown that, at little expense, fry can be made to release themselves from darkened troughs with up-welling water at about the same stage of development as that at which they emerge from the gravel in nature. The resulting fry exhibit a natural behaviour as regards hiding from light and migrating downstream in darkness.

The fry produced in 1960 showed a tendency to release themselves at an earlier than normal stage but it was discovered that this could be overcome by permitting escape from the release trough only at the time of day when the water was coolest. Laboratory experiments in the fall and winter of 1960-61 indicated that sockeye fry raised on open screens reached the "swim-up stage" earlier than fry on screens with one layer of gravel. Movements of fry in gravel are directed by water flow as well as gravity. A substantial time may elapse between the first swim-up stage and the period of main migratory activity.

In 1960 preparations were made for carrying out similar hatchery experiments on sockeye salmon at Lakelse Lake. The eggs from this run could be accommodated in a hatchery of about the same size as that at Kleanza. Natural propagation of this run has been studied intensively since 1944, giving good background for assessment of the effects of hatchery techniques. If successful, they would be applicable to such areas as Babine Lake where natural production of fry cannot fully use the rearing capacity of the lake.

Conditions for development of salmon eggs in spawning gravel of lakes. The "stand-pipe" instrument for measuring flows in the gravel of stream beds has been modified in 1960 and 1961 for use in the study of conditions in the gravels in lakes. Little is known of these conditions although there is increasing realization of the importance of lake spawning of sockeye in some areas. The modified instrument has now been tested and calibrated and found to measure very small changes in flow.

Use of the new instrument at Great Central Lake has shown three causes of water movements in lake gravels. Changes in lake level cause movement of water into the gravel back of the shore. Outflowing ground water, differing in temperature from the lake water, is found in certain places. Waves with a 2-minute period cause movements of water in the gravel; the persistent 20-minute seiche in Great Central Lake probably does so too but more careful measurements are needed to be sure.

Preliminary observations in co-operation with the Fish Culture Development Branch indicate that the gravel areas used by sockeye for spawning have higher permeabilities than neighbouring unused areas and are characterized by outflow of ground water; lake water temperatures may also play a part in the selection. Further research is desirable in view of the importance of natural and, perhaps, artificial sockeye spawning grounds in lakes.

Studies on salmon propagation at the Port John field station. Records and observations on the natural propagation of salmon have been maintained at Hooknose Creek, Port John, since 1947. For pinks and chums it has been found that the percent survival from eggs deposited to outgoing fry, although varying widely from year to year, is similar for the two species in a given year and they should be regarded as a single population in considering the effects of population size on survival. A great increase in fry output results from increase in size of spawning populations up to a level of some 10,000 spawning fish in this stream. Predation by sculpins and young coho is relatively heavier on small fry populations than on large ones and therefore tends to hinder the resurgence of stocks which have been depressed to a low level. Information is desired on the level of fry output that could be attained by elimination or control of predation, on how survival of fry after they enter the sea is affected by their numbers (if at all), and on the possible detrimental effect of heavy egg deposition on the survival of eggs deposited in a subsequent year.

Pink and chum escapements to Hooknose Creek in 1960 were relatively small. At least in the case of pink salmon, this is ascribed to the combined effects of heavier-than-average natural ocean mortality and high fishing intensity.

In 1955 to 1959 the sockeye fry produced in the main spawning area of the watershed (Tally Creek) were transferred to the mouth of Hooknose Creek in order to explore the possibility of promoting rapid growth and obviating freshwater mortality by acclimating the fish to a low-salinity environment. All other sockeye leaving the watershed as smolts were marked for subsequent recognition. Since few unmarked sockeye have returned to Hooknose Creek in the years up to and including 1960, it seems clear that the young fish did not survive well under the changed environmental conditions.

The output of coho smolts has been notably constant in the seven years ending with 1960, varying only from 4,513 to 6,756 (5,945 in 1960). This may indicate that escapements are large enough to permit full utilization of available territory and food.

Capacities of streams to produce coho smolts. The complex mixture of coho stocks in the fishery and the great number of spawnings widely scattered in space and time make it impossible to use the relationship between size of escapement and number of adults in the next generation to assess the status of coho stocks. No downward trend in coho catches is yet evident but it is desirable to know whether the increased fishing pressures are reducing the stocks below their most productive level. To throw light on this question investigations were started in 1960 to discover the capacities of streams to rear coho and the numbers of spawners necessary to use the streams to capacity. Analysis of earlier work at Hooknose, Nile, Waddell and Minter Creeks indicates that about 20 coho smolts per 100 square yards are produced (1% of eggs deposited) and that one pair of spawners per 120 square yards gives the maximum smolt production in these streams. A detailed study of the biology of coho smolt production will be made in a small stream 50 miles north of Nanaimo into which 833 adults were counted in October to January, 1960-61.

Early sea life of salmon. A major gap in our knowledge of the factors influencing the abundance of salmon lies in the period immediately following the entrance of the fry or smolts into the sea. Survival during their sea life is known to vary greatly and there are indications that much of the variation occurs very soon after they reach the sea but little is known of the mechanisms involved. Better knowledge of what variations occur, what factors influence them, and whether or not the numbers of young salmon play a part in their survival rate would have immediate value to salmon management by improving prediction of sea survival and of the numbers of adults likely to return and by discovering whether the capacities of the estuarial environments must be taken into account in planning regulation or artificial propagation. Towards the end of 1960-61 a field program was initiated at the Port John field station involving the marking of half of the seaward migrant pink and chum fry and observation of their movements, growth and survival after they enter salt water. Early observations have been promising.

Young sockeye in waters overlying high salinities. It has been suggested that a great potential for sockeye production lies in the damming of inlets to convert them into lakes similar to Owekino and Long Lakes which produce the important Rivers and Smith Inlets runs. In addition to the basic problems involved in establishment of a sockeye run in a new area, and to cost and engineering factors, it might not be easy to remove the salt water from the lower levels of such artificial lakes. To throw light on the suitability of fresh water overlying salt water as an environment for young sockeye two areas were briefly examined in 1960. Sakinaw Lake, which has had intrusions of salt water in the past, has trace salinities (0.12 per mille) in its surface waters but more saline, oxygen-poor water below 80 feet. The capture of 57 normal young sockeye in the surface waters with relatively little effort indicates that the lake is a satisfactory nursery area in spite of its unsuitable deeper waters. Wyclees Lagoon (between Long Lake and Smith Inlet) had more saline surface waters and apparently very few young sockeye.

EXPERIMENTAL STUDIES ON PHYSIOLOGY AND BEHAVIOUR OF SALMON

The need for developing a better understanding of the salmon's ability to withstand changes in its freshwater environment arises from the gradual, and sometimes rapid, changes which industrial growth can produce. In particular hydro-electric development, irrigation and pollution can conflict with the conservation of salmon. In order to be prepared to assess the limits of the changes salmon can tolerate, a broad program of research was initiated in 1957, dealing with such basic aspects as the energy demands of activity, changes in blood proteins during maturation, diagnosis of stress, factors affecting upstream migration, and orientation in salmon smolts. Progress is being made in all these fields and research is becoming concentrated on more particular objectives based on early findings.

The program in its early stages required the design and acquisition of facilities for holding and studying live salmon. Of the five species of Pacific salmon in our waters, four have now been successfully held in captivity, and detailed records made of their spawning behaviour. A large flume adaptable for use in studying performance and behaviour while swimming at speeds up to 3 feet per second was brought into use for the first time at Robertson Creek in 1960, with the co-operation of the Fish Culture Development Branch. This addition completes the basic facilities sufficient to investigate a considerable variety of the biological aspects of the problems posed by industrial development.

Swimming ability of adult sockeye. Because of the high level of activity which salmon must maintain to migrate up rivers, constantly meeting the river's current, experiments to determine their capacity for sustained swimming have been started. Sockeye, averaging 21 inches total length, were able to swim at 2.5 feet per second for at least 100 hours without rest of any sort. The threshold appears to be about 2.9 feet per second for uninjured or uninfected fish, above which fatigue sets in rapidly. In one exercising cage, placed near the high velocity end of the Robertson Creek flume, three fish were able to swim 235 miles at an average speed of 2.3 feet per second during 6.2 days. At this speed it was apparent that recovery from periods of greater activity, occasioned by aggressive contests for territory within the cage, was possible.

There has been considerable speculation about the rest required by salmon, and a belief that bursts of swimming not only characterized behaviour but were a physiological requirement. This appears to be true only for the "fatigue velocities" of 3.0 feet per second and above. It is now apparent that lesser velocities can be maintained 24 hours a day without cessation.

It was also observed that, at high velocities which would normally be fatiguing, salmon, if permitted, can glide in surface waves with no more than the effort of keeping fins appropriately spread. By fanning the pectoral fins forward and down they can also grip small irregularities on the bottom and readily hold against the current. The activity in quiet water appears, from a study of tail beats, to be equal to swimming at about 0.2 to 0.3 feet per second.

The frequency of tail beats at the threshold of fatigue was approximately 200 per minute.

Complications, arising from intense infection by the naturally-occurring fungus Saprolegnia at prevailing high temperatures (65° to 72°F), curtailed the month-long studies necessary for determinations of energy expenditures. This disease attacks and spreads from the slightest injury. It can kill an infected fish within five days. If the fish is forced to swim, the debilitating effects are apparent within three days. A study of the injuries on fresh-run fish captured in the Great Central Lake fishway showed 50% to 60% with some sort of damage. Any factor contributing to damage or to increased freshwater temperature, such as dams and reservoirs, can be expected to promote the occurrence of this disease.

Tolerance of salmon to pulp-mill effluents. Experiments have been conducted to discover the influence of variations in the normal environmental conditions of temperature, salinity and oxygen concentration on the tolerance of young coho salmon to weak oxidized black liquor, as measured by their survival time in various concentrations. Three levels of temperature (7, 12 and 17°C), oxygen (3, 5.5 and 8 parts per million) and salinity (0, 11.3 and 22.5 per mille) were used, which the young salmon can ordinarily tolerate. Their tolerance of the oxidized black liquor was found to be greatest at the intermediate level of salinity and to decrease both with increasing temperature and with decreasing oxygen. Poor environmental conditions, such as occur in nature when oxygen is depleted by the oxygen demand of pulp-mill effluent, reduced survival time of the young salmon in a 0.0025 solution of oxidized black liquor to one one-hundredth of their survival time in the same concentration when levels of temperature, salinity and oxygen were optimal. Such a variation in the resistance to the same concentration of a toxic substance emphasizes the fallacy of designating a single level as the "safe" limit of pollution, where other environmental factors vary. The toxicity of pollutants must be described throughout the range of other environmental factors and the permissible concentration of the pollutant adjusted to the conditions met in different situations.

It is important to note that the practice of discharging effluents into well-flushed, cool, coastal waters is strongly supported by the results of these bio-assays. The toxicity of the "full-bleach" effluent is related to its black liquor content which is normally low. Tests on fractions of the "unbleach" effluent, using Daphnia pulex, reveal that the sulphur components are the main contributing lethal constituents.

Toxicity of the insecticide "Thuricide" compared with that of DDT. A commercial formulation of "Thuricide", an insecticide derived from the associated toxin of Bacillus thuringiensis, was found to have only one-thirtieth of the toxicity of DDT to young salmon. The oil-wetting agent in the formulation proved to be toxic and to interact with the other ingredients contributing significantly to the toxic effects. However, this is the first alternative material to DDT which shows promise in being markedly less injurious to salmon.

Biochemistry of maturation in salmon. Maturation in female egg-laying vertebrates is associated with the appearance or increase of certain components of the blood plasma, which are then transported to the developing eggs. The two major classes of organic components of yolk are proteins and lipids, and their levels in the blood may serve as a guide in determining the stage of maturation of the fish.

An investigation of the qualitative changes in the plasma proteins of coho salmon during certain periods of their life cycle has now been completed. It was reported a year ago that fry in fresh water, immature fish of both sexes in salt water, maturing males and ripe females had four protein fractions in their blood plasma. A fifth fraction has now been demonstrated to be present and it is thought that it may be comparable to the γ-globulin of other vertebrates. The presence of a sixth protein fraction in maturing females has been confirmed, probably a mixture of the phosphoproteins lipovitellenin and lipovitellin which have been isolated from the plasma of other egg-laying vertebrates and extensively studied in bird egg yolk.

The temporary disappearance during the parr-smolt transformation of the leading plasma protein fraction, as separated by zone electrophoresis, has also been confirmed. Other investigators have recently reported a similar physiological change during amphibian metamorphosis. An experiment during the past year has shown that the blood picture of male sockeye salmon can be made to approach that of sexually maturing females by injection of the hormone estrogen. It was also demonstrated that injection of additional estrogen in maturing female salmon increased the serum changes associated with egg formation. These results indicate that the effects of estrogen on the serum constituents of sockeye salmon are similar to those obtained in other egg-laying invertebrates.

These results have made it possible to follow the development of maturity in living salmon by taking blood samples, and are being used to study the influence of environmental factors on maturation and on its timing.

Diagnosis of stress in salmon. Work was continued on the transaminases of salmonids to determine the value of serum enzymes as indicators of tissue damage and that of tissue transaminases as indicators of changes in metabolism. Existing methods for measuring several transaminases have been suitably modified and both serum glutamic-oxalacetic transaminases and tissue glutamic-pyruvic transaminases have been found in coho salmon and rainbow trout. The reversibility of the serum glutamic-oxalacetic transaminase has been shown; its optimum pH range is 8 to 9 and it continues to function to at least 35°C. Its action differs somewhat from the corresponding enzymes of mammals and bacteria. This line of investigation is being pursued in an attempt to develop a means of assessing stress or damage in living salmon by blood sampling. Major portions of the circulatory system of salmon have been photographed, using radiographic techniques, as an aid to physiological studies of metabolism.

Two new diseases of fish. A study of apparent bacterial "kidney disease" in cultured pink salmon (*Oncorhynchus gorbuscha*) has been completed. The disease is characterized by the presence of visible lesions, pustules, and necrotic areas in and on the major internal organs, particularly the kidney. Externally, however, most of the affected fish appeared normal. Both sexes were equally sensitive to the disease and there was no significant difference ($p > 0.5$) between the weights and lengths of healthy or diseased fish of either sex. This suggests that infected individuals continued to feed normally at least during the incipient stages of this slow-developing disease. The lesions and necrotic areas were found to contain masses of minute (0.5-0.7μ × 0.8-1.1μ) gram-positive rods, typical of kidney disease. Data indicate that these cultured pink salmon had an inherent predisposition to the disease.

A brief investigation was made of lingcod (*Ophiodon elongatus*) mortalities in the Porlier Pass area. The actual cause of death was not determined, but it was discovered for the first time that lingcod are hosts for the widespread protozoan, *Trichodina*. These micro-organisms were seen feeding on the gill epithelium and it is suggested that they are directly or indirectly involved in the death of the host.

Ecological studies on migrating salmon. The need to know more about the individual behaviour and environmental selections of migrating adult salmon has required the development of advanced techniques for underwater photography. A system of colour cine-recording has been devised, using natural light and correction filters designed to produce maximum identification of movement, form and background. Use of time-lapse photography in analyses of jumping, attacking and schooling is now possible.

Observations on the habits of adult sockeye and coho salmon in the clear waters of the Somass River and tributaries produced further evidence that spawning migrations are not just a matter of moving upstream in a simple obstacle-passing sequence. Migration is restricted to limited pathways through the total available water space, and continues for only limited periods during the total available time. The remainder of the time is spent performing many non-migratory activities such as wandering, finning, jumping, circling and holding. The actual routes and timing of migration appear to depend on the interaction of various biological and environmental factors, seven of which have been substantiated. These include daily, lunar and seasonal cycles of activity or behaviour (or both), environmental effects of weather changes, hydrodynamic forces and crowding, and interspecific differences. Passage through falls and rapids is by individual darts, interspersed with holding. In relatively calm river stretches, upstream movement, when it occurs, consists of sustained steady swimming along a narrow limited pathway close to the bottom of the deepest channel. The entry of salmon into rivers from the sea appears to be subject to influence from weather fronts which may be perceived by the salmon as a configurational stimulus of increasing cloud cover. There is the possibility that this sign stimulus releases the activity of swimming, which, if further influenced by increasing stream discharge due to rain, results in greatest upstream movement.

Spawning behaviour of salmon. Extensive observations on sockeye salmon captured soon after entering fresh water and held in a large tank indicate a steady increase in reproductive, aggressive and escape activities for at least two months prior to spawning, except in reproductive display which shows a late slump as aggressive behaviour reaches a peak. The spawning behaviour of this species compared with that for chum, pink and coho salmon shows very little difference in general pattern. Such differences as do exist relate mainly to intensity, duration and frequency of display and spawning movement. The spawning sequence for the female includes: slow swimming over gravel beds (searching), holding over and defending an area (standing), nosing the gravel and start of digging (nosing), scraping anal fin over gravel with intensive digging (scraping), holding over center of the redd with anal fin and body arched down (crouching), circling with concentrated digging (circling), body arched down into redd, mouth open, vibrating of dorsal and anal fin with release of eggs if accompanied by male in same attitude (spawning), and finally short digging to cover eggs with accompanying movements forward, feeling the gravel with anal fin again (closing nest). This last phase merges into scraping behaviour with the same pattern carried through to spawning two to five times until the female is spent.

Orientation in sockeye smolts. Orientation and daily cycles of activity in sockeye smolts have been studied by the use of a rotatable circular plastic tank shielded in such a way that vision of the sky only was permitted. These studies, conducted at the Biological Station, at Great Central Lake and at Babine Lake, indicated definite directional preferences, particularly late in the afternoon and at dusk. Overcast skies or artificial covering of the tank resulted in random directions. A gradual change in orientation occurred over a period of 3 months in the Great Central Lake smolts; also a marked shift occurred with the introduction of salt water.

In general it has been tentatively concluded (1) that the directional preferences correlate with the compass direction in which the sockeye smolts have to swim to get to sea, (2) that the orientation is related to vision of the sky, (3) that celestial phenomena alone are not sufficient for the fish to determine geographic position, and (4) that the orientation mechanism is an innate pattern.

POLLUTION

Pollution, accompanying industrial development and population growth, offers a serious long-term threat to fisheries, especially those for anadromous and inshore species. To help keep damage by pollution to a minimum the Station, working in close co-operation with the Area Director of Fisheries, carries out surveys of actual or potential cases of pollution and makes recommendations regarding disposal of waste materials. Research is also conducted on the chemistry of pollutants to develop means of recognition and, if possible, treatment to reduce their toxicity. The fundamental studies on salmon physiology and behaviour, reported in the preceding section, help to recognize, understand and predict damaging effects of pollution.

Annual survey of Fraser River Estuary and Burrard Inlet. In order to follow changes in pollution in this populous and industrialized area through which important salmon runs must pass, annual surveys have been made starting in 1957. The 1960 survey of the Fraser estuary was made a month later than usual, in early September, when low run-off and high temperatures might be expected to produce the most highly polluted conditions in the year. Nevertheless, relatively high oxygen concentration and normal alkalinity were found in all parts of the river and estuary.

Better-than-average conditions were also found in all parts of Burrard Inlet except near bottom at Port Moody. There the level of dissolved oxygen (less than 3 milligrams per litre) was lower than on any previous survey although surface water had 15 milligrams per litre. The heavy oil slicks and concentrations of phenol observed in 1959 were not present.

Observations at First Narrows showed considerable vertical mixing. The deep water of lower Burrard Inlet appears to be formed in this mixing area. No water saltier than 29 per mille penetrates over the sill at the First Narrows. Mixing in the two Narrows breaks Burrard Inlet into two circulation cells, one between Second Narrows and the upper part of Port Moody and the other in Vancouver Harbour between the two Narrows.

<u>Surveys relating to pulp-mill pollution</u>. The pocket of low dissolved oxygen (<1 mg/l) was noted again in the deep water behind the inner sill of the upper, constricted part of Howe Sound. Observations along the west side of the sound, past the pulp mill at Port Mellon, gave a vertical dissolved oxygen distribution typical of the wide, well-ventilated part of the sound. No measurable effect was noted from the kraft pulp mill at Port Mellon.

A survey of Malaspina Strait was conducted for the first time to note any effects of the pulp mill at Powell River. Dissolved oxygen in surface water at all stations was at least 100% saturated and in some cases considerably supersaturated. Deep water was about normal for this part of the Strait of Georgia with dissolved oxygen values of 40 to 50% of saturation.

There has been a marked decline in the amount of dissolved oxygen in the lower half of the water column in Alberni Harbour during the five late-summer surveys from 1954 to 1959. In 1954 the range was between 4 and 5 milligrams per litre in the bottom 10 feet and in 1959, 2 to 3, with a corresponding drop in pH. While data from 1939 and 1941, before the pulp mill was built, show low levels of dissolved oxygen in bottom water even then, the oxygen-poor layer appeared to be much thinner than it is now.

There was a slight increase in kraft mill effluent concentrations in the surface waters of Osborn Bay and Stuart Channel during the last year, which may be associated with increased production of the pulp mill or with a gradual accumulation of effluent in the waters adjacent to the pulp mill.

<u>Chemistry of kraft mill effluent</u>. Preliminary results have shown that the major toxic principle of unbleached kraft mill effluent can be separated by steam distillation. This toxic substance is unstable to heat and oxidation, and is partly extractable with hexane. A trace of steam-volatile, hexane-soluble, toxic cation is probably also present.

Because the black liquor was found to contribute most of the toxicity of kraft mill effluent, research has been concentrated on evaluating its characteristics. To overcome the rapid decline of its toxicity on exposure to air, a device has been constructed to sample the liquid anaerobically. Analytical techniques have been devised to determine the inorganic sulphur compounds present. So far sulphide and thiosulphate ions have been detected. Separation procedures have been devised involving ion exchange and, consecutively, carrier distillation, progressive acidification, and solvent extraction of liberated compounds, followed by gas and partition chromatography. Toxicity tests have been carried out on Daphnia.

By a series of ion exchange separations a toxic cation was removed and further concentrated by vacuum distillation. The gas from untreated black liquor was non-toxic but that removed from acidified liquor was quite toxic. Methyl mercapton and hydrogen sulphide have been identified in these gases by gas chromatography.

Solvent extraction with benzene has yielded neutral toxic components, consisting of sulphur-containing compounds, terpenes, etc. By progressive acidification with carbonic and hydrochloric acids, a series of weakly and strongly acidic substances has been concentrated. Partition chromatography of one of the fractions on a silicic acid column indicated the presence of several components having distinctly different odours. Further separations of the fractions have been effected using silicic acid and magnesium oxide chromatoplates.

Phenol determination in sea water. Using the 4-amino-antipyrine test for phenols, it was found that there is about 25% less colour development when sea water of 25‰ salinity is used for standards instead of distilled water. Aqueous phenol solutions and the 4-amino-antipyrine reaction mixtures were found to be quite unstable and should be processed as soon after sampling as possible. The chloroform extracts remain unchanged in absorbance for a day or two and can be stored for some time before spectrophotometry.

The simple nitroso test used for spent sulphite liquor determinations in sea water was found to be quite adequate for phenol concentrations in the range of 100 parts per billion to several parts per million or higher, when the high sensitivity of the 4-amino-antipyrine test is not required.

Radioactive pollution in the sea. Problems in this field have been kept under review through literature surveys and participation in committee work, and in a symposium. A number of reviews and theoretical evaluations on certain aspects of radioactive waste disposal have been completed and are being released as circulars or manuscript reports.

Samples of shellfish and salmon have been sent to the low-level radiation laboratory of Atomic Energy of Canada Limited for analysis. Preliminary results show that only zinc-65 is present in significant concentrations, but still much below maximum permissible levels for human food.

HERRING

Studies related to regulation of the fishery. The object of the Station's research on the British Columbia herring populations and fishery is to provide the scientific basis for a management program designed to permit the greatest catch possible from all stocks under conditions which will promote maximum recruitment. Results to date have indicated that abundance, and hence the size of the catch, depends on the strengths of the year-classes contributing the dominant age groups and that year-class strength appears to be determined by natural factors, possibly during the larval stage. Fishing would be a factor only if the size of the spawning stock remaining after the fishery bore a direct relationship to the size of the resulting year-class. No reliable suggestion of such a relationship has been found in any population (with the possible exception of that in the "Upper Central" district of the coast). The stocks therefore appear to be able to withstand the present high level of fishing intensity.

Total mortality rate in most populations in recent years has been estimated to be 80% or more (fishing mortality about 60% and natural mortality about 50%). Because of this high rate there is reasonable doubt whether the herring stocks could withstand any large, long-continued increase in fishing effort. Since the spawning stock has not yet been reduced to the point where the size of the resulting year-class is directly affected, existing regulations would appear to be unnecessarily restrictive. Before they are greatly modified, however, a test is desirable, in one population at least, to determine how much the fishing effort can be increased before the spawning stock is reduced to that point and whether this increased effort is economically profitable to the industry as a whole. Even if the effort could be increased enough to raise the total mortality rate to 90%, the catch would only be increased about 13% and this throws doubt on the economic feasibility of such an increase. If effort cannot be increased sufficiently then regulations to maintain the herring fishery would appear to be virtually unnecessary. If effort could be increased sufficiently and maintained economically, regulations should be modified to permit it. Depending on the results obtained, it might be necessary to carry out such tests on more than one population, because there is some indication that the amounts of spawn required to maintain the various stocks may differ considerably.

While the level of effort required to reduce the spawning stock below the critical level where year-class strength is directly affected could be determined most quickly through a large-scale commercial fishing experiment, pertinent information may be obtained over a period of years under existing conditions by study of the effects of reductions in spawning stock size from other causes. These might occur if a low level of population abundance coincided with a high level of availability to the fishing fleet and a good demand. Such conditions could occur in any stock at any time, and would be revealed by analysis of the relationship between year-class strength and spawn deposition. A continuing time-series of estimates of year-class strength is also necessary if light is to be thrown on the relationship between year-class strength and environmental conditions which is important to prediction of abundance and hence to both exploitation and regulation. For these reasons data on age composition, catch and spawn deposition are collected annually from all populations.

Distribution of herring in summer. In addition to these continuing population studies an investigation to determine the offshore distribution and abundance of herring during the summer was initiated in 1959 and continued in 1960. In both years it was limited to the west coast of Vancouver Island, mainly in the region off Barkley Sound. It has shown that, at that time of year in that area, herring are widely scattered over the coastal banks, and that the schools are small and fast moving. No large concentrations were found. The herring caught were mainly 2-year-olds; 3-year-olds, the dominant age group in the winter fishery, were not found in the numbers expected.

Gill nets, whether set as drift nets or as sunken nets, were found in 1959 to be an inefficient method of exploration. The mid-water trawl showed more promise but could not be fully tested because of loss or breakdown of equipment. Further development of the mid-water trawl was carried out in the winter of 1960. Improvements were made to the echo-sounder attached to the headline of the net, to indicate its depth and mouth opening, which reduced attenuation of signals resulting from the long length of wire between transducer and receiver. The Mark V Navy kite-otters were modified for use as otters. The lateral spread of the net attained was almost as great as with 80-inch aluminum boards, and the drag was considerably less, permitting greater speed for similar engine revolutions. Further modifications to the trawl are in progress.

Young salmon in commercial catches of herring. Observations were again made in 1960-61 on the numbers of young salmon (grilse) in herring landings. The numbers of grilse caught were relatively small and considerably less than in the previous season, possibly because the fishery started later and did not operate in the area where larger numbers were caught in 1959. More grilse were caught in Swanson Channel, off the lower east coast of Vancouver Island, than in other areas. None were found in the herring catches from the west coast of Vancouver Island or from northern districts. About three times as many grilse were caught when lights were used to attract herring as when no lights were used.

GROUNDFISH

A relatively small, year-round fishery for groundfish other than halibut takes place on various banks along the British Columbia coast. Otter-trawling is the principal method of fishing and this accounts for all landings of sole (six or seven species), grey cod, scrapfish for minkfood and about half the landings of lingcod. Most of the trawl catch comes from international waters where the fleet competes with vessels from the United States. A hand-line fishery for lingcod occurs in inshore waters, while in offshore waters there is a long-line fishery for blackcod, which takes place mainly during the closed season on halibut.

In recent years, annual total production of groundfish (by both Canada and United States) from grounds adjacent to British Columbia has been approximately 70 million pounds, or roughly the same as the production of halibut from the entire northeastern Pacific. Prospects for expansion of the fishery in local waters will depend on intensification of fishing on already exploited stocks, as most of the fishable grounds are within the working range of existing fleets. Over the long term, demand for groundfish products can be expected to increase, and, while this may encourage expansion of the fishery to currently unexploited grounds in the Gulf of Alaska, increasing pressure will be brought to bear on grounds closer to home.

Investigation of the British Columbia groundfish resource includes a number of long-term studies designed to provide information which is fundamental to management of the fishery on the basis of maximum sustained yield. For the past fifteen years, detailed statistics of catch and fishing effort have been gathered, for the purpose of determining changes in abundance and the effects of fishing. Consolidation of catch statistics on the important fisheries in international waters is being accomplished through co-operation with the (U.S.) Pacific Marine Fisheries Commission, and the status of various stocks of fish is reviewed periodically by an international Trawl Fishery Committee.

Routine sampling of commercial catches for species composition, age and length, provides information on changes in market selection, recruitment, growth rates and mortality rates.

Over the years, field work has consisted mainly of tagging, to identify populations and obtain additional information on growth and mortality rates. Current tagging involves the rock sole and grey cod, two species which bulk large in the present-day fishery by Canadian vessels.

Trends in catch. In 1960, British Columbia landings of groundfish other than halibut amounted to 31.1 million pounds, about 7% more than in 1959. Otter-trawlers accounted for 25.9 million pounds or 84% of the total. The catch of grey cod was down by 2.5 million pounds from the previous year, but it remained the dominant species in the trawl catch. The smaller landings of cod were offset by a 53% increase in the production of flatfish for human consumption. Gains were recorded in the landing of rock sole (4.0 million pounds), lemon sole (2.2 million pounds) and brill (0.98 million pounds). Landings of scrapfish for minkfood, consisting mainly of arrow-tooth sole and whiting (Alaska pollack), amounted to 5.8 million pounds, about 50% more than in 1959.

In the fisheries for lingcod and blackcod, line vessels continued to dominate in the production. They accounted for 58% of the total lingcod catch of 6.2 million pounds, and 90% of the blackcod catch of 1.5 million pounds.

Production of dogfish liver in 1960, stimulated largely by federal government subsidy, amounted to 1.1 million pounds, about the same as in 1959. This represented about 7.4 million pounds of whole dogfish.

Trends in abundance. From statistics of catch per unit of effort it is possible to estimate changes in abundance of groundfish. Apparent abundance of grey cod on offshore banks in 1960 averaged 36% less than in 1959 and this had a noticeable effect on Canadian catch which was 39% less than in the previous year. These sharp variations are of frequent occurrence and appear to be largely the result of variations in recruitment, as the fishable stock is composed of only two or three age groups.

The apparent sizes of two main stocks of brill (petrale sole) continue to fluctuate around a low level. Evidence of an improvement in recruitment observed between 1956 and 1959 did not continue in 1960. Thus, there is doubt that the stocks will soon return to former levels of abundance. Combined United States and Canadian catch from the northern stock of brill (in Hecate Strait and Queen Charlotte Sound) in 1960 was only 0.93 million pounds - the lowest on record and less than one-tenth of that in 1948. Catch from the southern (Vancouver Island and Washington) stock was 2.5 million pounds, about the same as in 1959 despite exploitation of grounds newly discovered by the United States Bureau of Commercial Fisheries.

In northern Hecate Strait there are important fisheries for lemon sole and rock sole. While the former appears to be undergoing no radical change in abundance, the latter is subject to pronounced year-to-year variations. These have substantial effect on annual production and appear to be largely the result of unstable recruitment. Strong year-classes are now entering the fishery and catch per effort is considerably above the long-term average.

Estimates of rock sole year-class strength. In population studies on rock sole in northern Hecate Strait, strengths of 15 year-classes (1939 to 1953) have been estimated by summing their numerical contributions to the catch per unit of effort between ages IV and VII. Some year-classes were found to be nearly seven times stronger than others. These variations in recruitment, although as great as those observed in the brill (petrale sole) populations, have tended to be non-directional over the long term and hence have not induced long-term trends in population size. This is in contrast to events in the brill populations in which changes in recruitment have been directional or non-random. Variations in the strengths of rock sole year-classes correspond roughly to those observed in the lemon sole population which co-habits northern Hecate Strait grounds.

Mortality rates in rock sole. Estimates, based on age composition of the northern Hecate Strait stock when it was in a near virgin state, and on the results of tagging, suggest that annual natural mortality rate is about 26% per year. Total mortality rate throughout the sixteen-year history of the fishery has averaged about 42%, while in recent years it has been about 50%. The current annual fishing mortality rate is estimated to be approximately 30%.

CRAB

Review of data on the Queen Charlotte Islands crab fishery, which accounts for about 70% of the annual British Columbia catch, was continued in 1960. The catch in Naden Harbour, in accordance with predictions, was lower than in 1959, but the total catch was higher, mainly because of increases in McIntyre Bay. In Hecate Strait the fishery was extended to exploit productive grounds as far south as Skidegate Inlet.

Experimental trap fishing in July and August showed that there are fewer soft-shelled crabs in McIntyre Bay about Venture Bank than in the sector east of Tow Hill. It has, therefore, been recommended that the westward boundary of the July 10 to September 20 closure to protect soft-shelled crabs be moved eastward.

Fishing was carried out in Naden Harbour to confirm predictions of the success of fishing from 1960 to 1962. The predictions were based on positive correlation between average catch of crabs per day's fishing in Naden Harbour and the mean seawater temperature at Langara Island lighthouse during April four years earlier. A lower-then-average fishery was expected in 1960, one about average in 1961 and the 1962 fishery was expected to be very good. Summer sampling confirmed the relatively low abundance of legal crabs and the 1960 fall fishery was lower than average; the abundance of 3-year-old crabs appeared to be about average so that the 1961 fishery should be as anticipated; and the expectations for a good operation in 1962 are confirmed by the high abundance of 2-year-olds.

Eight verified records of the occurrence of king crabs (*Paralithodes camtschatica*) on the British Columbia coast have been summarized. A cold-water species which breeds in shallow water in winter or early spring, it apparently occurs in some shallow inlets of northern British Columbia in winter, retiring to deeper water as temperatures rise in the summer. It is unlikely that it occurs anywhere on the British Columbia coast in commercial quantities.

SHRIMP

Since 1953 the Station's research on shrimps has been confined to exploratory fishing. The ground discovered in 1954 in Barkley Sound yielded 437,000 pounds in 1960, 26% of the total British Columbia production. No major explorations were carried out in 1960 but attention was given to the background for future improvement of the fishery. A start has been made in the modification of shrimp trawls to reduce incidental catches of fish and to facilitate the escape of small shrimps, and a study of seasonal changes in distribution, abundance, growth and reproduction was initiated in 1960.

A program of year-round sampling in the Strait of Georgia was started in November, 1960, and continued in January, 1961. During the interval average increases in carapace lengths of males of six species was from 1 to 3 millimetres, corresponding to increases in total length of approximately 5 to 12 millimetres. Because female shrimps were bearing eggs no growth was apparent. In English Bay, counts of whole shrimps per pound showed that the average size of "pink" shrimps (Pandalus borealis) decreased with depth to about 45 fathoms and increased thereafter, and "side-stripe" shrimps (Pandalopsis dispar) increased in size with increasing depth.

"Prawns" (Pandalus platyceros) are fished by traps on rock bottoms, and some attention was given to identifying the associated fauna on productive grounds so that this knowledge may assist in the search for new fishing grounds. Preliminary tests to improve the design of prawn traps showed that rectangular traps (24" × 12" × 13") having metal sides and two netting sloping-end entrances fished better than those covered wholly by netting or by metal.

OYSTERS

Forecasts of spatfalls. The warm summer of 1960 produced water temperatures high enough for successful oyster breeding, particularly in Pendrell Sound. The first large spawning occurred there on July 10 at 68°F, and a spatfall was forecast for the last week of July which reached a maximum of 100 spat per shell. Spatfall from an excellent spawning on July 29 at 74°F was forecast for mid-August; rapidly falling temperatures made it lighter than expected but it was nevertheless an adequate commercial set (33 spat per shell). About 35,000 shell strings, imported from Japan, were exposed by industry for the

August set and many sold to United States growers. Pendrell Sound remains the most consistent producer of seed oysters on the Pacific coast and will come into greater use as more reliance is placed on local spat rather than that imported from Japan.

Effects of pulp-mill pollution at Crofton. Observations on the condition of oysters at Crofton and Ladysmith were continued in order to follow its changes and assess the effects of pollution with kraft mill effluent. Condition was generally higher at Crofton in the autumn of 1960 than it has been for several years. A second tray experiment to determine variation in condition with distance from the source of the effluent, and consequently with its concentration, has not yet yielded conclusive results. It is evident that other factors are also involved in the differences in condition observed.

Oyster disease. For the first time in the history of oyster growing in British Columbia an oyster mortality occurred in 1960 which could be related to specific symptoms and which appears to be caused by infection. The mortality started in April at Henry Bay in Baynes Sound near Comox when the surface water temperature was about 47°F. By mid-April the mortality was about 10%, and 33% of the living oysters had characteristic pustules. Mortalities were heavier at the lower tidal levels. The mortality at the centre of infection was about 35%, and little spread was observed in 1960. The peak of the disease was in mid-May, and later in the summer the proportion of oysters having the pustules declined. No unusual oceanographic conditions were apparent. The specific cause was not found, although it appears to be neither bacterial nor fungal in nature. An outstanding feature was the rapid mortality of older oysters, still in excellent condition and showing no evidence of emaciation.

DEEP-WATER CLAM AND SCALLOP SURVEY

Using funds allotted by the Industrial Development Service of the Department of Fisheries, explorations were carried out for possible commercial supplies of clams and scallops, mainly in the areas north and south of Rose Spit in the Queen Charlotte Islands. Charts show an area of 1,600 square miles at depths of 5 to 20 fathoms with bottom consisting of sand, shell or gravel. Shells of bar or surf clams (Spisula alaskana), cockles (Clinocardium nuttalli), butter clams (Saxidomus giganteus) and horse clams (Schizothaerus nuttalli) occur on neighbouring beaches.

An 82-foot seiner-dragger, Western Crusader, was chartered for 68 days. Through the co-operation of the Board's Biological Station at St. Andrews, N.B., a deep-water hydraulic clam dredge, a Fall River rocker clam dredge and a Georges Bank type scallop dredge were obtained. Some 450 drags were made.

The results were discouraging. The bottom was found to be stonier and, consequently, less suitable for the hydraulic dredge than judged from charts. The survey disclosed no commercial quantities of deep-water clams; scallops were found but not enough to support a fishery. Some areas worthy of further study were found and the hydraulic principle was shown to be applicable to the harvesting of razor clams.

MARINE INVERTEBRATES GENERALLY

With limited personnel, much occupied with short-term demands such as the deep-water clam survey, the effects of pulp-mill pollution on oysters, the oyster disease and forecasts of spatfalls, little effort could be allotted to the broad studies of the distribution of marine invertebrates which have great long-term importance to an understanding of the fisheries resource. Collections were made associated with trawling operations of groundfish investigations which offer an economical means of studying changes in the distribution of the larger invertebrates. Research in this field is to be continued as resources permit.

WHALES

The whale fishery is kept under review in accordance with the requirements of the International Whaling Agreements. Whaling operations from the Coal Harbour station were discontinued in 1959 because of low prices for meal and oil after 12 successive years of whaling from 1948 to 1959. Study of biological data and specimens accumulated during past whaling seasons is being continued.

FUR SEALS

Investigations of fur seals, in co-operation with Japan, U.S.A. and U.S.S.R. under the terms of the Interim Convention on Conservation of North Pacific Fur Seals, entered their third year in 1960. Specimens were obtained from the chartered seiner Pacific Ocean according to plans proposed and approved at the third meeting of the Commission. A total of 512 seals were taken from 963 seen during the months of March, April and May. About 58% were taken off British Columbia mostly in April and May, and about 40% off Washington mostly in March and April.

Females comprised 84% of the catch in 1960. Males were all less than 5 years of age. The pregnancy rate among females 4 years of age and older was 65% in 1960 as compared to 81% in 1959. This increase in numbers of unsuccessful reproductions was mainly a result of an increased abortion rate. Special attention is being directed towards learning the cause of reproductive failure.

Food occurred in 51% of all stomachs examined in 1960. Feeding is at a maximum during early morning hours. Young seals select small schooling fish which they swallow whole; older seals also accept larger fish which may be swallowed piecemeal. Rockfish, squid and herring predominated in stomachs of seals taken off Washington; herring, sandlaunce and rockfish predominated off British Columbia. Herring continues to be the most important food species in the diet of fur seals in British Columbia waters.

SEA LIONS

The northern sea lion interferes with fishing operations, especially salmon gill-netting, and is believed by many to seriously damage stocks of commercial fish. It is under study to assess the need for control and to suggest the means.

A survey in 1956-57 showed a population of about 13,000 at the end of the summer pupping season. The population is concentrated in summer on two major rookeries located on the Scott Islands and the Kerouart Islands (Cape St. James). Another survey is planned for 1962 in order to assess the effect of heavy killing by the Department of Fisheries and by commercial interests since 1957.

Fifty sea lions were taken in June and in September, 1960, for study of age, growth, reproduction and feeding. Their stomachs contained mainly rockfish, ratfish, dogfish, flatfish, grey cod and salmon.

Sartine Island rookery has been reserved as a study area. For the third consecutive year more than 300 pups were tagged there, using modified cattle ear-tags attached to the foreflipper, in order to follow growth and migration. One yearling from the 1959 tagging was recovered on a closely adjacent island in 1960.

FISHING GEAR

The principal research project on fishing gear in 1960 was an engineering study of the mid-water trawl in order to improve its performance by re-design on the basis of technical data and scientific principles. On the Pacific coast, where the major fisheries on salmon, halibut and herring already have efficient methods, the greatest need for better equipment seems to be more effective gear for catching fish in mid-depths. This is important both for research and exploration, and for exploitation of any new pelagic stocks which may be discovered. The development of a better mid-water trawl is particularly timely now, when an ocean-going research vessel is being constructed and will soon be carrying out expanded research and exploration on the high seas.

Starting with the mid-water trawl developed at this Station (described in Fisheries Research Board Bulletin 123), modifications were made in the Barraclough-Johnson otter boards, making them stable at higher speeds although preventing their use for bottom fishing. Royal Canadian Navy minesweeping kites were modified for use as otters without the Oropesa floats required by the Navy. The spreading gear and rigging of the trawl have been improved enough to increase its speed by about two knots when towed by the Station's A.P. Knight at the same engine speeds. Analysis of the hydrodynamic data obtained in these experiments shows that still better performance can be achieved by improvements in rigging and by development of spreading hydrofoils with better lift-to-drag ratios, and a number of new types are now being tried. The instrumentation has also been developed for measurements of tensions in the trawl when in operation, and the hydrodynamic qualities of netting of various sorts are being studied. All of these lines of investigation are leading to the re-design of the trawl, and the testing of new types.

A considerable effort was spent in 1960 in participation in the working group of the Food and Agricultural Organization of the United Nations established at the fishing gear congress at Hamburg in 1957 to develop standard test procedures for fishing gear materials. Data are also being accumulated to support recommendation of a universal twine designation system as a step towards the development of better trade standards for fishing gear, as requested by our fishing industry. Testing of net materials and netting have been continued on the small scale necessary to keep abreast of new developments.

PUBLICATIONS

(1 Jan 60 to 31 Dec 60)

Anon. Progress in 1959 in Canadian research on problems raised by the Protocol. In "The research program". Annual Report of the International North Pacific Fisheries Commission for 1959, pp. 31-53, 1960. (Based on material from A. W. H. Needler).

Barraclough, W. E., and W. W. Johnson. Further midwater trawl developments in British Columbia. Bull. Fish. Res. Bd., No. 123, 45 pp., 1960.

Further developments of the B. C. mid-water trawl. In Western Fisheries, Vol. 60, No. 6, pp. 19-20, 22, 48-51; Vol. 61, No. 1, pp. 18, 20, 22, 24, 26, 1960, from Bull. Fish. Res. Bd., No. 123, 45 pp., 1960.

Bell, Gordon R., and J. E. Bateman. Some radiographic observations on the gastro-intestinal and urinary systems of anesthetized Pacific salmon (*Oncorhynchus*). Canadian Journal of Zoology, Vol. 38, No. 1, pp. 199-202, 1960.

Berkeley, E., and C. Berkeley. Notes on some Polychaeta from the west coast of Mexico, Panama, and California. Canadian Journal of Zoology, Vol. 38, No. 2, pp. 357-362, 1960.

Some further records of pelagic Polychaeta from the northeast Pacific north of Latitude 40° N and east of Longitude 175° W, together with records of Siphonophora, Mollusca, and Tunicata from the same region. Canadian Journal of Zoology, Vol. 38, No. 4, pp. 787-799, 1960.

Boston, N. E. J. Progress Report--Hecate Model, June 30, 1960. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-17, 4 pp.

Brett, J. R. Thermal requirements of fish--Three decades of study, 1940-1970. Transactions of the Second Seminar on Biological Problems in Water Pollution, April 20-24, 1959, (U. S. Public Health Service), 8 pp., 1959.

Butler, T. H. Maturity and breeding of the Pacific edible crab, Cancer magister Dana. J. Fish. Res. Bd., Vol. 17, No. 5, pp. 641-646, 1960.

Shrimp survey results positive. In Canadian Fisherman, Vol. 47, No. 3, pp. 31, 32, 34, 1960, from Fisheries Research Board of Canada, Nanaimo Biological Station Circular, No. 55, 7 pp., 1959.

Productive shrimp grounds found off Nootka Sound. In Western Fisheries, Vol. 59, No. 4, pp. 14-16, 1960, from Fisheries Research Board of Canada, Nanaimo Biological Station Circular, No. 55, 7 pp., 1959.

Carrothers, P. J. G. Monofilament nylon salmon gillnets. In Pacific Fisherman, Vol. 58, No. 3, p. 35, 1960, from Fisheries Research Board of Canada, Nanaimo Biological Station Circular, No. 54, 4 pp., 1959.

Dodimead, A. J. Northeast Pacific oceanographic survey, January 11 to February 10, 1960. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-4, 8 pp.

Proposed oceanographic survey of the northeast Pacific Ocean, July 28 to September 11, 1960. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-15, 4 pp.

Ellis, D. V. Marine infaunal benthos in arctic North America. Tech. Papers No. 5, Arctic Institute of North America, 53 pp., 1960.

Ellis, D. V., and J. Evans. Comments on the distribution and migration of birds in Foxe Basin, Northwest Territories. Canadian Field-Naturalist, Vol. 74, No. 2, pp. 59-70, 1960.

Fofonoff, N. P. Machine processing of oceanographic data. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-27, 12 pp.

Herlinveaux, R. H. Oceanographic observations from a helicopter. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-9, 5 pp.

Hollister, H. J. Daily seawater temperatures for January 1960 in B. C. coastal waters. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-1, 4 pp.

Daily seawater temperatures for February 1960 in B. C. coastal waters. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-6, 5 pp.

B. C. coastal seawater temperatures for March 1960. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-10, 4 pp.

B. C. coastal seawater temperatures for April 1960. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-12, 3 pp.

B. C. coastal seawater temperatures for May 1960. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-14, 4 pp.

B. C. coastal seawater temperatures for June 1960. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-18, 4 pp.

B. C. coastal seawater temperatures for July 1960. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-22, 4 pp.

B. C. coastal seawater temperatures for August 1960. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-25, 4 pp.

B. C. coastal seawater temperatures for September 1960. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-26, 4 pp.

B. C. coastal seawater temperatures for October 1960. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-28, 4 pp.

B. C. coastal seawater temperatures for November 1960. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-30, 3 pp.

Johnston, R. L., and S. Tabata. Oceanographic observations from weathership CGS St. Catharines, Cruise P-59-5, December 8, 1959-January 25, 1960. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-3, 11 pp.

Kennedy, O. D. Occurrence of zooplankton in the eastern sub-Arctic Pacific ocean during 1957. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-5, 8 pp.

Lane, R. K. Coastal observations from northeast Pacific survey, January 11 to February 10, 1960. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-7, 6 pp.

Coastal survey off Vancouver Island, May 3-14, 1960. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-16, 21 pp.

Coastal survey off Vancouver Island, June 6-17, 1960. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-24, 24 pp.

Coastal surveys along the west coast--October 3-9, 1960 and November 26-December 9, 1960. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-31, 20 pp.

McAllister, C. D. Oceanographic observations from weathership CGS St. Catharines, Cruise P-60-1, March 1-April 18, 1960. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-11, 10 pp.

McAllister, C. D., T. R. Parsons and J. D. H. Strickland. Primary productivity and fertility at station "P" in the north-east Pacific Ocean. Journal du Conseil, Vol. 25, No. 3, pp. 240-259, 1960.

McAllister, C. D., S. Tabata and K. Ferrier. Oceanographic conditions between "Swiftsure" lightship and station "P". Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-13, 2 pp.

McDonald, J. The behaviour of Pacific salmon fry during their downstream migration to freshwater and saltwater nursery areas. J. Fish. Res. Bd., Vol. 17, No. 5, pp. 655-676, 1960.

A possible source of error in assessing the survival of Pacific salmon eggs by redd sampling. Canadian Fish Culturist, No. 26, pp. 27-30, 1960.

Margolis, L. A new nematode of the genus Cucullanus (Camallanata:Cucullanidae) from a flounder, Parophrys vetulus Girard, 1854, with notes on the species from Pleuronectiformes. Canadian Journal of Zoology, Vol. 38, No. 5, pp. 839-849, 1960.

Neave, Ferris, and M. G. Hanavan. Seasonal distribution of some epipelagic fishes in the Gulf of Alaska region. J. Fish. Res. Bd., Vol. 17, No. 2, pp. 221-233, 1960.

Outram, D. N. Guide to marine vegetation encountered during herring spawn surveys in southern British Columbia. Fisheries Research Board of Canada, Nanaimo Biological Station Circular, No. 44, 18 pp., 1957.

Extent of '59 B. C. herring spawning. In Canadian Fisherman, Vol. 47, No. 3, pp. 40-43, 1960, from Fisheries Research Board of Canada, Nanaimo Biological Station Circular, No. 56, 13 pp., 1959.

'59 herring spawning better--still below average. In Western Fisheries, Vol. 59, No. 5, pp. 46, 48, 50-51, 1960, from Fisheries Research Board of Canada, Nanaimo Biological Station Circular, No. 56, 13 pp., 1959.

Pike, Gordon C. Pacific striped dolphin, *Lagenorhynchus obliquidens*, off the coast of British Columbia. J. Fish. Res. Bd., Vol. 17, No. 1, pp. 123-124, 1960.

Canada's share in the North Pacific fur seal resource. Canadian Department of Fisheries, Trade News, Vol. 13, No. 3, pp. 8-9, 1960.

Quayle, D. B. The intertidal bivalves of British Columbia. British Columbia Provincial Museum, Handbook No. 17, 104 pp., 1960.

Ricker, W. E. A population of dwarf coastrange sculpins (*Cottus aleuticus*). J. Fish. Res. Bd., Vol. 17, No. 6, pp. 929-932, 1960.

Vli͡ianie faktorov sredy i nasledstvennosti na morfologiiu i povedenie tikhookeanskovo lososi͡a Severnoĭ Ameriki. [The influence of environmental factors and heredity on the morphology and behaviour of Pacific salmon in North America.] Nauchnai͡a Informatsii͡a, pp. 1-12, 1960. VNIRO, Moscow.

Robertson, D. G., and J. Butters. Oceanographic observations from weathership CGS *St. Catharines*, Cruise P-60-3, August 2-September 19, 1960. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-29, 9 pp.

Stephens, K. V. Some miscellaneous information on the conductivity salinometers at P.O.G., Nanaimo, B. C. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-2, 2 pp.

Strickland, J. D. H. Measuring the production of marine phytoplankton. Bull. Fish. Res. Bd., No. 122, 172 pp., 1960.

Study of marine productivity and fertility using a large plastic bag. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-20, 5 pp.

Strickland, J. D. H., and K. H. Austin. On the forms, balance and cycle of phosphorus observed in the coastal and oceanic waters of the northeastern Pacific. J. Fish. Res. Bd., Vol. 17, No. 3, pp. 337-345, 1960.

Strickland, J. D. H., and T. R. Parsons. A manual of seawater analysis. Bull. Fish. Res. Bd., No. 125, 185 pp., 1960.

Tabata, S. Characteristics of water and variations of salinity, temperature, and dissolved oxygen content of the water at ocean weather station "P" in the northeast Pacific Ocean. J. Fish. Res. Bd., Vol. 17, No. 3, pp. 353-370, 1960.

Oceanographic observations from weathership CGS St. Catharines. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-21, 11 pp.

Tabata, S., and C. D. McAllister. Oceanographic conditions between "Swiftsure" lightship and ocean station "P". Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-8, 3 pp.

Tabata, S., D. G. Robertson and J. Butters. Sea temperatures between "Swiftsure" lightship and station "P". Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-23, 2 pp.

Thomson, J. A., and N. A. Yates. British Columbian landings of trawl-caught groundfish by month, by major statistical area. Fisheries Research Board of Canada, Nanaimo Biological Station Statistical Circular, No. CNS 1, Vol. 1, 1945-1949, 74 pp., 1960.

Tully, J. P. On structure, entrainment, and transport in estuarine embayments. Journal of Marine Research, Vol. 17, pp. 523-535, 1958.

Structure, entrainment and transport in estuarine embayments. Preprints of Abstracts, International Oceanographic Congress, 1959, pp. 711-713. American Association for the Advancement of Science, 1959.

Canadian Pacific oceanography since 1953. Proceedings of the 9th Pacific Science Congress, 1957, Vol. 16, pp. 6-13, 1958.

Recent advances in oceanography. American Peoples' Encyclopedia Yearbook 1960. Spencer Press Inc., Chicago, Ill., p. 764.

The Northwest Passage. McGraw-Hill Encyclopedia of Science and Technology, McGraw-Hill Book Co. Inc., New York, 2 pp.

Arctic Ocean. McGraw-Hill Encyclopedia of Science and Technology, McGraw-Hill Book Co. Inc., New York, 2 pp.

Tully, J. P., and F. G. Barber. An estuarine analogy in the sub-Arctic Pacific Ocean. J. Fish. Res. Bd., Vol. 17, No. 1, pp. 91-112, 1960.

Tully, J. P., A. J. Dodimead and H. J. Hollister. Outlook--Surface seawater temperatures off British Columbia. Fisheries Research Board of Canada, Pacific Oceanographic Group Circular, No. 1960-19, 4 pp.

Tully, J. P., A. J. Dodimead and S. Tabata. An anomalous increase of temperature in the ocean off the Pacific coast of Canada through 1957 and 1958. J. Fish. Res. Bd., Vol. 17, No. 1, pp. 61-80, 1960.

Waldichuk, M. Some oceanographic characteristics of a polluted inlet in British Columbia. Journal of Marine Research (T. G. Thompson Seventieth Anniversary), Vol. 17, pp. 536-551, 1958.

Effects of pulp and paper mill wastes on the marine environment. Transactions of the Second Seminar on Biological Problems in Water Pollution, April 20-24, 1959, (U. S. Public Health Service), 8 pp., 1959.

Containment of radioactive waste for sea disposal and fisheries off the Canadian Pacific coast. In "Disposal of Radioactive Wastes", Conference Proceedings, Monaco, 16-21 November 1959, Vol. 2, pp. 57-77, 1960.

Pulp mill pollution in British Columbia. Nanaimo Biological Station Circular, No. 57, 18 pp., 1960.

MANUSCRIPT REPORTS, ETC.
(1 Jan 60 to 31 Dec 60)

Barber, F. G., O. D. Kennedy and R. L. Johnston. Atlas of distribution of speed of sound, North Pacific Survey, August 4 to September 1, 1959. Defence Research Board, Pacific Naval Laboratory, MS Report 60-2, 44 pp.

Dodimead, A. J. Atlas of oceanographic data. North Pacific survey, January 12 to February 10, 1960. MS Rept. Oceanogr. and Limnol., No. 69, 49 pp., 1960.

Dodimead, A. J., K. B. Abbott-Smith and H. J. Hollister. Oceanographic data record. North Pacific survey, January 12 to February 10, 1960. MS Rept. Oceanogr. and Limnol., No. 63, 127 pp., 1960.

Dodimead, A. J., L. F. Giovando, R. H. Herlinveaux, R. K. Lane and H. J. Hollister. Oceanographic data record. North Pacific surveys, July 10 to September 6, 1960. MS Rept. Oceanogr. and Limnol., No. 82, 323 pp., 1960.

Fofonoff, N. P. Transport computations for the North Pacific Ocean, 1955. MS Rept. Oceanogr. and Limnol., No. 77, 93 pp., 1960.

Transport computations for the North Pacific Ocean, 1956. MS Rept. Oceanogr. and Limnol., No. 78, 93 pp., 1960.

Transport computations for the North Pacific Ocean, 1957. MS Rept. Oceanogr. and Limnol., No. 79, 93 pp., 1960.

Transport computations for the North Pacific Ocean, 1958. MS Rept. Oceanogr. and Limnol., No. 80, 93 pp., 1960.

Fofonoff, N. P., and C. Froese. Programs for oceanographic computations and data processing on the electronic digital computer ALWAC III-E. M-1, miscellaneous programs. MS Rept. Oceanogr. and Limnol., No. 72, 35 pp., 1960.

Froese, C. Programs for oceanographic computations and data processing on the electronic digital computer ALWAC III-E. DP-3, oceanographic station data program. MS Rept. Oceanogr. and Limnol., No. 73, 23 pp., 1960.

Herlinveaux, R. H., O. D. Kennedy and H. J. Hollister. Oceanographic data record. Coastal seaways project, November 16 to December 11, 1959. MS Rept. Oceanogr. and Limnol., No. 58, 136 pp., 1960.

Hollister, H. J. Bathythermograms and meteorological data record. Swiftsure Bank and Umatilla Reef lightships, 1959. MS Rept. Oceanogr. and Limnol., No. 62, 96 pp., 1960.

Observations of seawater temperature and salinity on the Pacific coast of Canada, Vol. XIX, 1959. MS Rept. Oceanogr. and Limnol., No. 67, 112 pp., 1960.

Classifications of daily observations of seawater temperature and salinity on the Pacific coast of Canada, 1915-1959. MS Rept. Oceanogr. and Limnol., No. 68, 141 pp., 1960.

Lane, R. K., R. H. Herlinveaux, W. R. Harling and H. J. Hollister. Oceanographic data record. Coastal and seaways projects, October 3 to 26, 1960. MS Rept. Oceanogr. and Limnol., No. 83, 140 pp., 1960.

Lane, R. K., J. H. Meikle and H. J. Hollister. Oceanographic data record. Coastal project, May 4 to 14, 1960. MS Rept. Oceanogr. and Limnol., No. 70, 120 pp., 1960.

Oceanographic data record. Coastal project, June 6 to 16, 1960. MS Rept. Oceanogr. and Limnol., No. 76, 176 pp., 1960.

Manzer, J. I., T. H. Bilton and K. H. Mosher. The ocean distribution of sockeye salmon originating in Rivers and Smith Inlets. MS Rept. Biol., No. 702, 5 pp., 1960.

Manzer, J. I., and H. J. Hollister. Data record of bathythermograms observed by Fisheries Research Board chartered fishing vessels, March-September, 1959. MS Rept. Oceanogr. and Limnol., No. 66, 44 pp., 1960.

Margolis, L. Report on the use of parasites to determine the continental origin of sockeye salmon taken on the high seas from May to August, 1959. MS Rept. Biol., No. 703, 18 pp., 1960.

Neave, Ferris. Observations of the vertical distribution of salmon in the Northeast Pacific, 1960. MS Rept. Biol., No. 701, 9 pp., 1960.

Parsons, T. R. A data record and discussion of some observations made in 1958-1960 of significance to primary productivity research. MS Rept. Oceanogr. and Limnol., No. 81, 15 pp., 1960.

Pike, G. C., D. J. Spalding, I. B. MacAskie and A. Craig. Report on Canadian pelagic fur-seal research in 1960. MS Rept. Biol., No. 700, 101 pp., 1960.

Tabata, S., C. D. McAllister, D. G. Robertson and H. J. Hollister. Data record. Ocean weather station "P" (Latitude 50°00'N, Longitude 145°00'W), January 21-November 24, 1959. MS Rept. Oceanogr. and Limnol., No. 59, 171 pp., 1960.

Tanaka, S., M. P. Shepard and T. H. Bilton. Scale characteristics of chum salmon (Oncorhynchus keta) in coastal areas and on the high seas of the North Pacific ocean. MS Rept. Biol., No. 704, 96 pp., 1960.

Tully, J. P., M. Pirart and R. K. Lane. Airborne radiation thermometer Mark I feasibility tests. MS Rept. Oceanogr. and Limnol., No. 61, 27 pp., 1960.

Withler, F. C. Skeena Salmon Management Committee, Annual Report, 1959. MS Rept. Biol., No. 699, 31 pp.

STAFF LIST BY INVESTIGATIONS

(for period April 1, 1960, to March 31, 1961 - casual help excluded; organization as brought into effect December 1, 1960)

Director	A.W.H. Needler, Ph.D.
Assistant Director	F.C. Withler, M.A.
Salmon Consultant	
Principal Scientist in charge	R.E. Foerster, Ph.D.
Marine Salmon Investigation	
Principal Scientist in charge	F. Neave, Ph.D.
Associate Scientist	J.I. Manzer, M.A.
Associate Scientist	H. Godfrey, M.A.
Assistant Scientist	R.J. LeBrasseur, M.A. (on leave w/o pay from 26 Apr 60)
Technician 3	C.E. Turner
Technician 2	D.B. Donnelly
Student Assistant	G.I.M. Cowan (2 May to 3 Oct)
Student Assistant	J.D. Fulton (2 May to 22 Sep)
Student Assistant	G.P. Schroh (2 May to 29 Sep)
Clerk 2	Jacqueline A. Lee (13 Feb to 31 Mar)
Salmon Management	
Principal Scientist in charge	M.P. Shepard, Ph.D.
Senior Scientist	D.J. Milne, Ph.D.
Associate Scientist	A.S. Hourston, Ph.D.
Associate Scientist	H.T. Bilton, B.A.
Technician 2	R.M. Humphreys
Technician 2	D.W. Jenkinson
Technician 2	E.A.R. Ball
Technician 1	K. Mueller (15 May to 8 Dec)
Assistant Technician 3	Sigrud A.M. Ludwig
Assistant Technician 3	E.T. Butler (14 Jun to 31 Oct)
Assistant Technician 3	R.F. Pullitt (7 Jun to 2 Oct)
Assistant Technician 2	Lynda D. Musgrove (from 13 Jun)
Assistant Technician 2	Margaret MacKinnon (2 May to 10 Sep)
Stenographer 2	Hazel H. Turner (1 Apr to 2 Jun)
Stenographer 2	Elizabeth A. Thomson (1 Apr to 2 Jun)
Salmon Management (Lake Sockeye)	
Senior Scientist in charge	W.E. Johnson, Ph.D.
Technician 2	J.R. Kolodychuk (1 Apr to 25 Mar)
Assistant Technician 3	W.L. Wiley (1 Apr to 7 Jan)
Assistant Technician 3	W.P. Henry (4 May to 17 Sep)
Assistant Technician 2	M.H. Steen (28 Apr to 1 Nov)
Student Assistant	R.O. Schlick (9 May to 16 Sep)
Student Assistant	E. Muzsi (9 May to 24 Sep)
Student Assistant	I.H. Carlson (1 May to 30 Sep)

Skeena Salmon Management

Senior Scientist in charge	J. McDonald, M.A.
Associate Scientist	K.V. Aro, B.A.
Associate Scientist	H.W.D. Smith (from 3 Jan)
Technician 2	J. Martell
Technician 2	I. Miki
Technician 2	F.P. Jordan
Technician 1	J. Lucop
Assistant Technician 3	R. Leahy (1 Apr to 15 Oct)
Assistant Technician 3	C.E. Twaites (1 Apr to 20 Aug)
Assistant Technician 3	W.G. Ferguson (2 Apr to 14 Oct)
Assistant Technician 3	R.J. Anderson (1 Apr to 15 Sep)
Assistant Technician 3	A.R. Morgan (2 Apr to 15 Oct)
Assistant Technician 3	R.L. Martin (2 Apr to 15 Oct)
Assistant Technician 2	D.G. Crabtree (1 Apr to 14 Oct)
Assistant Technician 2	S.L. South (1 Apr to 15 Oct)
Assistant Technician 2	J.K. Garrow (1 Apr to 14 Oct)
Assistant Technician 2	W.D. Grinnell (1 Apr to 29 Aug)
Assistant Technician 2	L.N. Macleod (1 Sep to 15 Oct)
Student Assistant	R.A. Hankin (2 May to 14 Sep)
Student Assistant	H.H. Webber (2 May to 15 Sep)
Student Assistant	P.E. Whitehead (2 May to 9 Sep)
Student Assistant	A.E. Neumeyer (2 May to 31 Aug)
Observer	D. Moore (part-time 1 Apr to 30 Jun)
Observer	Fiora G. Dougan (part-time from 1 Jul)
Stenographer 1	Hisami Nakanishi (27 Jun to 10 Sep)

Salmon Propagation

Principal Scientist in charge	F.C. Withler, M.A.
Senior Scientist	R.R. Parker, Ph.D. (from 25 Aug)
Associate Scientist	W.P. Wickett, M.A.
Associate Scientist	R.A. Bams, Phil. Drs.
Technician 3	R.C. Wilson
Technician 2	A.S. Coburn
Technician 2	W. Caulfield
Technician 1	H. Neate
Technician 1	P.W. Neave
Technician 1	G.E. Johnston
Technician 1	P.R. Houlihan (1 Apr to 13 Jan)
Technician 1	E.W.H. Moore (from 1 Mar)
Assistant Technician 3	J.T.W. Dewar (1 to 8 Apr)
Assistant Technician 3	R.E. Hippisley (from 1 Apr)
Assistant Technician 3	R.F. Pollitt (1 Apr to 6 Jun)
Assistant Technician 3	A.J. Robinson (30 Jun to 31 Aug)
Assistant Technician 3	E.T. Butler (1 Apr to 13 Jun)
Assistant Technician 3	A.J. Solmie (1 Apr to 31 Oct)
Assistant Technician 2	J. Kellog (13 Apr to 31 May)
Caretaker 3	E.E. Chandler (1 Nov to 20 Mar)

Experimental Biology

Principal Scientist in charge	J.R. Brett, Ph.D.
Associate Scientist	D.F. Alderdice, M.A.
Associate Scientist	G.R. Bell, Ph.D.
Associate Scientist	D.V. Ellis, Ph.D.

Associate Scientist	W.E. Vanstone, Ph.D.
Associate Scientist	C. Groot, Pil.Drs.
Assistant Scientist	T. Gene Murata, M.Sc. (from 3 Oct)
Technician 2	D.B. Sutherland
Technician 2	C.T. Shoop
Technician 1	F.P.J. Velsen
Technician 1	W.L. Wiley (from 8 Feb)
Technician 1	A. Brown (1 Apr to 31 Dec)
Technician 1	K. Vermeer (1 Apr to 15 Aug)
Assistant Technician 3	D. Pozar
Student Assistant	F.C-W Ho (20 May to 12 Sep)
Student Assistant	R.J.F. Smith (2 May to 4 Oct)
Student Assistant	A.C-K Watt (2 May to 7 Sep)

Pollution

Senior Scientist in charge	M. Waldichuk, Ph.D.
Technician 4	A.E. Werner
Technician 1	J.R. Markert (from 1 Aug)
Student Assistant	S.Y.C. Mak (2 May to 18 Sep)

Parasitology

Senior Scientist in charge	L. Margolis, Ph.D.
Assistant Scientist	Renata A.I.B. Brall, B.A. (19 Sep to 31 Jan)
Assistant Scientist	S.U. Qadri, M.Sc. (1 Apr to 16 Sep)
Technician 2	N.P. Boyce, B.Sc.
Student Assistant	Judith H. Whittaker (2 May to 14 Sep)
Student Assistant	Christine L. Machemer (2 May to 14 Sep)

Marine Commercial Fisheries

Principal Scientist in charge	K.S. Ketchen, Ph.D.
Senior Scientist	F.H.C. Taylor, Ph.D.
Associate Scientist	W.E. Barraclough, M.A.
Associate Scientist	T.H. Butler, M.A.
Assistant Scientist	D.N. Outram, B.A.
Assistant Scientist	J.A.C. Thomson, M.Sc.
Technician 3	C.R. Forrester
Technician 2	R.M. Wilson
Technician 2	A.N. Yates
Technician 2	J.S. Rees
Technician 2	R.S.K. Isaacson
Technician 2	E.J.R. Lippa
Technician 1	A. Rigby
Technician 1	E.W. Stolzenberg
Assistant Technician 3	B. Wildman
Student Assistant	Sandra A. Shaw (2 May to 15 Sep)
Student Assistant	Katherine J. Casper (2 May to 5 Jul)
Student Assistant	A.R. Hakstian (2 May to 17 Sep)
Student Assistant	Margaret A. Kinne (4 Jul to 10 Sep)

Marine Mammals	
Associate Scientist in charge	G.C. Pike, M.A.
Assistant Scientist	D.J. Spalding, B.A. (returned from leave w/o pay 2 May)
Assistant Scientist	Allison M. Craig, B.Sc. (from 1 Apr)
Technician 2	I.B. MacAskie
Assistant Technician 3	E. Binnersley (1 Apr to 31 Jul and 15 Feb to 31 Mar)
Marine Invertebrates	
Senior Scientist in charge	D.B. Quayle, Ph.D.
Technician 2	L.G. Eytcheson (2 May to 20 Jan)
Technician 2	J. Flury (from 15 Feb)
Student Assistant	R. Malkin (2 May to 16 Sep)
Fishing Gear Research	
Associate Scientist in charge	P.J.G. Carrothers, S.M.
Technician 2	W. Pinckard (1 Aug to 31 Aug)
Technician 2	M.A. Pope (from 12 Sep)
Technical Services (responsible to Assistant Director)	
Technician 4 (Electronics Lab)	M.A. Pirart, A.M.I.R.E.
Technician 1 (Drafting)	G.D.G. Denbigh
Technician 1 (Photography)	C.J. Morley
Technician 1 (Statistics)	Dorothy P. Dzendolet
Clerk 3 (Library)	Evelyn M. Wardropper
Student Assistant (Library)	Lynn A. Curry (2 May to 8 Sep)
Secretarial Services	
Clerk 4 in charge	Ethel E. Robinson
Clerk 3 (Files)	Margaret K. Philp
Stenographer 3	Ruth Cote
Stenographer 2	Deanna M. Holmberg
Stenographer 2	Rosaline Pullan (26 Jan to 31 Mar)
Stenographer 1	Joan E. Perry (from 27 Apr)
Stenographer 1	Audrey R. Barner
Stenographer 1	Carol A. Zasburg (from 4 Jul)
Administration and Maintenance	
Administrative Officer 3 in charge	G.F. Hart (1 Apr to 31 Aug)
	I.J. Strong (from 15 Sep)
Purchases, Accounts and Personnel	
Administrative Asst. (Purchases)	O.O. Morgan
Administrative Asst. (Accounts and Personnel)	L.A. Noon
Clerk 3	S.C. Grando
Clerk 2	A. Louise Muir (1 Apr to 16 Sep)
Clerk 2	Elizabeth A. Taylor (from 26 Sep)
Stenographer 2	Doris Braydic

Stenographer 2	Laura Rasmussen (from 1 Apr)
Typist 1	Mildred A. Hannah (1 Apr to 7 Jan)
Typist 1	Mary J. Greenwell (from 18 Jan)
Maintenance and Services (Nanaimo)	
Superintendent of buildings, vessels and grounds	J.R. Gilmour (16 Jan to 15 Mar)
	R. Simpson (from 20 Mar)
Maintenance Supervisor 5 in charge	A.G. Paul
Caretaker 5	J.C. Wallace (to 12 Jan - retired)
	J.R. Jardine (from 1 Mar)
Caretaker 3	J.R. Jardine (to 28 Feb)
Caretaker 3	J.H. Merner
Caretaker 3	J.G. Naysmith (from 1 Mar)
Watchman	J.M. McArthur
Watchman	W.W. Thompson
Cleaning Service Man	L. Klobchar
Cleaning Service Man	N.R. Marsh
Maintenance (boats, gear, field stations, workshop)	
Technician 3 in charge	K. Sutherland (from 1 Oct)
	L.G. Quickenden (to 20 Sep)
Technician 2 (Master Mechanic)	A. Brown (from 1 Jan)
	K. Sutherland (to 30 Sep)
Technician 1 (Master Carpenter)	M. Ilich
Technician 1 (Technical Storekeeper)	R. Hancock
Vessels	
"A.P. Knight"	
Technician 4 (Captain)	H. Mahle
Chief Engineer	P.G. Squarebriggs
Mate	H.T. Wetting
Second Engineer	A. Mollevik
Cook-Deckhand	G. Moum
Netman	W. Ryles
"Investigator No. 1"	
Technician 2 (Captain)	C. Watson
Engineer	W.P. Winstanley
Mate	R.A. Dean
Cook-Deckhand	E. Bateman
"Alta"	
Technician 1 (Captain-Engineer)	R.E. Hirst
Cook-Deckhand	J.L. Day
Pacific Oceanographic Group	
Oceanographer in charge	J.P. Tully, Ph.D.
Senior Scientist	J.D.H. Strickland, Ph.D.
Senior Scientist	N.P. Fofonoff, Ph.D.
Associate Scientist	F.G. Barber, B.A. (to 6 Jun - transferred to Dept. Mines and Tech. Services)

Associate Scientist	A.J. Dodimead, M.Sc.
Associate Scientist	L.F. Giovando, Ph.D.
Associate Scientist	S. Tabata, M.A.
Associate Scientist	T.R. Parsons, Ph.D.
Associate Scientist	C.D. McAllister, M.A.
Associate Scientist	N.J. Antia, Ph.D. (from 3 Oct)
Associate Scientist	P.B. Crean, M.Sc. (from 25 Jan)
Associate Scientist	V.K. Jain (from 1 Sep)
Assistant Scientist	N.E.J. Boston, B.Sc.E.
Assistant Scientist	R.K. Lane, B.Sc.
Technician 4	H.J. Hollister
Technician 4	L.D.B. Terhune
Technician 4	R.H. Herlinveaux
Technician 3	J.A. Stickland
Technician 2	K.V.C. Stephens
Technician 2	R.L. Johnston (to 14 Jul)
Technician 2	W. Atkinson (from 1 Aug)
Technician 2	D.G. Robertson
Technician 2	J.H. Meikle
Technician 1	N.F. Bdinka (to 22 Sep)
Technician 1	R. Cagna
Technician 1	J.D. Carswell
Technician 1	R.B. Tripp (from 25 Nov)
Technician 1	W.R. Harling
Assistant Technician 3	Mary C. Cairns
Stenographer 3	M. Madeleine Smith
Student Assistant	N.K. Chippindale (2 May to 24 Sep)
Student Assistant	J.A. Gow (2 May to 20 Sep)
Student Assistant	W.H. Bell (2 May to 15 Sep)
Student Assistant	K.W.N. Ferrier (9 May to 15 Sep)
Student Assistant	J. Hildebrandt (9 May to 24 Sep)
Student Assistant	R.H. Loucks (2 May to 16 Sep)
Student Assistant	W. Wai (2 May to 31 Aug)
Student Assistant	Y.K-C. Yu (5 May to 9 Sep)

C O N T E N T S

SALMON ON THE HIGH SEAS

F. Neave

High-seas fishing operations, which have been part of Canada's contribution to the work of the International North Pacific Fisheries Commission since 1956, were continued in 1960 with some change in the areas examined and in the methods of investigating salmon distribution. Repetition of the collection of large samples of salmon from specific localities for detailed examination by specialists was not considered essential in 1960. Attention was given to the depth distribution of salmon in the open ocean, by prolonged fishing in a single area, and an initial attempt was made to seine and tag salmon in ocean waters relatively near the coasts of British Columbia and southeast Alaska.

Information on the vertical distribution of the fish is considered necessary for satisfactory interpretation of the catches made by the shallow floating gill-nets which have been used almost exclusively by commercial and research vessels fishing on the high seas. It is hoped that the data obtained by Canadian vessels will be supplemented by observations in other areas of the North Pacific Ocean and the Bering Sea. In conjunction with the depth fishing, investigations of the distribution of food organisms and the feeding habits of salmon are being conducted.

The purpose of the tagging operation was to obtain information on the distribution and movements of salmon in areas through which fish of Canadian origin may pass before entering the inshore fishing areas. Unfortunately, persistent bad weather and a widespread scarcity of salmon prevented a satisfactory operation in 1960.

During the year the work of one scientist (J. I. Manzer) was largely devoted to the compilation of a joint report, with United States and Japanese scientists, on the distribution of salmon in the North Pacific Ocean and the Bering Sea. A very large body of data, including records of the Japanese fishing fleet from 1952 to 1959 and the information obtained by research vessels since 1955, has been examined and evaluated.

Further study was made of the ocean distribution of sockeye salmon originating in the Rivers Inlet-Smith Inlet area. These fish can be distinguished from all other known stocks by characteristics of the scale pattern. Examination of additional high-seas material supported previous findings which showed the ocean distribution extending westward to the Aleutians, with adults, in summer, occurring east of about Longitude 155° W and immatures west of this line.

1. Vertical distribution of salmon in the western Gulf of Alaska

F. Neave

In 1960 further investigation of the vertical distribution of salmon in the high seas was carried out by the chartered vessel Fort Ross which left Nanaimo on May 6 and returned on July 25. As much as possible of this period was spent in fishing and making related observations in an area about 100 to 150 miles south of Kodiak Island, in the northwest part of the Gulf of Alaska (Lat. 55° N, Long. 152° to 155° W). This location was selected because previous experience had shown that salmon were relatively numerous in these waters and because it was thought that conditions would be favourable for observing relationships between salmon distribution and the temperature structure of the ocean.

The essential part of the gear consisted of a nylon gill-net of 4 1/2" mesh, 40 feet deep, with an initial length of 400 fathoms. This was suspended from buoys by drop-lines. By using drop-lines of different length, the net could be set at any one of five levels which collectively covered a depth range of 200 feet from the surface. In conjunction with this adjustable net, a conventional surface gill-net was used. This was of 4 1/2" mesh throughout, 20 feet in depth, with an initial length of 300 fathoms. Due to loss or damage incurred during operations, both nets were subsequently shortened, as shown in Table I.

Catches and associated data are summarized in Table I. The depth net was set on 29 occasions and yielded a total of 435 salmon (276 sockeye, 132 chum, 27 pink). The surface net was set on 26 occasions and yielded 711 salmon (497 sockeye, 131 chum, 70 pink, 3 coho). Since the surface net differed from the adjustable net in length, depth, and possibly in tension and catching efficiency, it served mainly as a general indicator of the availability of fish at the surface during the periods when the depth net was operated at the various levels. Since the depth net was set at the surface as well as at deeper levels the catches from this gear alone are considered in Figures 1 and 2. These figures show the percentages of sockeye and chum salmon caught at each level after weighting for the number of sets made, the amount of gear set and the number of hours fished.

Table I. Salmon catches by M/V Fort Ross, 1960.

Date	Fishing time (hr.)	Surface Net: Length of net (fath.)	Sockeye	Chum	Pink	Coho	Total	Depth Net: Fishing depth (feet)	Length of net (fath.)	Sockeye	Chum	Pink	Total
DAY SETS													
17.5[a]	6.25	300	19	6	0	0	25	0-40	400	10	4	0	14
18.5[a]	5.00	300	4	2	0	0	6	40-80	400	3	6	0	9
19.5[a]	5.75	300	6	1	0	0	7			- Net lost -			
2.6	6.00	300	94	1	0	0	95	80-120	200	76	5	0	81
4.6	9.00	300	19	2	0	0	21	120-160	200	24	2	0	26
5.6	6.00	250	10	1	0	0	11	160-200	200	9	11	0	20
6.6	7.50			- Not set -				0-40	200	5	3	0	8
7.6	6.00	250	4	1	0	0	5	40-80	200	12	4	0	16
22.6	8.00	250	3	0	0	0	3	160-200	200	0	1	0	1
23.6	6.00			- Not set -				0-40	200	4	1	0	5
24.6	8.50	250	8	6	0	0	14	40-80	200	25	1	0	26
1.7	6.50	250	8	7	0	0	15	80-120	200	1	0	2	3
2.7	6.50	250	8	3	0	0	11	120-160	200	0	0	0	0
4.7	7.00	250	2	9	0	0	11	160-200	200	0	0	0	0
		Total	185	39	0	0	224			169	38	2	209
NIGHT SETS													
18.5[a]	11.00	300	14	5	0	0	19	0-40	400	15	2	1	18
19.5[a]	9.00	300	13	3	0	0	16	40-80	400	2	26	0	28
3.6	8.50	300	54	1	0	0	55	80-120	200	38	3	0	41
4.6	9.00	300	52	4	0	0	56	120-160	200	1	0	0	1
5.6	9.00	250	29	5	0	0	34	160-200	200	0	0	0	0
6.6	11.00			- Not set -				0-40	200	5	11	0	16
7.6	9.50	250	19	11	0	0	30	40-80	200	4	13	0	17
8.6	8.50	250	19	12	0	1	32	80-120	200	4	6	0	10
10.6	10.00	250	10	3	0	0	13	120-160	200	5	0	0	5
23.6	9.00	250	4	10	4	0	18	160-200	200	0	0	0	0
24.6	9.00			- Not set -				0-40	200	11	2	0	13
1.7	9.50	250	21	3	0	0	24	40-80	200	15	12	15	42
2.7	11.00	250	29	18	43	1	91	80-120	200	0	10	7	17
4.7	9.00	250	17	4	16		37	120-160	200	0	0	0	0
5.7	7.50	250	23	5	1	0	29	160-200	200	0	0	0	0
13.7	10.50	300	8	18	6	1	33	0-40[b]	200	8	8	2	18
		Total	312	102	70	3	487			108	93	25	226

[a]Position: Lat. 55°N, Long. 155°W. All other sets made at Lat. 55°N, Long. 152°W.

[b]3 1/4" mesh used (depth net only). All other sets made with 4 1/2" mesh.

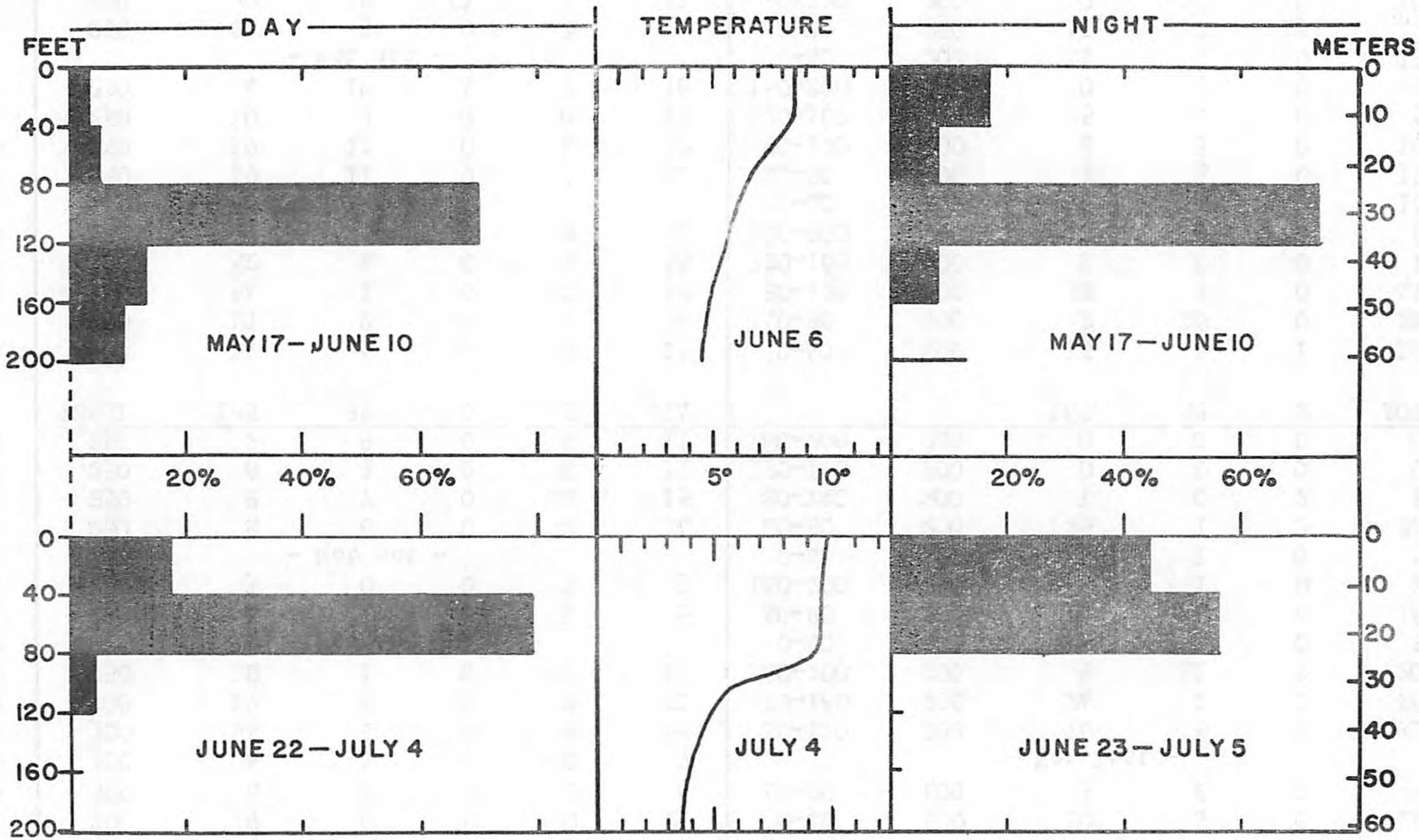

Figure 1. Percentage of sockeye salmon caught at each depth fished (weighted for fishing effort).

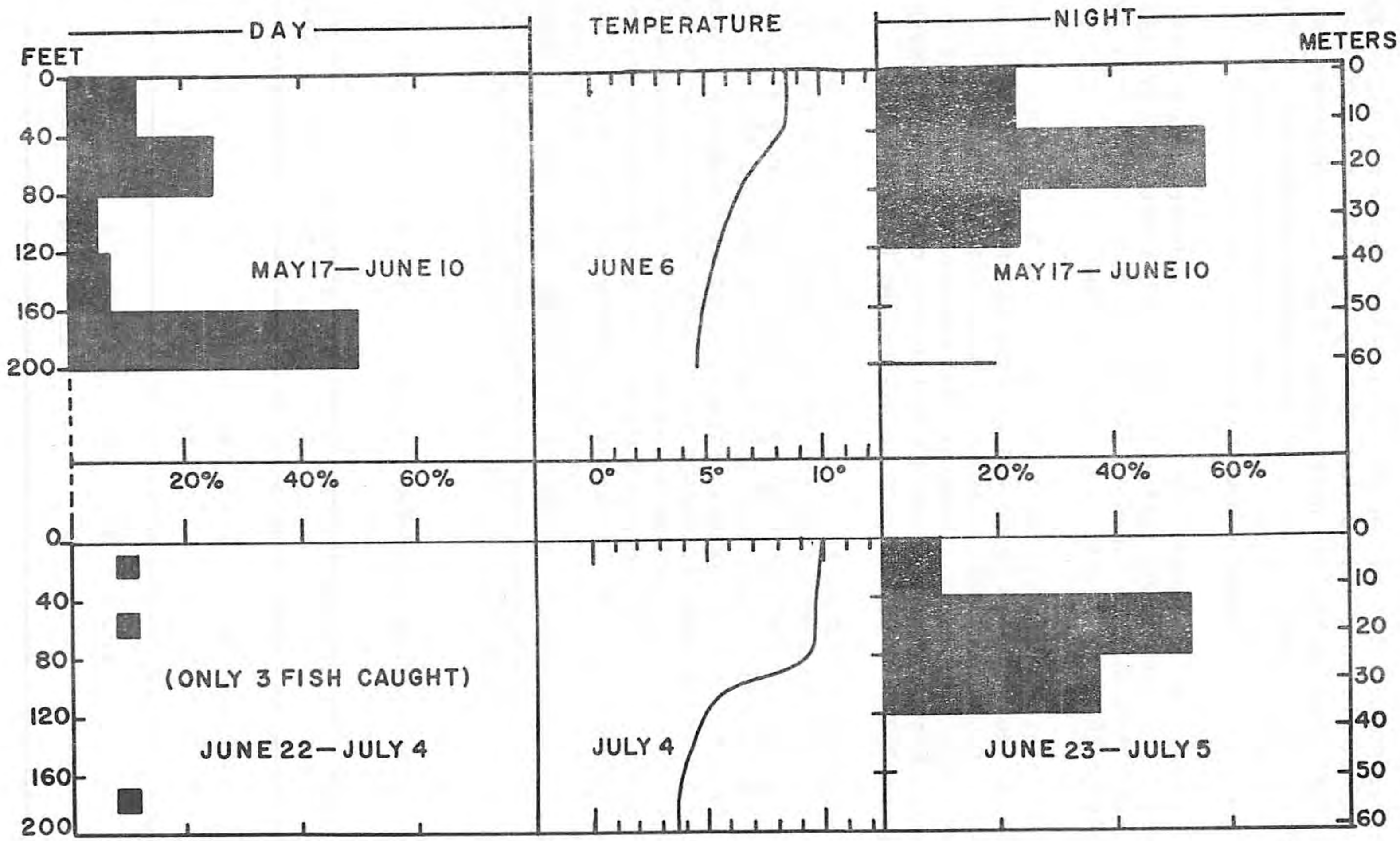

Figure 2 Percentage of chum salmon caught at each depth fished (weighted for fishing effort).

Sockeye salmon. Daytime fishing during the early period showed sockeye to be distributed throughout the vertical range which was investigated. The large preponderance of fish at the 80- to 120-foot level may be exaggerated, since the surface gill-net showed that sockeye were also plentiful at the surface at the time when these fish were caught (Table I). Nevertheless it is concluded that only a small fraction of the sockeye population was available to surface gill-nets fishing by day at this time of year, the rest of the population being distributed at depths downward to more than 160 feet.

Night-time fishing during the same period indicated some upward shift, inasmuch as no fish were caught below 160 feet and relatively greater numbers than in daytime fishing were taken in the top 80 feet. Many fish, however, were still present at the same levels as in the daytime.

In the later fishing period (June 22 to July 5) only one sockeye was caught below 80 feet. Again there was an indication of a shift to the surface by some fish at night, but again there were many fish present at the same level as in the daytime. This level, however, was not so deep as in the early part of the season. Except at the 0- to 40-foot level, catches of sockeye were consistently greater in daytime than in night-time fishing.

The temperature within the vertical interval in which fishing was carried out (over the whole fishing season and at all levels) varied from about 4.5°C to 10°C. Since the species has been found elsewhere in temperatures as low as 3°C and as high as 15°C (in surface fishing) it is obvious that no absolute limits were imposed by this factor. Actually, bathythermograph records showed that 4° water prevailed down to depths of at least 750 feet. Nevertheless the catch records indicate that during the night-time of the earlier period of fishing and during both day and night of the later period, sockeye were confined to a much shallower zone. It is noteworthy, however, that whereas the wide vertical range observed in the daytime during the first period coincided with a condition of small temperature change with depth, the limit of downward distribution in the later period was accurately represented by the thermocline which had then developed (Fig. 1). This is in agreement with data obtained in 1959.

The age-composition of sockeye caught by the depth net was as follows:

Age	4_1	4_2	5_2	5_3	6_3	Unknown
May 17 to June 10, no.	1	114	40	27	21	9
%	-	54	19	13	10	4
June 22 to July 5, no.	0	36	7	9	0	4
%	0	64	12	16	0	7

While 4_2 fish predominated in both periods, the figures indicate that the 6_3 and some of the 5_2 fish had moved out of the area by late June. No third-year fish were taken, probably because of the relatively large mesh-size used.

Maturing and immature fish in these catches were segregated by weighing the gonads and applying the criteria proposed by Godfrey (1959). According to this classification, 97% of all fish caught during the earlier period were maturing, whereas only 49% in the later period were in this condition.

No consistent differences in vertical distribution were found between maturing and immature fish or between the various age groups.

<u>Chum salmon</u>. Early season daytime fishing showed that chum, like sockeye, were present at all depths investigated (Fig. 2). There was also evidence of a withdrawal of fish from the deepest level and a greater concentration at the surface during the night. Many fish were still present, however, at intermediate levels.

In the later period, chums did not show the marked upward shift which characterized the distribution of sockeye. Daytime sets, while only yielding 3 fish, were sufficient to show the presence of the species down to the 160- to 200-foot level. Night catches were consistent with the previously noted tendency of both chum and sockeye to make a moderate upward shift at this time.

In contrast with the sockeye, it was noted that chum catches were consistently greater in night sets than in daytime sets (except at levels where the species appeared to be absent at night). This suggests a difference between the two species in the rhythm of diurnal activity and perhaps in time of feeding.

Since chums are known to tolerate temperatures from 1° or 2°C to 15°C, it is even more evident than in the case of the sockeye that the observed depth distribution was much less extensive than the limits imposed by this factor. A relationship with the thermocline was strongly suggested by night catches but was not evident for the few fish caught by day (Fig. 2).

Age determinations of chums caught in the adjustable net were as follows:

Age	3	4	Unknown
May 17 to June 10, no.	8	80	8
%	8	83	8
June 22 to July 5, no.	15	9	3
%	56	33	11

All chums caught in the earlier period were considered to be maturing fish. In the later period, 30% were placed in this category. Preliminary examination of the data has not disclosed differences in vertical distribution that can be associated with differences in age or state of maturation.

<u>Pink salmon</u>. The small number of pink salmon caught does not permit any detailed conclusions on depth distribution. The species was taken at depths between the surface and the 120-foot level.

General. The data show that on a comparative basis the majority of the sockeye and chum caught (by day and by night and throughout the fishing season) were at levels below the reach of standard floating gill-nets.

The 1960 observations were made in a restricted area. A general picture of vertical distribution cannot be presented until findings have been reported from other parts of the North Pacific Ocean and Bering Sea.

2. Salmon tagging in the eastern Gulf of Alaska — H. Godfrey

The purse seiner Key West II was chartered by Canada to tag salmon in the eastern part of the Gulf of Alaska during the summer of 1960. The charter commenced on May 16 and terminated on August 13, a period of 90 days. The main effort was concentrated in the areas bounded by North Latitudes 56° and 54° out to 145° West Longitude (about 400 miles offshore), and along the west coast of the Queen Charlotte Islands. During the last cruise the vessel fished off the west coast of Vancouver Island. The tags used were Petersen-type plastic discs.

With the exception of positions near the entrance to the Strait of Juan de Fuca, salmon were generally very scarce during the 1960 season. Also, bad weather and unfavourable seas seriously hampered the operations in the northern areas and resulted in very small catches. For the whole season, a total of 49 sets were made; 1,268 salmon were caught (including 3 by long-line) of which 1,226 were tagged. The great bulk of the catch (mainly sockeye) was made off the west coast of Vancouver Island at the end of the season. In the northern areas the largest single catch was only 44 fish, and the average per set only 8.5 fish.

Invariably larger catches were made close inshore; whenever the vessel fished offshore few or no salmon were taken. With one or two exceptions, "jumpers" were observed only off the west coast of Vancouver Island close inshore.

A Japanese-type horizontal long-line (employing a total of 250 hooks) was tried out on several occasions. It caught 3 pink salmon and 3 black cod. It is believed that the general scarcity of salmon, their wide dispersal in both horizontal and vertical planes, and the type of bait used, were factors contributing to the small catch. Strips of frozen and salted herring, and coloured plastic lures ("hoochie-koochies") were used; all 6 fish were taken by the lures.

Plankton hauls (standard INPFC net and a 3-ft. Isaacs-Kidd midwater trawl) and oceanographic observations (water temperatures and water samples) were made throughout the season.

The seining effort and catches are summarized in Table II and recoveries in Table III. The rate of recovery from all salmon tagged in the northern areas was 5.7%; that from the sockeye tagged off the west coast of Vancouver Island was 28.6%.

Table II. Seine sets and salmon catches, MV Key West II, 1960.

Obs. No.	Date	Lat. N.	Long. W	Sock-eye	Pink	Chum	Coho	Chinook	Total
KW-2	23/5	52°07'	131°31'	-	-	-	-	-	-
KW-3	23/5	52°07'	131°31'	2	30	-	-	-	32
KW-7	25/5	54°34'	133°43'	-	-	-	-	-	-
KW-13	30/5	56°00'	139°38'	3	-	-	-	-	3
KW-14	30/5	55°58'	139°36'	1	-	-	-	-	1
KW-22	2/6	54°08'	140°43'	-	-	-	-	-	-
KW-23	3/6	54°00'	138°05'	3	-	-	-	-	3
KW-24	3/6	54°05'	137°35'	1	-	-	-	-	1
KW-26	4/6	54°05'	135°00'	1	2	-	-	-	3
KW-28	7/6	54°17'	132°58'	-	1	3	-	2	6
KW-29	8/6	54°10'	133°22'	-	-	-	-	-	-
KW-30	8/6	54°00'	133°20'	-	-	8	-	-	8
KW-31	9/6	54°13'	133°13'	-	14	-	2	2	18
KW-32	16/6	54°47'	133°24'	-	3	-	1	-	4
KW-34	19/6	55°13'	134°42'	-	16	-	-	-	16
KW-36	26/6	55°51'	136°20'	-	33	-	1	1	35
KW-38	27/6	55°51'	136°23'	1	33	10	-	-	44
KW-39	27/6	55°51'	136°24'	-	3	-	-	-	3
KW-40	27/6	55°50'	136°55'	-	1	-	-	-	1
KW-45	8/7	53°39'	133°08'	-	2	-	-	-	2
KW-46	8/7	53°39'	133°08'	7	4	-	-	-	11
KW-47	9/7	53°36'	133°04'	-	-	17	-	-	17
KW-48	9/7	53°36'	133°04'	1	2	1	-	-	4
KW-49	9/7	53°36'	133°04'	-	-	23	-	6	29
KW-50	10/7	53°37'	133°20'	-	1	-	-	-	1
KW-51	10/7	53°37'	133°20'	-	3	-	-	-	3
KW-53	11/7	52°52'	132°17'	-	1	-	5	1	7
KW-54	15/7	54°11'	133°10'	1	-	-	-	-	1
KW-55	18/7	52°41'	132°02'	-	-	-	-	-	-
KW-56	19/7	52°04'	131°15'	-	-	3	-	-	3
KW-57	19/7	52°00'	130°56'	-	-	-	-	-	-
KW-58	20/7	51°48'	130°39'	3	4	-	-	-	7
KW-60	20/7	51°32'	130°02'	1	1	2	-	-	4
KW-62	21/7	51°02'	128°58'	3	6	1	-	-	10
KW-63	21/7	50°41'	128°29'	9	8	-	-	3	20
KW-64	27/7	48°35'	125°06'	36	1	-	21	2	60
KW-65	27/7	48°34'	124°52'	185	-	-	15	-	200
KW-66	28/7	48°31'	124°31'	297	1	-	-	1	299
KW-67	28/7	48°31'	124°31'	137	-	-	1	2	140
KW-68	29/7	48°29'	125°06'	1	-	-	3	-	4
KW-69	29/7	48°45'	125°26'	29	-	-	7	3	39
KW-70	30/7	48°54'	125°34'	7	-	-	10	23	40
KW-71	31/7	48°55'	126°02'	10	-	-	15	4	29
KW-72	1/8	49°14'	126°26'	69	-	-	2	-	71
KW-73	1/8	49°12'	126°39'	-	1	-	4	1	6
KW-74	2/8	49°30'	127°13'	-	-	-	-	-	-
KW-75	2/8	49°52'	127°16'	32	-	-	5	1	38
KW-77	4/8	50°01'	127°44'	7	4	-	11	8	30
KW-78	6/8	50°26'	129°09'	-	1	-	8	3	12
				847	176	68	111	63	1265*

*Also 1 steelhead, Obs. No. KW-45.

Table III(a). Recoveries from taggings off southeast Alaska and the Queen Charlotte Islands.

Tag No.	Species	Tagged			Recovered
MS 080	Pink	19/6	55°13'N	134°42'W	27/8 - nr. Cape Addington, Alaska
MS 099	Pink	26/6	55°51'N	136°20'W	18/7 - Namu, B. C.
MS 096	Pink	26/6	55°51'N	136°20'W	30/8 - Kitkatla Inlet, B. C.
MS 166	Pink	27/6	55°51'N	136°23'W	11/7 - Swann Is., Semour Can., Alaska
MS 103	Pink	27/6	55°51'N	136°20'W	25/7 - Gravina Is., Clarence Str., Alaska
MS 173	Pink	27/6	55°51'N	136°24'W	26/7 - Funter Bay, Alaska
MS 272	Pink (?)	21/7	50°41'N	128°29'W	31/7 - Bella Coola, B. C.
MS 055	Chum	8/6	54°00'N	133°20'W	10/7 - Kincolith, Nass R., B. C.
MS 157	Chum	27/6	55°51'N	136°23'W	?/7 - Quadra Arm, Clarence Str., Alaska
MS 193	Chum	9/7	53°36'N	133°04'W	8/8 - Munsie Pt., Seaforth Channel, B.C.
MS 198	Chum	9/7	53°36'N	133°04'W	2/8 - Fisher Channel, B. C.
MS 237	Chum	9/7	53°36'N	133°04'W	? - Garnet Pt., Alaska
MS 146	Sockeye	27/6	55°51'N	136°23'W	26/7 - Stikine R., Alaska
MS 187	Sockeye	8/7	53°39'N	133°08'W	Week of July 20, Wright Sound, B. C.
MS 220	Chinook	9/7	53°36'N	133°04'W	31/7 - Spike Rk. (Umatilla Rk.), Wash.
MS 247	Chinook	11/7	52°52'N	132°17'W	16/8 - Barnston Is. slough, Fraser R., B. C.
MS 243	Coho	11/7	52°52'N	132°17'W	8/8 - Kwakume Pt., Fitzhugh Sd., B.C.

Table III(b). Recoveries from taggings off the west coast of Vancouver Island.

Tag No.	Species	Tagged			Recovered
MS 779	Coho	28/7	48°31'N	124°31'W	2/8 - San Juan, B. C.
MS 967	Coho	29/7	48°29'N	125°06'W	25/8 - Sekiu, Wash. (?)
MS 1012	Coho	30/7	48°54'N	125°34'W	16/8 - San Juan, B. C.
MS 1024	Coho	30/7	48°54'N	125°34'W	5/9 - Pt. Gardner, Everett, Wash.
MS 1042	Coho	30/7	48°54'N	125°34'W	26/9 - Strait of Juan de Fuca
MS 1052	Coho	31/7	48°55'N	126°02'W	18/9 - Sequi, Wash.
MS 1054	Coho	31/7	48°55'N	126°02'W	? - Skagit Bay, Wash.
MS 1060	Coho	31/7	48°55'N	126°02'W	13/8 - Cape Cook, B. C.
MS 1072	Coho	31/7	48°55'N	126°02'W	7/8 - Sooke, B. C.
MS 1073	Coho	31/7	48°55'N	126°02'W	11/8 - Estevan Pt., B. C.
MS 1204	Coho	4/8	50°01'N	127°44'W	28/9 - Canoe Pass, Fraser R., B. C.
MS 1232	Coho	6/8	50°26'N	129°09'W	25/8 - Estevan Pt., B. C.
MS 273	Chinook	21/7	50°41'N	128°29'W	11/9 - Nehalem R., Oregon
MS 1046	Chinook	30/7	48°54'N	125°34'W	? - Kalama R., Wash.
MS 1155	Chinook	2/8	49°52'N	127°16'W	4/10 - Frankfort, Columbia R., Wash.
MS 1197	Chinook	4/8	50°01'N	127°44'W	22/8 - Alderbrook, Columbia R. fishery
MS 1231	Chinook	6/8	50°26'N	129°09'W	25/8 - Steveston, B. C.
	Sockeye	Some 230 sockeye recoveries have been reported to date, mainly from Convention waters in British Columbia and Washington. Information from the International Pacific Salmon Fisheries Commission indicates that the speed of migration of these fish was consistent with the speeds of sockeye tagged in earlier years at Sooke, B. C.			

3. Ocean distribution of Rivers and Smith Inlets sockeye

J. I. Manzer and
T. H. Bilton

The study of the use of scale patterns for recognizing Rivers and Smith Inlets type fish from other stocks of sockeye, begun in 1959, was refined in 1960. The study was carried out in co-operation with United States investigators and formed part of the research program of the International North Pacific Fisheries Commission.

Examination of scales from sockeye salmon originating in different watersheds and coastal areas along the Pacific rim revealed that the pattern for Rivers and Smith Inlets sockeye salmon were similar and that these differed from the patterns for all other known stocks. So apparent are these differences that separation is possible in some cases on a visual basis. Characters considered typical of these two stocks include (1) a small freshwater zone, (2) narrow-spaced circuli in the first ocean year, and (3) the width of the second ocean growth zone exceeds that of the first. Values for these characters for Rivers and Smith Inlets scales, as well as those for other stocks examined, are given in Table IV. These values in combination clearly indicate the differences between the Rivers and Smith Inlets types and sockeye from other areas. The apparent similarity between the scale patterns reported by Gilbert in 1914 and by current investigators suggests that the characteristics observed are consistent for these stocks rather than peculiar to certain brood years.

Examination of every tenth scale from scale samples collected from the commercial catch in 1958 in the Rivers Inlet area indicated that 126 of 156 sockeye, or 76.2%, possessed the typical pattern. The remainder may have included Rivers and Smith Inlets fish possessing atypical patterns, or other stocks passing through the area enroute to their spawning grounds elsewhere.

Of more than 5,500 scales examined from sockeye caught on the high seas by Canadian, Japanese and United States research vessels in 1957, 1958 and 1959, 45 were considered to be of Rivers and Smith Inlets types. Values for the characters of these fish are summarized in Table V. Comparing this table with Table IV, the values for Rivers and Smith Inlets indicate a high degree of similarity, supporting the belief that the origins of these fish were either Rivers or Smith Inlet.

The high-seas locations of Rivers and Smith Inlets type sockeye are given in Figure 3. From these it is seen that from mid-May through to mid-August these stocks were distributed generally within the Gulf of Alaska as far west as Longitude 170° W. Information about distribution in 1959 is partial since it is based on Canadian research vessel catches only. Examination of scale samples of catches either by the Japanese high-seas commercial fishery or by research vessels in other regions of the North Pacific and the Bering Sea have failed, to this time, to indicate the occurrence of these sockeye elsewhere. That some individuals can occur further westward is shown, however, by a sockeye salmon tagged south of Kiska (51°47' N, 177°45' W) as an immature in 1957 and recovered two year later in Rivers Inlet.

A consideration of the catches of immature and maturing individuals reveals that the two groups are distributed differently. Mature individuals were caught from off the British Columbia coast westward to Longitude 155° W, being present off the British Columbia coast as early as mid-June and persisting until early August. Along Longitude 155° W they were present as late as late June. Immature individuals, in their second ocean year, were caught in waters between Longitudes 153° W and 170° W between late June and mid-August. Information on the oceanic distribution of one-ocean-year fish is lacking.

Table IV. Summary of scale characters of sockeye salmon of known origin

Origin	Sample size	Freshwater zone				Radius of 1st annulus (mm) / No. circuli in 1st annulus		II ocean annulus / I ocean annulus	
		No. circuli		Radius (mm.) X100		Range	Mean	Range	Mean
		Range	Mean	Range	Mean				
Fraser R.	20	10-18	14.0	30-55	38.8	3.0-4.3	3.75	0.5-1.3	0.82
Smith I.	21	6-16	9.6	16-48	23.7	2.6-3.9	3.12	0.9-1.9	1.40
Rivers I.	23	5-13	9.7	14-38	23.4	2.5-3.6	2.95	1.1-1.9	1.43
Skeena R.	20	13-15	13.9	37-59	42.8	3.4-4.4	3.82	0.5-0.9	0.74
Bristol Bay	20	9-19	12.8	28-52	37.3	3.5-4.9	4.10	0.5-1.1	0.71
Bolshaya R.	20	8-14	10.1	23-37	29.3	3.4-4.6	3.92	0.5-0.9	0.65

Table V. Summary of scale characters of presumed Rivers and Smith Inlets sockeye caught on the high seas

Year	Number	Freshwater zone				Radius of 1st annulus (mm) / No. circuli in 1st annulus		II ocean annulus / I ocean annulus	
		No. circuli		Radius (mm.) X100		Range	Mean	Range	Mean
		Range	Mean	Range	Mean				
1957	12	6-18	10.7	19-54	29.5	2.5-3.5	3.00	1.1-1.7	1.33
1958	18	7-14	9.8	19-32	26.3	2.7-4.3	3.28	1.0-2.0	1.23
1959	15	7-12	9.3	18-38	26.4	2.3-4.5	3.15	1.0-1.9	1.34

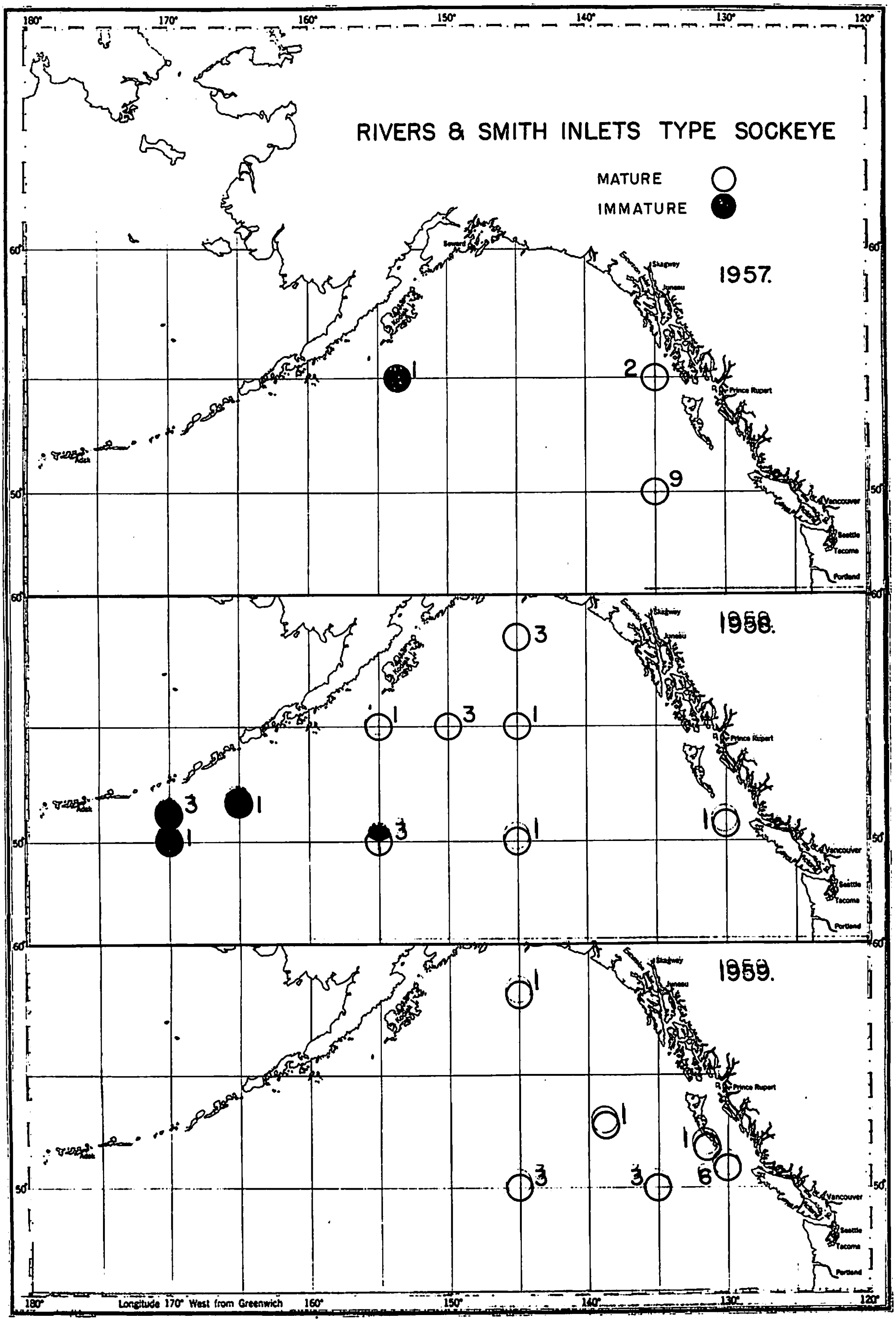

Fig. 3. High-seas distribution of Rivers and Smith Inlets type sockeye.

4. <u>Studies on high-seas zooplankton and salmon food</u> F. Neave

<u>Zooplankton</u>. In conjunction with the investigation of the vertical distribution of salmon in the western Gulf of Alaska (Lat. 55° N, Long. 152-155° W), macroplankton samples were taken in three ways: (1) Vertical hauls from 150 m to surface with a standard plankton net, diameter 45 cm, mesh 0.33 mm (39 samples). (2) Horizontal hauls of 10 minutes' duration with the same net at: surface, 10 m, 40 m, 85 m and 135 m (3 daytime series, 3 night-time series). (3) Horizontal hauls of 10 minutes' duration with an Isaacs-Kidd midwater trawl, 6-ft opening, mesh 3 inches to 1/8 inch, at surface, 10 m, 25 m, 60 m (3 daytime series, 3 night-time series).

The wet weight of each sample was taken and a rough quantitative assignment of the chief categories of constituent organisms was made by eye.

The findings for the horizontal hauls (which yielded information on the vertical distribution of salmon food organisms) are summarized in Tables VI and VII.

In catches made by the plankton net copepods were dominant. Amphipods were consistently represented. Fish and euphausians were not or were very inadequately sampled. The trawl produced extremely low catches of all planktonic forms in the daytime in the upper 10 meters of water. In general, however, it gave better results than the plankton net for euphausians and, in night hauls, usually yielded small quantities of fish. Amphipods and copepods were to a large extent excluded. Chaetognaths formed a larger proportion of trawl catches than of plankton net catches. It is unlikely that the two kinds of gear, even in conjunction, gave a very good picture of the relative abundance of the various organisms.

Amphipods in daytime hauls showed a fairly uniform vertical distribution throughout the depths sampled. At night the maximum concentration was definitely at the surface, although some were taken at all depths. On two out of three occasions copepods showed a maximum abundance at 40 m by day and at the surface by night, with representation, however, at all levels. Euphausians were taken in abundance only at the 25 m and 40 m levels and, within the limits of the data, showed no night-time rise toward the surface. Chaetognaths also remained plentiful at night at depths of 40 m and 60 m.

The sporadic appearance in the trawl catches of large quantities of euphausians suggests that these organisms occur in swarms or patches. Reference can also be made to the relative scarcity of copepods in the hauls made on June 5 by both plankton net and trawl at almost all levels. Patchiness of distribution, in space or time, adds much to the difficulty of quantitative assessment of the zooplankton.

The vertical hauls made with the plankton net from 150 m to the surface of course gave no information on the intermediate depths at which organisms were caught. A comparison between the estimated percentage wet weight of the predominant organisms taken by the plankton net in all horizontal and vertical hauls showed reasonable agreement, as follows:

Table VI. Wet weight (g.) of daytime plankton catches at Lat. 55° N, Long. 152°-155° W, in 1960.

Depth (m.)	Date	Plankton Net								Isaacs-Kidd Trawl								
		Pter.	Amph.	Cop.	Eu.	Chaet.	Coel.	Fish	Total	Pter.	Amph.	Cop.	Eu.	Chaet.	Coel.	Fish	Sq.	Total
0	17/5	x	x	0.7	-	-	0.3	-	1.1	-	x	x	-	-	-	x	-	0.7
0	5/6	x	11.1	10.6	x	x	x	x	22.3	-	-	-	-	x	x	x	-	0.5
0	23/6	-	3.1	-	-	x	-	-	3.1	-	x	x	x	-	x	130.0	-	136.8
Mean		-	4.7	3.8	-	-	0.1	-	8.8	-	-	-	-	-	-	43.3	-	45.6
10	17/5	x	0.9	85.0	-	x	x	-	86.7	-	x	3.8	x	2.2	x	x	-	6.4
10	5/6	-	5.9	9.9	-	x	0.2	-	16.5	-	-	-	-	0.5	0.1	x	-	0.7
10	23/6			sample missing						-	x	2.2	x	1.5	-	-	-	3.7
Mean		-	3.4	47.5	-	-	-	-	51.6	-	-	2.0	-	1.4	-	-	-	3.6
25	17/5									x	x	21.1	x	16.5	x	x	-	38.5
25	5/6									x	x	x	92.0	x	x	-	-	94.0
25	23/6									-	x	3.5	x	4.2	-	x	-	7.8
Mean										-	-	8.2	30.7	6.9	-	-	-	46.8
40	17/5	x	x	128.0	x	1.3	-	-	132.6									
40	5/6	x	1.2	2.8	-	x	x	-	4.2									
40	23/6	x	2.3	224.0	-	4.6	-	-	232.6									
Mean		-	1.2	118.3	-	2.0	-	-	123.1									
60	17/5									x	1.0	9.8	x	8.4	x	-	-	19.6
60	5/6									x	2.0	x	1.6	x	x	x	-	4.0
60	23/6									-	1.0	5.4	x	3.5	-	-	-	10.0
Mean										-	1.3	5.1	0.5	4.0	-	-	-	11.2
75	17/5	x	0.8	78.8	x	1.7	0.8	-	83.6									
85	5/6	x	0.6	7.7	0.6	2.3	-	-	11.3									
85	23/6	-	3.8	25.5	x	x	x	-	31.9									
Mean		-	1.7	37.3	0.2	1.3	0.3	-	42.3									
135	17/5	x	x	73.5	x	1.6	0.8	x	81.7									
135	5/6	x	5.6	6.7	x	1.7	1.7	-	16.6									
135	23/6	x	x	17.6	x	1.6	1.0	-	20.5									
Mean		-	1.9	32.6	-	1.6	1.2	-	39.6									

Pter. - pteropod
Amph. - amphipod
Cop. - copepod
Eu. - euphausian
Chaet. - chaetognath
Coel. - coelenterate
Sq. - squid
x - present in insignificant quantity

Table VII. Wet weight (g.) of night-time plankton catches at Lat. 55° N, Long. 152°-155° W, in 1960.

		Plankton Net								Isaacs-Kidd Trawl								
Depth (m.)	Date	Pter.	Amph.	Cop.	Eu.	Chaet.	Coel.	Fish	Total	Pter.	Amph.	Cop.	Eu.	Chaet.	Coel.	Fish	Sq.	Total
0	26/5	×	36.0	78.0	×	2.4	-	-	120.5	1.0	0.1	1.0	0.2	2.0	1.0	2.0	2.5	9.9
0	10/6	×	13.0	199.0	×	×	×	-	212.9	-	1.1	2.1	0.7	1.4	×	0.4	-	7.1
0	4/7	×	26.0	44.0	-	1.5	-	-	73.4	×	×	4.5	-	4.2	×	-	-	9.3
Mean		-	25.0	107.0	-	1.3	-	-	135.6	0.3	0.4	2.5	0.3	2.5	0.3	0.8	0.8	8.8
10	26/5	0.9	1.7	69.0	×	12.8	×	-	84.7	×	×	3.0	0.5	2.0	3.0	1.5	-	10.0
10	10/6	×	0.8	68.0	×	3.0	2.3	-	76.1	-	×	40.0	4.2	6.9	×	1.1	-	57.6
10	4/7	×	×	61.0	×	7.2	×	-	66.7				sample missing					
Mean		0.3	0.8	66.0	-	7.7	0.8	-	75.8	-	-	21.5	2.4	4.5	1.5	1.3	-	33.8
25	26/5									×	2.8	11.2	1.1	2.8	31.3	5.6	-	55.8
25	10/6									×	×	×	18.2	1.2	20.2	-	-	40.5
25	4/7									×	×	0.3	-	10.5	×	×	-	11.1
Mean										-	0.9	3.8	6.4	4.8	17.2	1.9	-	35.8
40	26/5	×	×	78.0	×	3.1	21.0	-	104.0									
40	10/6	×	×	16.0	-	0.4	1.1	-	37.4	-	×	8.6	39.0	0.6	×	5.6	-	57.2
40	4/7	3.4	×	36.0	×	7.2	×	-	48.1	-	×	3.1	-	24.5	0.3	0.3	-	25.6
Mean		1.1	-	43.3	-	3.6	7.4	-	63.2	-	-	5.9	19.5	12.6	0.2	3.5	-	41.4
60	26/5									×	×	×	4.1	×	32.0	9.1	-	45.7
60	10/6									×	×	×	16.2	6.2	3.2	6.5	-	32.4
60	4/7									×	×	×	1.5	26.5	0.9	-	-	28.3
Mean										-	-	-	7.3	10.9	12.0	5.2	-	35.5
75	26/5	×	0.7	67.4	×	1.4	0.7	-	71.7									
85	10/6	×	1.8	27.4	×	1.3	5.3	-	35.5									
85	4/7	×	0.6	26.9	×	0.9	×	-	29.8									
Mean		-	1.0	40.6	-	1.2	2.0	-	45.7									
135	26/5	×	×	40.0	0.5	5.0	4.0	-	50.0									
135	10/6	0.3	1.6	28.5	×	0.3	1.0	-	32.8									
135	4/7	×	0.5	16.2	×	0.7	×	-	18.1									
Mean		0.1	0.7	28.2	0.2	2.0	1.7	-	33.6									

Pter. - pteropod
Amph. - amphipod
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Eu. - euphausian
Chaet. - chaetognath
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Sq. - squid
× - present in insignificant quantity

	Total catch (g)	Estimated % wt. of organisms Amph.	Cop.	Chaet.	Coel.
Vertical hauls from 150 m	190	4.3	76.9	3.5	7.1
Horizontal hauls at 0, 10, 40, 80, 135 m	1,808	6.5	84.4	3.2	2.2

In addition to those made in the fishing area, 16 vertical hauls were made during the passage of the Fort Ross from the northern end of Vancouver Island to her destination south of Kodiak Island. The wet weight of zooplankton obtained at these stations is shown in Figure 4. Dominant forms were copepods and coelenterates. An area of relatively low abundance of these organisms is indicated for the central part of the Gulf of Alaska. Large quantities of diatoms (not included in the assigned weights) were encountered at the three stations marked "D".

Salmon food. The stomach contents of sockeye and chum salmon caught in the indicated area south of Kodiak Island have been examined in part. For each fish examined the total volume of stomach contents was determined and the recognizable organisms were classified. In addition, a rough visual assessment was made of the volumetric proportions contributed by the major categories of food organisms represented. Because of the crudeness of the method and the varying degree to which different kinds of food are recognizable with advancing digestion, these quantitative estimates must be regarded as subject to considerable error, although assessment was aided by the fact that individual stomachs commonly contained only from one to three kinds of food in large amount.

Since only about half of the available stomachs have been examined to date, no attempt is made in this report to consider stomach contents in relation to diurnal or seasonal time-periods or to depth at which fish were taken.

The frequency of occurrence of the main categories of food organisms in the stomachs examined is shown below. Empty stomachs have been excluded from the tabulation.

Species	No. of stomachs	Frequency of occurrence (%) Pter.	Amph.	Cop.	Dec.	Eu.	Fish	Squid
Sockeye	232	8.2	78.9	19.0	5.6	66.5	49.5	1.7
Chum	66	9.1	92.5	15.1	0	66.7	28.8	4.5

By volume, amphipods and euphausians predominated heavily and together probably constituted 80% or more of the diet of both sockeye and chum, although the proportions of these two categories of crustaceans differed for the two species of salmon. This difference is not adequately represented by the "frequency of occurrence". By volume, euphausians undoubtedly ranked first and amphipods second in the food items eaten by sockeye. The order was reversed for chums.

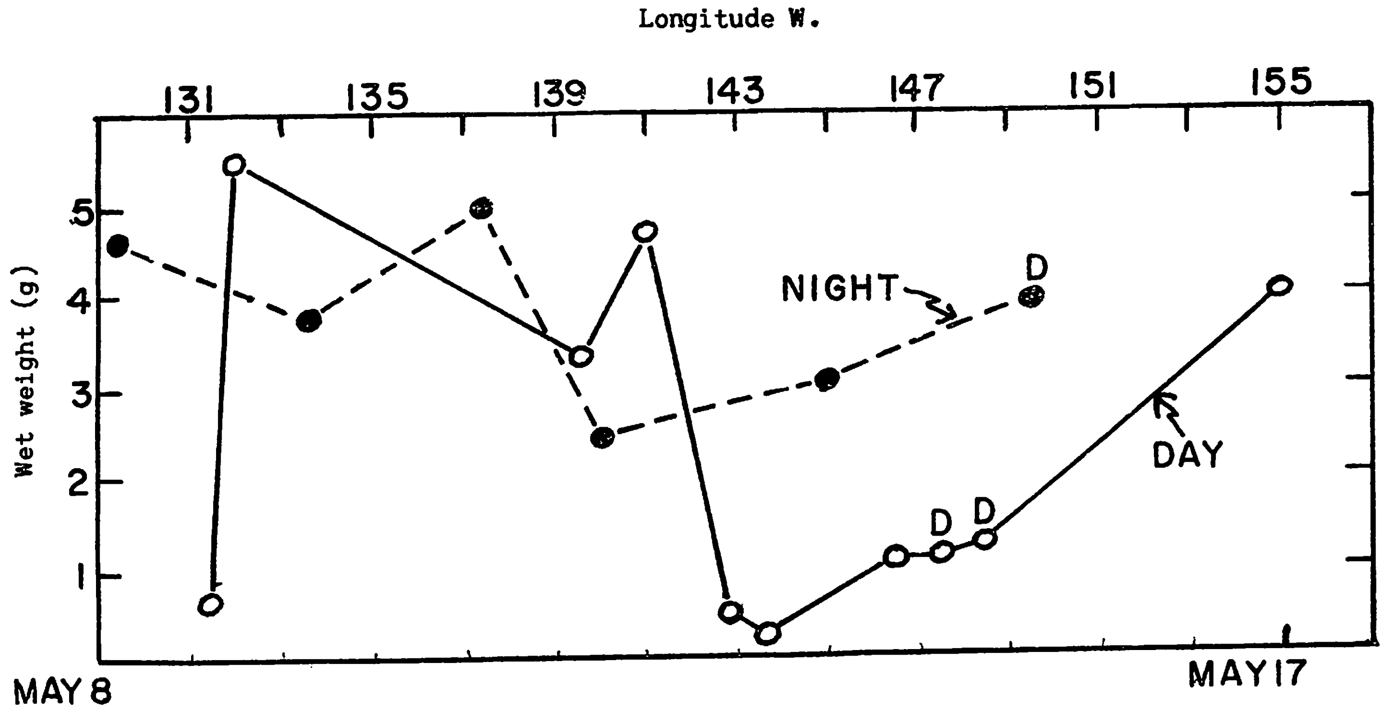


Fig. 4. Wet weight of zooplankton samples, Gulf of Alaska, 1960.

It is concluded that both sockeye and chum salmon fed selectively rather than taking organisms at random from the biomass of macroplankton. This is indicated by the very different proportion of items occurring in stomachs and in plankton and trawl samples. In spite of errors which may be involved in the quantitative methods used, it is probable that amphipods and euphausians were eaten to a greater extent than their general abundance would indicate. Copepods, on the other hand, in spite of their abundance, constituted an insignificant proportion, by volume, of the diet. Chaetognaths, which frequently appeared in appreciable numbers in plankton samples, were not found in stomachs. Selectivity in feeding is also evident from the frequent occurrence in stomachs of a food mass consisting essentially of only one kind of organism. In other instances two kinds predominated, each occupying a separate portion of the gastric space. It may be that the preferred organisms frequently occur in dense patches which are attractive to feeding salmon.

Fish were present in a rather high proportion of stomachs, especially those of sockeye, but in most cases were represented by only a few small larval forms. Although the digestive process may result in underestimation of this type of food, it was not thought to be a major constituent of the diet.

The scarcity of euphausians in plankton samples taken from the upper 10 meters suggests that much feeding by salmon takes place at greater depths. The finding of considerable concentrations of euphausians at depths of 25 and 40 meters in early June coincided with relatively large catches of sockeye at or near these levels.

A detailed study of the stomach contents of salmon caught in high-seas operations in 1958 has been made by R.J. Le Brasseur (on leave of absence).

5. <u>Joint report on distribution and relative abundance of salmon on the high seas</u> J. I. Manzer

Since its implementation, the research program of the International North Pacific Fisheries Commission has been concerned with biological problems related to the Protocol of the Convention. Essential to the solution of these problems is a comprehensive description of the distribution of Pacific salmon in the North Pacific Ocean and the adjacent seas.

At the sixth annual meeting (1959) of the INPFC the Committee on Biology and Research established a working party whose function is to prepare a report on the high-seas distribution of Pacific salmon. The group, consisting of one scientific member from each of the three signatory countries, Canada, Japan and the United States, met twice in 1960. The first meeting took place in Japan in late May for a two-month period to examine and evaluate available catch statistics and biological data from operations of research vessels and mothership operations, and to discuss methods of analyses and presentation of these data. A start was also made on the analyses of the large mass of data. A second meeting was held during the seventh annual meeting (October-November, 1960) to review progress.

Main approaches

Information on distribution is being derived from the following:

(1) Catch statistics. The principal sources of catch and effort data are the mothership and INPFC research vessel operations. Supplementary data are also available from Japanese training vessels and vessels of other research agencies operating in the North Pacific.

The Japanese motherships operate in the North Pacific and Bering Sea west of Longitude 175° W, usually from May through July, and in the Okhotsk Sea during June and July. Catch and effort data from these operations have been made available by the Japanese Fishery Agency for each year since 1952 by statistical areas of 2 degrees of Latitude and 5 degrees of Longitude and 10-day periods. Changes in distribution and relative abundance are being determined for each of the five species of salmon from catch-per-unit-effort indices.

Fishing by research vessels has been carried out in the North Pacific and the Bering Sea since 1955. Since 1957 standard surface gill-nets have been used by the three countries. The purpose of this fishing was (1) to study salmon distribution, and (2) to collect adequate samples for racial studies which are also part of the INPFC research program. Considering these two functions it is obvious that research vessel data are capable of revealing changes in distribution only in a gross manner. Since research vessels fished with varying numbers of gill-nets of different mesh size, catch data are weighted so that each mesh size is equally represented.

(2) Maturity studies. The seasonal distribution pattern of salmon on the high seas is affected by the movements of immature and maturing individuals. Maturing fish during the early season undertake spawning migrations while immature fish throughout the year conduct feeding migrations. Because of these two kinds of migrations, and the rapidity with which they are conducted, it has been necessary to separate the two groups of fish. Separation was made according to methods developed by Canadian and Japanese scientists, using gonad weight to body weight ratios. In the absence of these data, size, age or length of marine residence was used, but with less reliability.

(3) Age and size data. These data are being examined to determine whether or not in a given year significant differences exist between salmon caught in different regions. The study at present is in its early stages but appears to be yielding promising results for pink salmon.

(4) Environmental studies. Research vessels have observed water temperatures, salinities and plankton in each year since the research program began. A start has been made to determine if changes in the relative abundance and distribution of salmon are related to these factors. Information of this kind is necessary if seasonal and annual changes in the distribution and movements of salmon are to be better understood.

To expedite preparation of the report each member is responsible for preparing sections dealing with one of the three major species, which will then be reviewed jointly. The United States is concerned with sockeye, Japan with pinks, Canada with chums. Canada, in addition to this responsibility, is assisting the other members in the analyses of mothership data and has begun analyses of data for coho and chinook salmon.

Summary of results

The analyses of data dealing with various aspects of salmon distribution are still incomplete but nevertheless a considerable amount of information has emerged for each species. Pink salmon are excluded from reporting at this time. The salient features for the other four species are summarized below.

(1) Sockeye salmon. In May, sockeye are widely distributed in offshore waters in the North Pacific, being present as far south as Latitude 43° N in the western region and 48° N in the eastern. Largest catches recorded by motherships were in the southwest Aleutian area between Longitudes 165° E and 180° and Latitudes 48° N and 52° N. The catches in this area consisted almost entirely of mature fish. The distribution of maturing sockeye includes the area south of the Aleutians. The limited sampling by research vessels carried out in the Bering Sea suggests that few sockeye are present in this area. In the western Gulf of Alaska, south of the Alaska Peninsula and Kodiak Island, immatures are found in fair abundance. Catches in the coastal waters of the Gulf of Alaska are of maturing fish but rarely are they as abundant as in the Aleutian area.

June catches show maturing sockeye to be abundant, with annual fluctuations, in the southeast Kamchatka region, and central and eastern Bering Sea. In the southwest and in central Aleutian areas immatures replace matures in dominance during the latter half of the month in research vessel catches. Frequently the abundance level rises with the influx of these fish. In the western Bering Sea the abundance levels are low through June in the years of sampling (1958 and 1959). In the Gulf of Alaska, particularly in the southwestern portion, immature individuals are abundant. In the central Gulf region sockeye are less abundant than in other areas of the North Pacific. Abundance in the coastal Gulf region varies and virtually all fish are maturing individuals.

July catches near southeast Kamchatka show a rapid replacement of maturing sockeye by immatures, though abundance levels remain relatively high. Immatures continue to occur at relatively high abundance levels immediately south of the Aleutians while catches south of 50° N diminish coincidentally with seasonal warming of the surface waters. The central and eastern parts of the Bering Sea show a rapid decline in the relative abundance of sockeye with the emigration of the maturing fish. The remaining fish, everywhere low in abundance at first, are immatures. Immatures increase in abundance in the north-central Bering Sea and are found in rapidly increasing abundance in the western Bering Sea as the month progresses. In the eastern Bering Sea immatures remain at low abundance levels. In the western Gulf of Alaska immatures continue to occur in fair abundance while the central Gulf shows a decreasing abundance of both maturing and immature sockeye. In the eastern coastal region matures predominate but are generally at low levels of abundance.

August catches in the southeast Kamchatka area show a slight decline in abundance levels which, however, still remain relatively high. Sockeye at this time are almost all immature fish. South of the Aleutians immatures continue to be present at high levels of abundance. The south-central and eastern parts of the Bering Sea show a continuing low abundance of immature sockeye while in the north-central and western parts they are at a much higher level of abundance. In the western Gulf of Alaska immatures are fairly abundant in August but catches show some decline from the July level. By mid-August sockeye are virtually absent in the salmon catches made in the central and coastal Gulf of Alaska regions.

(2) Chum salmon. The study of the high-seas distribution of chum salmon is more difficult than that for other species of salmon. The difficulty is principally due to chums spending longer periods at sea and maturing at different ages and over an extended period of each year.

In May, not unlike sockeye salmon, chums are widely distributed in the North Pacific. In the western region they occur as far south as Latitude 40° N and in the eastern region as far south as Latitude 46° N. Training vessel operations indicate, in some years, that large concentrations are present off northern Japan and the southern Kurile Islands, tending to decrease eastwards. Motherships operating farther to the east indicate that large concentrations occur again between Longitudes 165° E and 175° E. North of Latitude 50° N catches consisted virtually entirely of mature fish. Information for other regions of the North Pacific was obtained from research vessel catches and is rather meagre. South of the Aleutians abundance levels and areas of concentrations fluctuate annually. Sampling in 1957 indicated that maturing and immature fish are about equally represented in the catches. South of the Alaska Peninsula and in the Gulf of Alaska matures predominate in catches, which suggests abundance levels are low.

Information for the Bering Sea, provided by research vessels, is restricted to the eastern region. Chums in this area are mainly maturing individuals and range from low to moderate levels of abundance.

In June in the northwest Pacific as far east as the eastern Aleutians abundance levels continue to fluctuate through the month, suggesting that chums are migrating rapidly. Fish are most abundant east of Longitude 165° E, approximating or at times exceeding levels observed in May. The proportion of immatures in the catches, however, is greater than in May. South of the Alaska Peninsula and in the western Gulf of Alaska abundance levels increase as immatures form a greater portion of the catch than in May. Abundance levels are lowest in the central Gulf region and are somewhat higher in the coastal region.

In the Bering Sea chums are most abundant in the central region and their numbers increase progressively through the month. The proportion of matures in the catches increases from west to east.

In the Okhotsk Sea abundance levels of chums exceed those in either the North Pacific or the Bering Sea. Abundance levels are maximal during early June and decline steadily thereafter. Almost all fish caught are mature.

In July in the northwest Pacific chums increase from virtual absence in offshore waters off Hokkaido to high levels of abundance southeast of Kamchatka. Eastward to the central Pacific abundance levels are lower.

This decline, along with a larger proportion of immatures than in June, indicates that maturing individuals are emigrating from these waters. South of the Alaska Peninsula and in the western Gulf of Alaska abundance levels rise over those in June as immatures become more numerous. In the eastern Gulf fish are less abundant than to the westward. The proportion of matures increases as the coastal areas are approached.

In the Bering Sea abundance levels are generally high, particularly in the central region where catches consist almost entirely of immature fish.

Abundance of chums in the Okhotsk Sea are higher than elsewhere but show a sharp decline from June levels. Fishing by research vessels in 1959 indicated that 40% of the fish were immature.

August catches show that abundance levels in the northwest Pacific continue to decline and that the proportion of immatures increases. South of the Aleutians and the Alaska Peninsula, and in the western region of the Gulf of Alaska abundance levels are high and catches consist almost entirely of immature fish. In the eastern and coastal portions of the Gulf chums are less abundant and mainly mature.

Limited fishing by research vessels in the Bering Sea suggests that abundance increases progressively northward, the centre being located in the western region.

The southern limit of chum salmon in the North Pacific shifts northward from May through August. This shift coincides with the progressive northward movement of the 12°C and 13°C isotherms.

Chum salmon were caught in waters having surface temperatures ranging from 1°C to 15°C. The preferred temperature range appears to be between 4°C and 12°C, but good catches on occasion have been made in waters colder than 4°C.

(3) Coho and chinook salmon. Information so far obtained on coho and chinook salmon is based on research vessel catches exclusively. More detailed knowledge of the distribution of these species in the western Pacific and the Bering Sea undoubtedly will become available as mothership data are analysed.

Coho salmon are much less abundant than any of the three major species of salmon. In May and June they are scattered over wide areas of the North Pacific and the Gulf of Alaska, being present in the central Pacific as far south as about Latitude 43° N in May and appearing more frequently in the catches in more northern waters through June. During July they are widely distributed in the North Pacific and the Gulf of Alaska and also occur in the Bering Sea where previously they were not caught. In contrast to the low levels of abundance noted in these areas coho are moderately abundant southwest of the Aleutians. In August, coho are still present south of the Aleutians and in the Gulf of Alaska but larger numbers are to be found off the east coast of Kamchatka, particularly to the southeast.

Chinook salmon are the least abundant of the five species. In June they are present generally in the North Pacific, except in the coastal Gulf of Alaska region, occurring in some years (1956) as far south as Latitude 42° N. In the Bering Sea abundance levels are higher than in the North Pacific, particularly in the eastern region. In July, abundance in the Aleutian area increases but is still low. This rise is coincidental with declining levels of abundance observed in the Bering Sea. Chinooks are also present in waters east of Kamchatka and in the western portion of the Gulf of Alaska north of Latitude 50° N. August catches show that the increase south of the Aleutians, off Kamchatka and in the Gulf of Alaska, and the decline in the Bering Sea, noted for July, continues. Chinooks are absent in surface waters of the Gulf of Alaska coastal region.

Although fishing was carried out in waters ranging from 1°C to 15°C coho were caught only in waters of 5°C or warmer, chinooks in waters ranging between 1°C and 14°C. Largest catches of coho were made in waters warmer than 6°C. The progressive occurrence of coho northward through May and June coincides with the warming of southern waters. The preferred temperature for chinooks appears to be between 5°C and 11°C, abundance levels being relatively higher in the lower temperatures of this range.

STUDY OF SOCKEYE SALMON PARASITES TO DISTINGUISH STOCKS

L. Margolis

The parasites of pink and sockeye salmon have been thoroughly studied from the point of view of determining their usefulness as "natural markers" of the geographical origin of these fish caught on the high seas. In the case of pink salmon, as reported in earlier Annual Reports, the results were not promising and the work on this species was discontinued. On the other hand, significant findings were achieved with sockeye salmon. Two of the more than 50 species of parasites encountered in sockeye proved to be useful indicators of the high-seas distribution of some stocks of sockeye. These are the freshwater parasites Triaenophorus crassus (Cestoda) and Dacnitis truttae (Nematoda). Details of the life history and ecology of these parasites have been presented in earlier reports. Triaenophorus is found in some western Alaskan sockeye and Dacnitis occurs in some sockeye of Asian origin. Since streams north of Bristol Bay in western Alaska produce negligible quantities of sockeye, relative to the production in Bristol Bay, the Triaenophorus-infected sockeye are mainly from Bristol Bay. Triaenophorus is by far the more important of the two indicator parasites because apparently it is more prevalent in western Alaskan sockeye than is Dacnitis in Asian sockeye.

The present summary presents the results obtained from samples collected in 1959 on the distribution of Triaenophorus-infected and Dacnitis-infected sockeye. Results of the examination of samples collected in the years 1955 to 1958 were summarized in the Annual Reports for 1955, 1956-57, 1957-58, 1958-59 and 1959-60.

Close to 5,000 sockeye, collected almost entirely from May to August, 1959, were examined. This represents an increase of 50% over the previous year's sampling and is a little more than 60% of the total number of sockeye sampled in the 4 years from 1955 to 1958, inclusive.

The bulk of the increase was in the high-seas samples, particularly of maturing fish. Area coverage for maturing fish was more extensive in the Bering Sea and for the first time some adequate samples of maturing fish were obtained in May and June from immediately south of the Aleutians between 175° E and about 169° W. Sampling of the spawning runs to North American streams was much the same as in 1958, the main exception being that the sample size was increased from 25 to 50 sockeye from each of the main Bristol Bay rivers. Also, samples from two Asian rivers (almost all from the Ozernaya River, west Kamchatka) were available for the first time since this study was initiated.

Lists of the samples of smolts, of adults from their rivers of origin, and of high-seas specimens are presented in Tables VI, VII and VIII, respectively. The numbers of sockeye and the date of collection of each sample are shown and for the high seas the numbers of maturing and immature sockeye (as determined by gonad development) in each sample are given. In these tables the incidence of Triaenophorus and Dacnitis in the maturing and immature fish from each location are included. The number of fish in each sample which had spent only one year at sea is shown; almost all of these were immatures. The total number of smolts examined was 299, the number of adults from coastal areas 761 (617 from North America and 144 from Asia) and the number of high-seas sockeye 3,900 (2,528 maturing, 1,353 immatures and 19 undetermined). Of the maturing sockeye from the high seas, 2,168 were taken in May and June and only 360 in July and August. Of the immatures, 375 were taken in May and June and 978 in July and

Table VI. Incidence of *Triaenophorus* in sockeye smolt samples from North America in 1959

Locality	Date collected	No. examined	Infected with *Triaenophorus*	
			No.	%
Port John, British Columbia	26-IV	25	-	-
Chignik River, Alaska	28-V	25	-	-
Bristol Bay, Alaska				
Ugashik River	29,30-V	50	-	-
Egegik River	30-V	50	-	-
Naknek River	9-VII	49	4	8
Kvichak River	18-V	50	-	-
Wood River	18-VI	50	42	84
Total		299	46	

Table VII. Incidence of *Triaenophorus* in adult sockeye samples from coastal areas in 1959.

Reference letter	Locality	Date collected	No. examined	Infected with *Triaenophorus* No.	Infected with *Triaenophorus* %
	North America				
	Washington-Oregon				
A	Columbia River	24-VI	25	-	-
	British Columbia				
B	Fraser River	10-VIII	25	-	-
C	Rivers Inlet	11-VII	25	-	-
D	Skeena River	14-VIII	25	-	-
	Alaska				
E	Stikine River	22-VI	25	-	-
F	Copper River	5-VI	25	-	-
G	Kenai R., Cook Inlet	15-VII	26	-	-
H	Fish Creek, Cook Inlet	17,18-VII	25	-	-
I	Karluk R., Kodiak Island	24-VI	25	-	-
J	Red R., Kodiak Island	25-VI	25	-	-
K	Chignik River	2-VIII	23	-	-
L	Bear River	23 to 31-VII	25	-	-
M	Ugashik R., Bristol Bay	14-VII	50	2	4
N	Egegik R., Bristol Bay	7-VII	50	-	-
O	Naknek R., Bristol Bay	2-VII	50	4	8
P	Kvichak R., Bristol Bay	14,26-VII	49	2	4
Q	Wood R., Bristol Bay	29-VI	50	15	30
R	Togiak R., Bristol Bay	5-VII	45	-	-
S	Kuskokwim River	25-VI	24	2	8
	Asia (USSR)				
T	Ozernaya River	1-IX	139[a]	-	-
U	Bolshaya River	30-VIII	5	-	-
		Total North America	617	25	
		Total Asian	144		
		Total No. fish examined	761		

[a]The viscera of only 126 fish from the Ozernaya River were examined; they were not available for the remaining 13 fish.

Table VIII. Incidence of *Triaenophorus* and *Dacnitis* in high-seas sockeye samples collected in 1959

Ref. No.	Locality	Date collected	No. examined					Infected with *Triaenophorus*				Infected with *Dacnitis*			
			Maturing	Immature	Undetermined	Total	1-ocean age[a]	Maturing No.	Maturing %	Immature No.	Immature %	Maturing No.	Maturing %	Immature No.	Immature %
1	51°N, 159°28'E	8-VIII	2	46	-	48	-	-	-	-	-	-	-	-	-
2	48°31'N, 162°31'E	15-VI	41	9	-	50	-	-	-	-	-	-	-	-	-
3	52°32'N, 163°48'E	5-VII	14	36	-	50	-	-	-	-	-	-	-	2	6
4	48°24'N, 163°55'E	15-VI	43	7	-	50	-	-	-	-	-	-	-	-	-
5	54°N, 164°E	19-VIII	-	4	-	4	-	-	-	-	-	-	-	-	-
6	54°N, 166°E	20-VIII	-	50	-	50[b]	-	-	-	-	-	-	-	-	-
7	46°21'N, 168°06'E	5-VI	30	20	-	50	-	-	-	-	-	-	-	-	-
8	48°48'N, 168°36'E	15-VII	8	42	-	50	-	-	-	-	-	-	-	2	5
9	48°N, 169°12'E	27-V	40	10	-	50	-	-	-	-	-	1	3	2	20
10	48°57'N, 169°29'E	26-V	39	11	-	50	-	-	-	-	-	-	-	1	9
11	57°N, 170°E	2-VIII	2	46	-	48	-	-	-	2	4	-	-	-	-
12	49°06'N, 170°52'E	25-VI	16	34	-	50	-	-	-	-	-	-	-	-	-
13	55°N, 171°E	8-VI	46	-	-	46	-	1	2	-	-	-	-	-	-
14	54°20'N, 171°E	6-VI	46	-	-	46	-	1	2	-	-	-	-	-	-
15	51°21'N, 171°20'E	5-VI	47	3	-	50	-	-	-	-	-	1	2	-	-
16	50°25'N, 171°20'E	28-V	20	-	-	20	-	-	-	-	-	-	-	-	-
17	48°20'N, 172°08'E	27-V	26	-	-	26	-	-	-	-	-	-	-	-	-
18	56°49'N, 173°22'E	5-VII	44	6	-	50	-	1	2	-	-	-	-	-	-
19	58°N, 175°E	5-VII	8	40	-	48	-	-	-	1	3	-	-	-	-
20	56°N, 175°E	21-VI	16	-	-	16	-	1	6	-	-	-	-	-	-
21	55°N, 175°E	15-VII	2	14	-	16	-	-	-	2	14	-	-	-	-
22	54°N, 175°E	16-VII	6	2	-	8	-	-	-	-	-	-	-	-	-
23	51°30'N, 175°E	22-VII	6	36	-	42	-	-	-	5	14	-	-	-	-
24	51°N, 175°E	22-V	24	1	-	25	-	3	13	-	-	-	-	-	-
25	50°30'N, 175°E	23-VII	8	27	-	35	-	-	-	1	4	-	-	-	-
26	49°N, 175°E	24-V	22	2	-	24	-	-	-	-	-	-	-	-	-
27	48°N, 175°E	25-V	14	11	-	25	-	-	-	-	-	-	-	-	-
28	51°30'N, 175°03'E	20-V	19	1	-	20	-	2	11	-	-	-	-	-	-
29	56°N, 179°E	19-VI	14	1	-	15	-	-	-	-	-	-	-	-	-
30	52°59'N, 179°55'E	23-VI	40	7	-	47	-	4	10	-	-	-	-	-	-
31	60°N, 180°	30-VI	11	9	-	20	-	-	-	1	11	-	-	-	-
32	57°N, 180°	27-VI	95	5	-	100	-	9	9	-	-	-	-	-	-
33	56°N, 180°	26-VI	48	1	-	49	-	7	14	-	-	-	-	-	-
34	55°N, 180°	25-VI	46	1	-	47	-	4	9	-	-	-	-	-	-
35	53°30'N, 180°	13-VI	49	-	-	49	-	4	8	-	-	-	-	-	-

continued ....

Table VIII continued

Ref. No.	Locality	Date collected	No. examined					Infected with Triaenophorus				Infected with Dacnitis			
			Matur-ing	Im-mature	Undeter-mined	Total	1-ocean age[a]	Maturing No.	Maturing %	Immature No.	Immature %	Maturing No.	Maturing %	Immature No.	Immature %
36	51°N, 180°	2-VI	63	1	-	64	-	2	3	-	-	-	-	-	-
37	56°N, 179°W	18-VI	39	1	-	40	-	3	8	-	-	-	-	-	-
38	52°38'N, 178°47'W	22-VI	44	3	-	47	-	9	20	-	-	-	-	-	-
39	51°29'N, 176°38'W	29-VII	45	51	1	97	7	-	-	1	2	-	-	-	-
40	51°32'N, 176°34'W	14-VI	49	-	-	49	-	3	6	-	-	-	-	-	-
41	51°32'N, 176°31'W	12-VI	96	-	-	96	-	11	11	-	-	-	-	-	-
42	56°N, 176°W	24-VI	49	1	-	50	-	4	8	-	-	-	-	-	-
43	55°N, 176°W	23-VI	49	1	-	50	-	5	10	-	-	-	-	-	-
44	54°N, 176°W	22-VI	83	-	-	83	-	8	10	-	-	-	-	-	-
45	49°01'N, 175°04'W	6-VI	5	15	-	20	-	-	-	-	-	-	-	-	-
46	57°N, 175°W	25-VI	92	1	-	93	-	10	11	-	-	-	-	-	-
47	56°N, 175°W	15-VI	22	-	-	22	-	-	-	-	-	-	-	-	-
48	52°59'N, 175°W	21-VI	21	6	-	27	-	2	10	2	33	-	-	-	-
49	51°N, 175°W	5-VIII	4	96	-	100	-	1	25	9	9	-	-	-	-
50	50°N, 175°W	6-VIII	1	48	-	49	-	-	-	3	6	-	-	-	-
51	49°N, 175°W	7-VIII	-	25	-	25	19	-	-	1	4	-	-	-	-
52	51°41'N, 171°57'W	28-V	49	-	-	49	-	2	4	-	-	-	-	-	-
53	53°58'N, 170°01'W	2-VII	19	1	-	20	-	1	5	-	-	-	-	-	-
54	59°N, 170°W	27-VI	48	-	-	48	-	5	10	-	-	-	-	-	-
55	58°N, 170°W	28-VI	45	-	-	45	-	3	7	-	-	-	-	-	-
56	55°59'N, 170°W	30-VI	99	1	-	100	-	12	12	-	-	-	-	-	-
57	53°18'N, 170°W	3-VII	13	2	-	15	-	-	-	-	-	-	-	-	-
58	51°N, 169°56'W	5-VII	25	24	1	50	-	-	-	-	-	-	-	1	4
59	52°N, 169°53'W	4-VII	10	89	-	99	3	-	-	5	6	-	-	-	-
60	51°56'N, 169°39'W	27-V	49	-	-	49	-	6	12	-	-	-	-	-	-
61	53°30'N, 165°W	11-VII	28	72	1	101	10	-	-	-	-	-	-	-	-
62	52°N, 165°W	6-VII	4	21	-	25	-	-	-	1	5	-	-	-	-
63	52°58'N, 164°58'W	12-VII	14	36	-	50	-	-	-	4	11	-	-	-	-
64	49°55'N, 160°05'W	22-VII	3	37	2	42	3	-	-	-	-	-	-	-	-
65	53°N, 160°W	14,24,25-VI	27	37	2	66	19	1	4	1	3	-	-	-	-
66	50°N, 160°W	27-VI	9	53	1	63	44	-	-	5	9	-	-	-	-
67	51°57'N, 159°58'W	24-VII	14	86	-	100	19	-	-	-	-	-	-	-	-
68	53°55'N, 159°40'W	26-VII	11	16	-	27	16	-	-	1	6	-	-	-	-
69	55°N, 155°W	10,12-VI	97	7	3	107	10	11	11	-	-	-	-	-	-
70	50°N, 155°W	29-VI	-	50	-	50	46	-	-	3	6	-	-	-	-
71	55°N, 153°W	27-IV	13	-	-	13	-	-	-	-	-	-	-	-	-

continued ....

Table VIII continued

Ref. No.	Locality	Date collected	No. examined					Infected with *Triaenophorus*				Infected with *Dacnitis*			
			Maturing	Immature	Undetermined	Total	1-ocean age[a]	Maturing No.	Maturing %	Immature No.	Immature %	Maturing No.	Maturing %	Immature No.	Immature %
72	54°10'N, 150°30'W	25,26-VII	11	25	1	37	19	-	-	-	-	-	-	-	-
73	55°39'N, 150°23'W	10,11-VI	31	15	-	46	-	-	-	-	-	-	-	-	-
74	55°N, 150°W	25 to 28-V	39	-	-	39	-	4	10	-	-	-	-	-	-
75	58°N, 145°W	25,26-V	96	1	2	99	-	8	8	-	-	-	-	-	-
76	55°N, 145°W	21 to 23-V	69	4	3	76	6	2	3	-	-	-	-	-	-
77	50°N, 145°W	18,19-V	16	33	1	50	-	-	-	1	3	-	-	-	-
78	52°30'N, 142°W	15 to 21-VII	23	-	1	24	1	-	-	-	-	-	-	-	-
79	55°N, 141°W	17 to 21-V	77	12	-	89	5	-	-	-	-	-	-	-	-
80	53°30'N, 138°53'W	7-VIII	8	-	-	8	-	-	-	-	-	-	-	-	-
81	50°N, 135°W	5 to 11-VII	27	-	-	27	-	-	-	-	-	-	-	-	-
		Totals	2,528	1,353	19	3,900	227	150		49		2		8	

No. matures May-June	2,168[c]
No. immatures May-June	375
No. undetermined May-June	12
Total May-June	2,555

No. matures July-August	360
No. immatures July-August	978
No. undetermined July-August	7
Total July-August	1,345

[a]These fish are immature, except for a very few from the Gulf of Alaska.

[b]The viscera of only 35 fish from 54°N, 166°E were examined; they were not available for the remaining 15 fish.

[c]Includes 13 fish taken in April.

August. It is thus apparent that most of the May-June samples consisted of maturing fish whereas in July and August the majority of the fish were immature.

The distribution of all adult samples from coastal areas and all high-seas samples can also be seen in Figure 4. In Figure 5 the distribution of samples of maturing fish are shown separately for the May-June and July-August periods. Figure 6 shows the distribution of the immatures for the same two periods.

High-seas distribution of North American and Asiatic sockeye in 1959 as determined by *Triaenophorus* and *Dacnitis*. In coastal adult and smolt samples, *Triaenophorus*-infected sockeye were again found only in western Alaska with the Wood River (Nushagak River system), Bristol Bay showing the highest incidence as in previous years (Tables VI and VII and Figure 4).

Dacnitis truttae, as in previous years, was not found in any North American samples of smolts or adults returning to spawn. In an earlier report it was noted that *Dacnitis* has been reported in the USSR literature as occurring in sockeye in Kamchatka River and our finding it in the Okhotsk Sea samples from 1955 to 1958 suggested that it probably occurs in some sockeye originating on the west coast of Kamchatka. Corroborative evidence of its presence in west Kamchatka rivers was not obtained. *Dacnitis* was not found in 126 sockeye from the Ozernaya River nor in 5 sockeye from the Bolshaya River collected in 1959. However, in high-seas samples of maturing sockeye taken in the waters between southeast Kamchatka and the western Aleutians which, as will be noted later, seem to be almost entirely of Asian origin, only 2 out of 362 sockeye (338 in May-June and 24 in July-August) were infected with *Dacnitis*, i.e., about 0.06%. If a similar very low rate of infection prevailed in the Ozernaya and Bolshaya River stocks it is not surprising that *Dacnitis* was not found in the samples from these rivers. Furthermore, the Ozernaya River sample was taken at the end of the "run" (September 1) and the parasite fauna of these fish may not be representative of the main body of Ozernaya sockeye.

In Figure 4 and Table VIII the distribution of high-seas sockeye infected with *Triaenophorus* (i.e., of western Alaskan, mainly Bristol Bay, origin) or *Dacnitis* (i.e., of Asian origin) are shown in relation to all samples examined in 1959. One hundred and ninety-nine sockeye infected with *Triaenophorus* were found in high-seas samples from 145° W in the Gulf of Alaska to as far west as 171° E. On the other hand, only 10 sockeye infected with *Dacnitis* have been observed in the 1959 samples; 9 came from about 171° E and westward and one from about 51° N, 170° W.

Distribution of maturing sockeye. Figure 5 and Table VIII show the distribution and incidence of *Triaenophorus*-infected and *Dacnitis*-infected sockeye in samples of maturing fish.

Only two *Dacnitis*-infected maturing sockeye were found in the 1959 samples. They were taken in late May and early June in the waters to the south and west of the extreme western Aleutians (at 48° N, 169°12' E and at 51°21' N, 171°20' E), an area in which a few sockeye have been identified as of Asian origin, because of their infection with *Dacnitis*, in each year since 1955.

The results of the distribution of *Triaenophorus*-infected maturing sockeye are far more significant. One hundred and fifty maturing sockeye

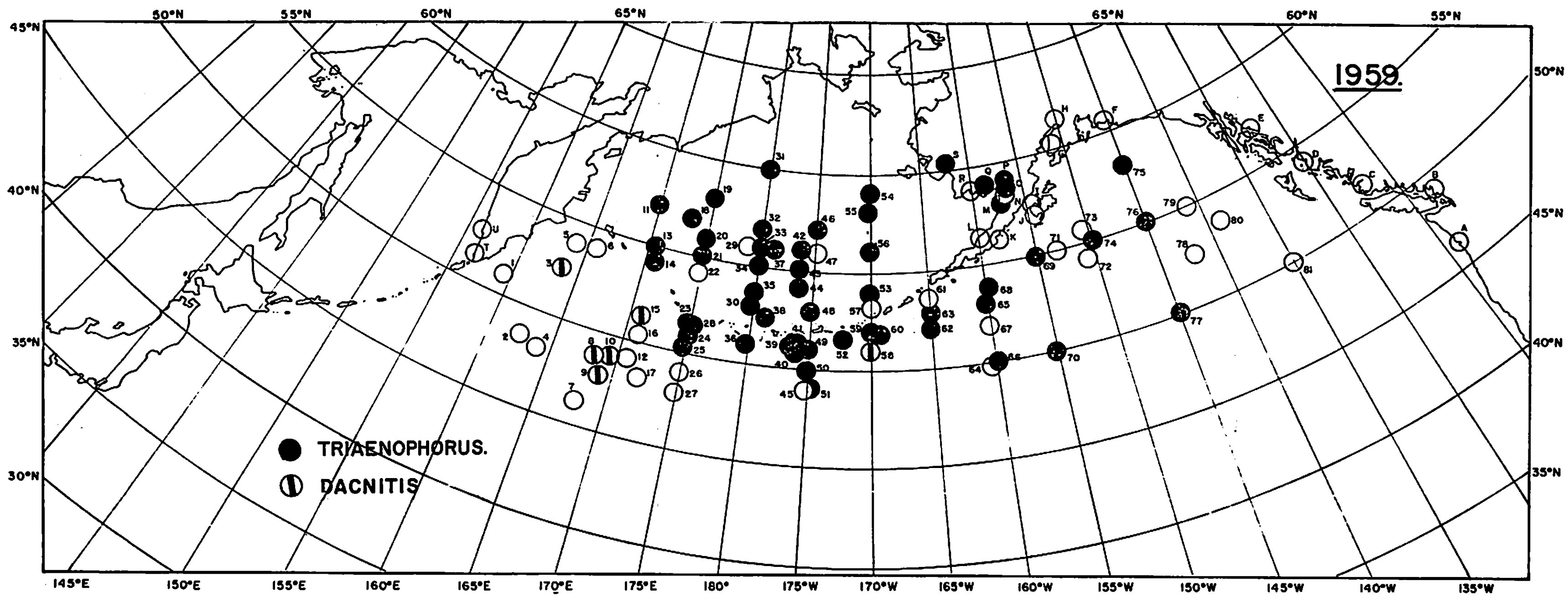


Fig. 4. Distribution of high-seas and coastal sockeye samples in 1959 and occurrence of <u>Triaenophorus</u> and <u>Dacnitis</u>. Letters and numbers are locality references as given in Tables VII and VIII.

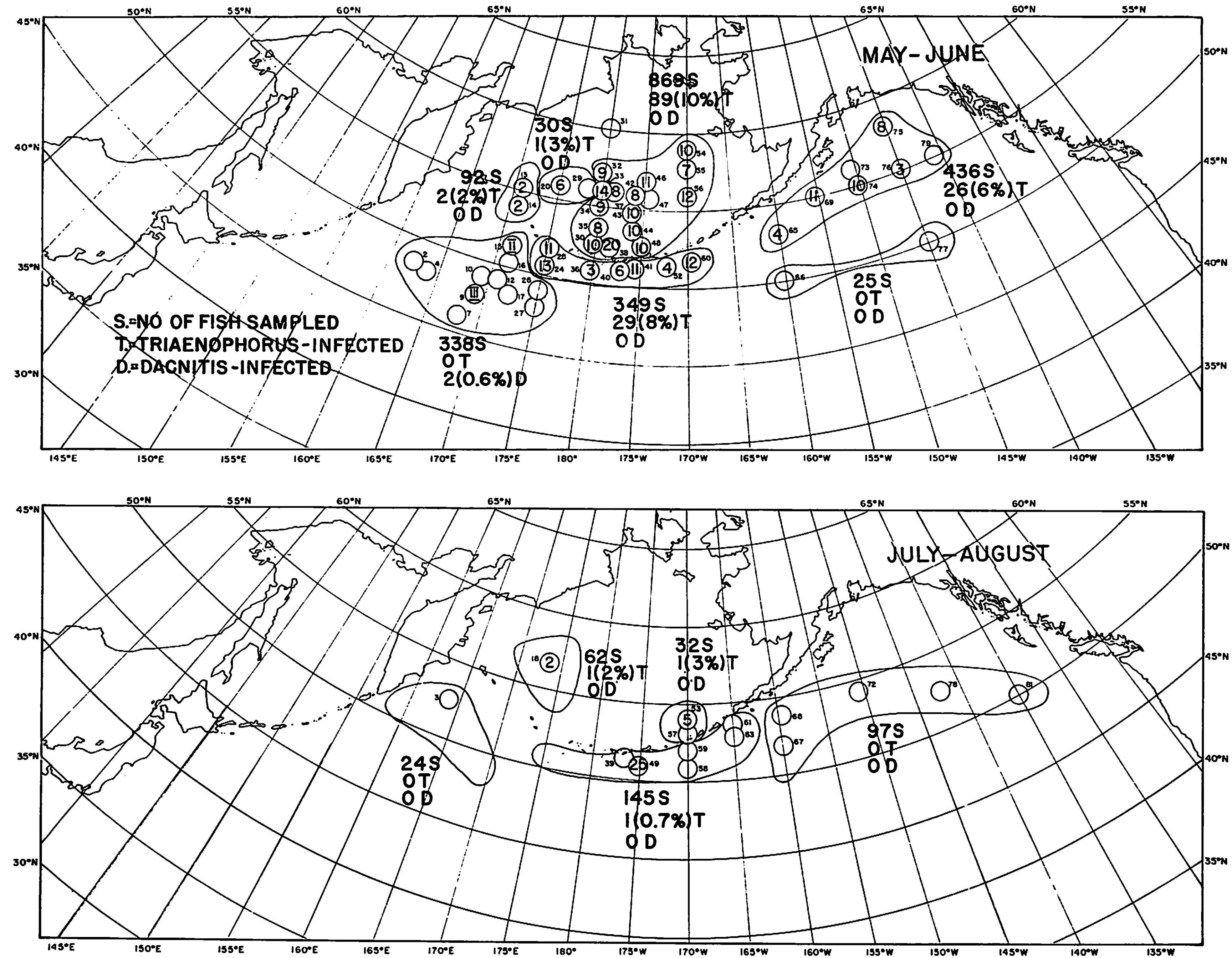


Fig. 5. Percentage of _Triaenophorus_-infected and _Dacnitis_-infected sockeye in high-seas samples of _maturing_ fish in 1959. Samples of less than 9 fish are not shown individually, except for a sample of 4 fish at station 49 in August. Arabic numerals and Roman numerals within the circles are percent infection with _Triaenophorus_ and _Dacnitis_, respectively. Small numerals outside the circles are locality references as in Table VIII.

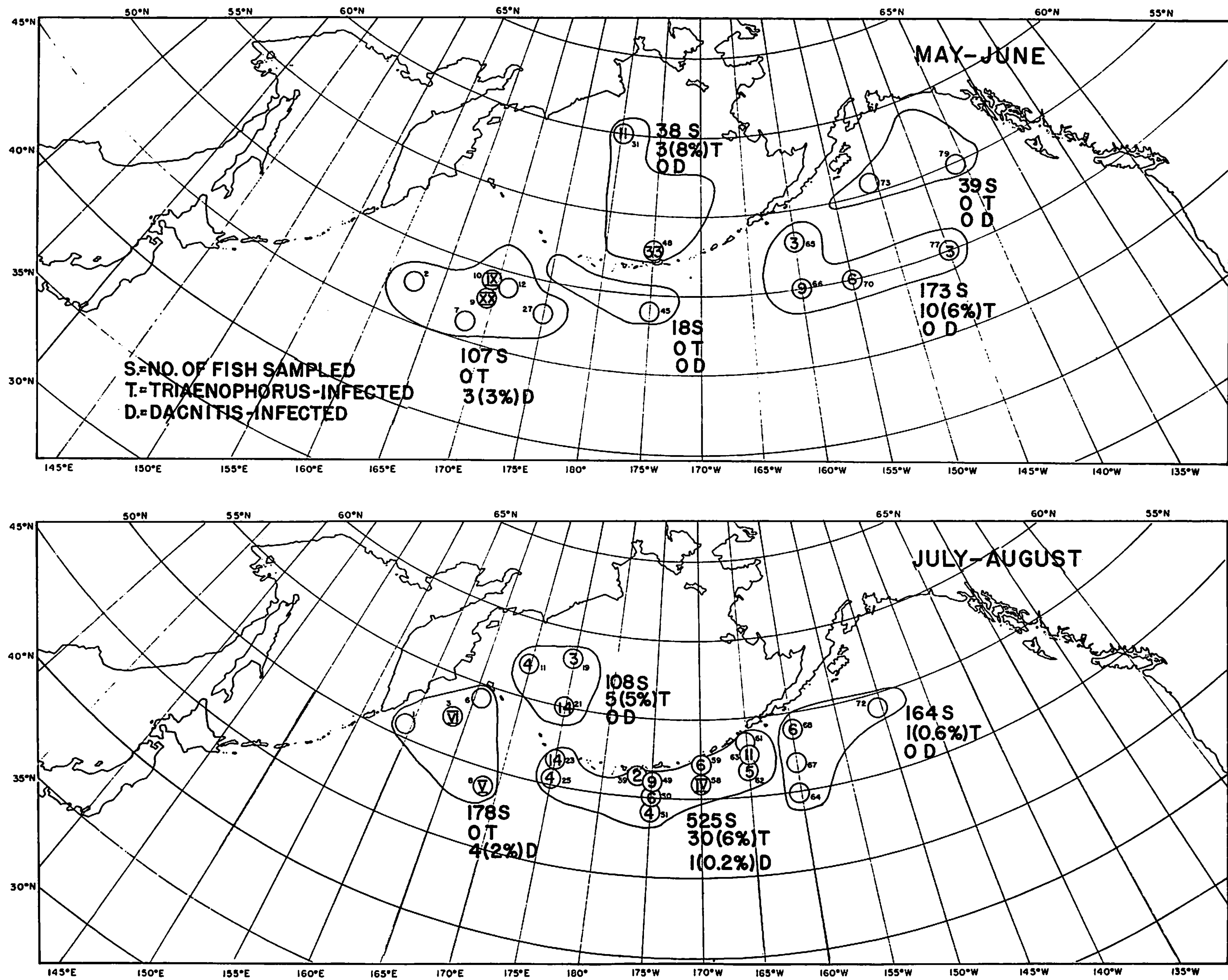


Fig. 6. Percentage of <u>Triaenophorus</u>-infected and <u>Dacnitis</u>-infected sockeye in high-seas samples of <u>immature</u> fish in 1959. Samples of less than 9 fish are not included except for a sample of 6 fish at station 48 in June. Arabic and Roman numerals have the same significance as in Fig. 5.

infected with Triaenophorus were observed in the 1959 samples from 145° W to 171° E. Those having spent 2 winters at sea were as widely distributed as those having spent 3 winters at sea (Table IX and Figure 7).

One hundred forty-seven of the Triaenophorus-infected maturing sockeye were found in samples taken in May and June; 2 were caught in early July and 1 in early August (Figure 5 and Table VIII). The scarcity of Triaenophorus-infected sockeye on the high seas in July and August is in accord with the timing of the "runs" arriving in Bristol Bay. Generally the peak of these spawning "runs" occurs within the first half of July. It appears that most of the maturing western Alaskan sockeye leave the open ocean by the end of June but some may remain until early August as evidenced by the occurrence of a maturing Triaenophorus-infected sockeye in the mid-Aleutian area (51° N, 175° W) on August 5. Similar findings from the 1958 samples were reported last year.

Some general conclusions on the quantitative distribution of Bristol Bay maturing sockeye in the samples examined can be drawn from data on the incidence of Triaenophorus in the samples taken in May and June, 1959. Precise proportions of Bristol Bay sockeye in the individual samples cannot be determined, however, because the numbers of fish in the standard samples from the individual Bristol Bay rivers, as well as in the high-seas samples, were not large enough to permit placing narrow confidence limits on the estimates.

To use data on rates of Triaenophorus infection to determine the quantitative distribution of maturing sockeye of Bristol Bay origin in high-seas samples, it is necessary to assume that the stocks from individual Bristol Bay rivers are homogeneously mixed in offshore waters during the months of May and June prior to their arrival in Bristol Bay. This assumption does not seem unreasonable. There is no apparent reason why the stocks from the different Bristol Bay rivers, which are geographically relatively close to one another, should occupy significantly different areas during their oceanic period of life, and the time of arrival of the stocks in the different Bristol Bay rivers is approximately the same. Also, as noted above, Triaenophorus-infected maturing sockeye which had spent 2 years at sea showed much the same distribution as those which had spent 3 years at sea, suggesting that there is no significant difference in distribution of Bristol Bay sockeye of different ocean ages, at least during their last two months at sea.

In spawners returning to Bristol Bay as a whole, in 1959, the incidence of Triaenophorus was estimated to be between 10% and 13% (Table X).

From Figure 5 it is seen that the percentage of Triaenophorus-infected sockeye in samples of maturing fish from the Bering Sea from 180° to 170° W in the latter half of June generally was quite uniform. Of 16 samples, 14 showed an incidence of 7 to 14% with 12 of these falling in the range of 8 to 12%. One sample had 20% infected and in a sample of 22 fish at 56° N, 175° W, none were infected. The mean incidence (about 10%) in 869 sockeye from this area was similar to that estimated for the Bristol Bay stocks as a whole. This suggests that these samples consisted largely of a uniform mixture of sockeye of Bristol Bay origin. At 171° E in the Bering Sea the incidence of Triaenophorus was only 2% (about 1/5 to 1/7 of the percentage estimated for the Bristol Bay stocks as a whole) in each of 2 samples of 46 fish taken in early June, indicative of a marked reduction in the percentage of Bristol Bay sockeye in the samples. The sockeye predominating in these samples and accounting for this marked reduction of the percentage Bristol Bay fish were most likely of Asian

Table IX. Ocean age of sockeye infected with *Triaenophorus* in 1959 samples.

Locality	Maturing			Immature			
	2 years at sea	3 years at sea	Undetermined	1 year at sea	2 years at sea	3 years at sea	Undetermined
Bristol Bay, Alaska							
Ugashik River	2	-	-	-	-	-	-
Naknek River	2	2	-	-	-	-	-
Kvichak River	1	1	-	-	-	-	-
Wood River	14	-	1[a]	-	-	-	-
North of Bristol Bay							
Kuskokwim River	-	2	-	-	-	-	-
50°N, 145°W	-	-	-	-	1	-	-
55°N, 145°W	2	-	-	-	-	-	-
58°N, 145°W	6	2	-	-	-	-	-
55°N, 150°W	4	-	-	-	-	-	-
50°N, 155°W	-	-	-	3	-	-	-
55°N, 155°W	9	2	-	-	-	-	-
53°55'N, 159°40'W	-	-	-	1	-	-	-
50°N, 160°W	-	-	-	4	1	-	-
53°N, 160°W	1	-	-	-	1	-	-
52°58'N, 164°58'W	-	-	-	-	4	-	-
52°N, 165°W	-	-	-	-	1	-	-
51°56'N, 169°39'W	3	3	-	-	-	-	-
52°N, 169°53'W	-	-	-	1	4	-	-
55°59'N, 170°W	8	-	4[a]	-	-	-	-
58°N, 170°W	3	-	-	-	-	-	-
59°N, 170°W	4	1	-	-	-	-	-
53°58'N, 170°01'W	-	1	-	-	-	-	-
51°41'N, 171°57'W	1	1	-	-	-	-	-
49°N, 175°W	-	-	-	1	-	-	-
50°N, 175°W	-	-	-	-	3	-	-
51°N, 175°W	1	-	-	-	7	1	1[a]
52°59'N, 175°W	-	2	-	-	2	-	-
57°N, 175°W	6	3	1[a]	-	-	-	-
54°N, 176°W	4	4	-	-	-	-	-
55°N, 176°W	3	1	1[a]	-	-	-	-
56°N, 176°W	1	3	-	-	-	-	-
51°32'N, 176°31'W	9	1	1[a]	-	-	-	-
51°32'N, 176°34'W	1	1	1[a]	-	-	-	-
51°29'N, 176°38'W	-	-	-	-	-	-	1[a]
52°38'N, 178°47'W	6	3	-	-	-	-	-
56°N, 179°W	2	1	-	-	-	-	-
51°N, 180°	1	1	-	-	-	-	-
53°30'N, 180°	4	-	-	-	-	-	-
55°N, 180°	2	2	-	-	-	-	-
56°N, 180°	5	1	1[a]	-	-	-	-
57°N, 180°	5	3	1[a]	-	-	-	-
60°N, 180°	-	-	-	-	1	-	-
52°59'N, 179°55'E	3	1	-	-	-	-	-
51°30'N, 175°03'E	1	1	-	-	-	-	-

continued ......

Table IX continued

Locality	Maturing			Immature			
	2 years at sea	3 years at sea	Undetermined	1 year at sea	2 years at sea	3 years at sea	Undetermined
50°30'N, 175°E	-	-	-	-	1	-	-
51°N, 175°E	1	2	-	-	-	-	-
51°30'N, 175°E	-	-	-	-	5	-	-
55°N, 175°E	-	-	-	-	2	-	-
56°N, 175°E	-	1	-	-	-	-	-
58°N, 175°E	-	-	-	-	1	-	-
56°49'N, 173°22'E	1	-	-	-	-	-	-
54°20'N, 171°E	-	1	-	-	-	-	-
55°N, 171°E	1	-	-	-	-	-	-
57°N, 170°E	-	-	-	-	1	-	1[a]
Totals	117	47	11	10	35	1	3

[a]On the basis of weight and length these fish had spent at least 2 years at sea.

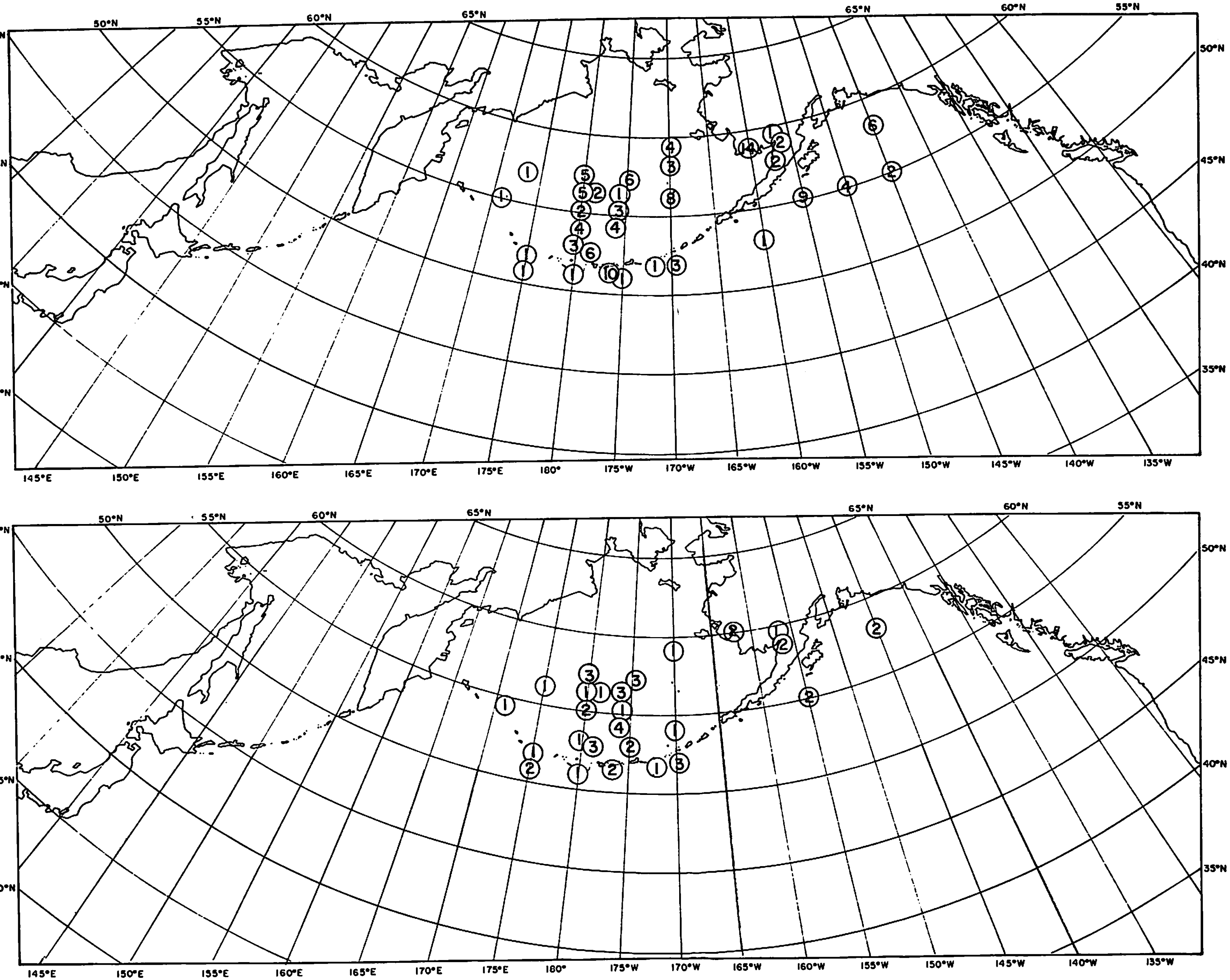


Fig. 7. Distribution and number of Triaenophorus-infected maturing sockeye which have spent 2 and 3 winters at sea. Upper chart = 2 winters. Lower chart = 3 winters.

Table X. Incidence of *Triaenophorus* in adult sockeye runs to Bristol Bay in 1959

Locality	Size of "run" (catch + escapement)	Sample size	% infected with *Triaenophorus*	Estimated no. infected in total "run"
Nushagak				
Wood River	3,500,000	50	30	1,050,000
Igushik River	1,000,000	0	?	?
Kvichak-Naknek				
Kvichak River	975,000	49	4	39,000
Branch River	1,200,000	0		
Naknek River	3,200,000	50	8	256,000
Egegik River	1,735,000	50	0	0
Ugashik River	635,000	50	4	25,400
Bear River	535,000	25	0	0
Sandy River	125,000	0	?	?
Total	12,905,000			1,370,400
Total in sampled areas	10,580,000			

Estimated incidence of *Triaenophorus* based on sampled areas - ca. 13%.

If Igushik, Branch and Sandy Rivers, which were not sampled, were free of *Triaenophorus*, the estimated incidence for all areas combined is ca. 10%.

If Igushik rate of infection is similar to the Wood River, Branch River similar to Kvichak River and Sandy River similar to Bear River, the estimated incidence for all areas combined is ca. 13%.

origin. Between 180° and 171° E in the Bering Sea only two samples were available; these consisted of 14 and 16 maturing sockeye from 56° N, 179° E and 56° N, 175° E, respectively, during the third week of June. One (6%) Triaenophorus-infected sockeye was found in the sample from 175° E. No reasonable quantitative interpretation can be drawn from the results from these small samples.

Samples taken in late May and early June from the area immediately south of the Aleutians (within about 60 miles or less) between approximately 169° W and 175° E showed less consistency between samples in the incidence of Triaenophorus than did those from the eastern half of the Bering Sea. Also, the overall incidence (8%) in 349 fish was lower than in the eastern half of the Bering Sea, but nevertheless relatively high. The incidence of Triaenophorus was as high at 175° E as at 169° W but varying percentages were observed between these two meridians. The results suggest that immediately south of the Aleutians between 169° W and 175° E the combined samples contained a somewhat smaller (but still predominant) proportion of Bristol Bay sockeye than did those in the eastern half of the Bering Sea. The area of origin of the maturing sockeye present in the area in addition to those from Bristol Bay cannot be determined from our data but it is conceivable that they could be from either other North American areas or from Asia. Unfortunately, samples from close to the south side of the Aleutians west of 175° E were not examined in 1959.

To the south and west of the extreme western Aleutians (i.e., from 175° E and westward), excluding the waters within about 60 miles of the Aleutians, Triaenophorus was not found in any of 338 maturing sockeye collected in May and June, suggesting that there was a very small percentage, if any, Bristol Bay fish in these samples (Fig. 5). It seems most likely that the maturing sockeye taken in the waters to the south and west of the extreme western Aleutians are mainly of Asian origin. The finding of Dacnitis-infected maturing sockeye within this region is positive evidence of the presence of Asian sockeye.

Triaenophorus-infected maturing sockeye were also well represented in the northern part of the Gulf of Alaska in late May and early June, much the same as in 1958. At 55° N, 155° W on June 10 and 12 and at 55° N, 150° W from May 25 to 28, the incidence of Triaenophorus in samples of 97 and 39 maturing sockeye was 11% and 10%, respectively, which is very similar to the incidence in Bristol Bay, suggesting that the samples consisted largely of Bristol Bay sockeye. At 58° N, 145° W on May 25 and 26 a sample of 99 maturing fish yielded 8% infected with Triaenophorus, again indicating a high proportion of Bristol Bay sockeye. Proceeding eastward at 55° N in May, there was a decrease in the incidence of Triaenophorus-infected sockeye down to zero at 141° W. The dilution of maturing Bristol Bay sockeye in May in the eastern half of the northern Gulf of Alaska is probably brought about by the presence of sockeye from North American areas to the south and east of the Alaska Peninsula.

At about 55° N, 150° W, two samples taken about two weeks apart appear to indicate that maturing Bristol Bay sockeye move out of the Gulf of Alaska quite rapidly. In the sample of 39 fish taken from May 25 to 28, 4 (10%) were infected with Triaenophorus, whereas a sample of 31 maturing sockeye taken on June 10 and 11 was entirely free of Triaenophorus. Further evidence that the sockeye present in the area in June were a different group from those found in May is offered by the fact that all sockeye caught in May were maturing whereas of those taken in June only about two-thirds were maturing.

Distribution of immature sockeye. The high-seas distribution and percentages of immature sockeye infected with Dacnitis or Triaenophorus are shown in Figure 6 and Table VIII.

Eight Dacnitis-infected immature sockeye were found in the 1959 samples. All had spent either 2 or 3 winters at sea. Seven were taken off southeast Kamchatka between about 164° E and 170° E in late May and the first half of July, and one was caught at about 51° N, 170° W in July. This latter record extends the eastward distribution of immature Asian sockeye previously determined by the presence of Dacnitis. In 1956 one was found at 175° W in the Bering Sea and in 1958 another one was taken at 175° W south of the Aleutians.

Forty-nine immature sockeye infected with Triaenophorus were found in the 1959 samples of immature fish - 36 in July and August and 13 in May and June. They had spent one or two (rarely three) winters at sea (Fig. 8 and Table IX) and were found from 145° W in the Gulf of Alaska to as far west as 175° E south of the Aleutians and from 175° W to 170° E in the Bering Sea.

During July and August, Triaenophorus-infected immature sockeye were taken south of the Aleutians from 175° E to 165° W and at 160° W in the western Gulf of Alaska and also in the Bering Sea at 170° E and 175° E. In May and June, the immature Triaenophorus-infected sockeye were taken principally in the southern part of the Gulf of Alaska along 50° N, as far east as 145° W; three were also present in small samples taken during the latter part of June in the Bering Sea at 60° N, 180° W and about 53° N, 175° W. The southern distribution of immatures in the Gulf of Alaska is in contrast to the more northern distribution of the maturing Triaenophorus-infected sockeye caught there.

The distribution of 1-ocean-winter and 2-ocean-winter immature sockeye infected with Triaenophorus is shown in Table IX and Figure 8. As noted in Table VIII, few 1-ocean-winter fish were examined from areas west of the Gulf of Alaska, although large catches of these young fish were made by research vessels in the Aleutian area (INPFC Annual Report for 1959). Therefore, it is impossible to make an adequate comparison of the ocean distribution of immature Bristol Bay sockeye of 1-ocean-winter age with that of older fish. In 1958, when samples of both 1-ocean- and 2-ocean-winter fish were examined from the waters to the north and south of the Aleutians, it was noted that Triaenophorus was found in both of these age-groups as far west as 175° E.

The application of rates of Triaenophorus infection of immature sockeye to quantitative analysis is far more complicated than for maturing fish, if at all possible, and has not been attempted.

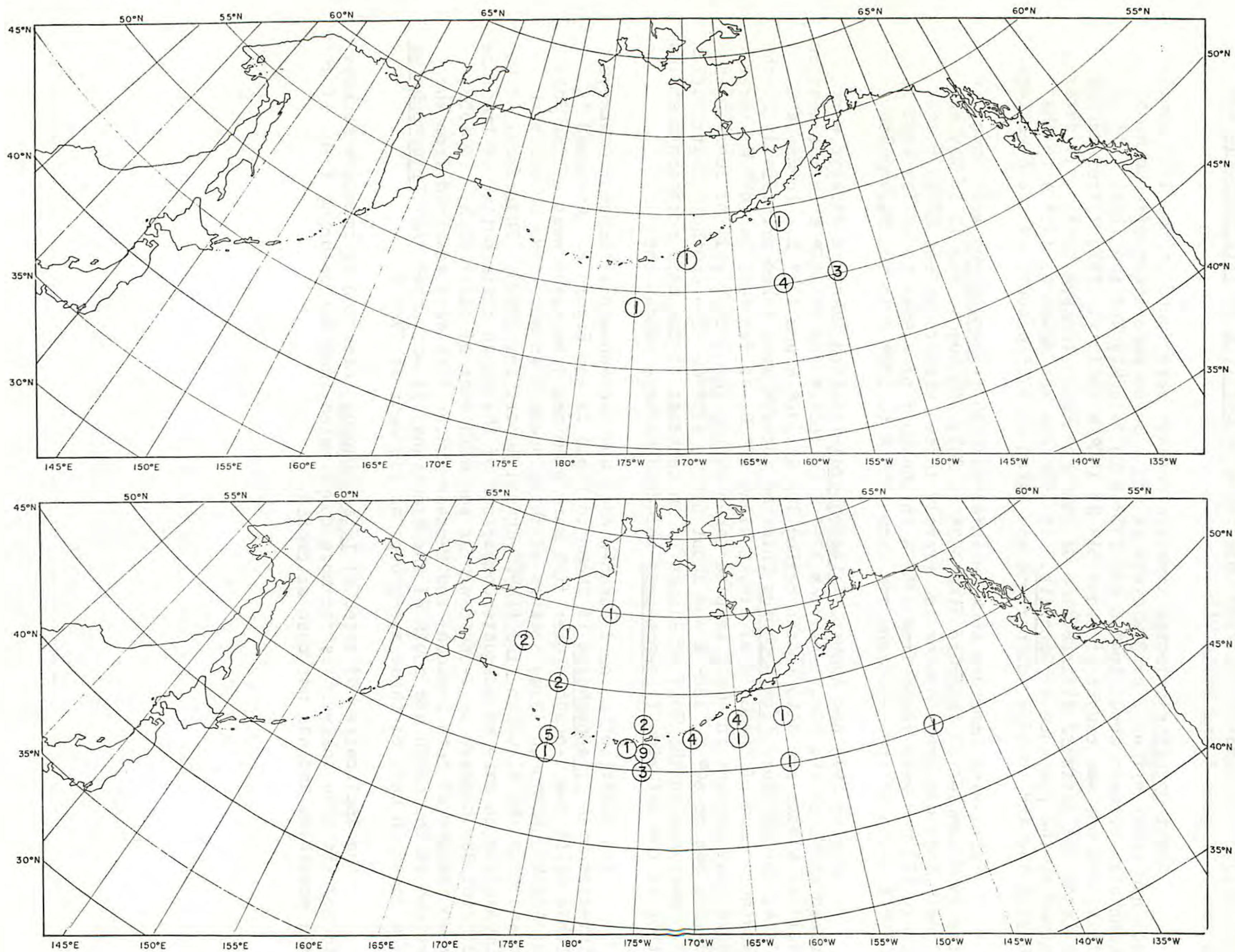


Fig. 8. Distribution and number of _Triaenophorus_-infected _immature_ sockeye according to numbers of winters spent at sea. Upper chart = 1 winter. Lower chart = 2 and 3 winters.

SALMON MANAGEMENT INVESTIGATIONS

M.P. Shepard and
F.C. Withler

Salmon provide British Columbia's most valuable fishery. They are actively sought throughout coastal waters and were it not for stringent restrictions the present-day fishery could remove virtually every salmon approaching the coast. Under these circumstances, the main problems facing those responsible for management of the fisheries are first to decide how many fish should be allowed to escape to different rivers and second to learn how to regulate the fisheries to provide such escapements.

Research to provide answers to these problems is required urgently and forms a major part of this Station's program. The work involves basic studies of salmon and their environment to determine levels of optimum escapements required for maximum production and to determine causes of fluctuations in abundance. Surveys and analyses of abundance and migratory movements of particular stocks are carried out to provide information of immediate use to management.

The main divisions of the work are:

(a) <u>Salmon stock assessments</u> - a "watching brief" on the performance of major British Columbia salmon stocks of all five species. The work consists of: (1) compilation and analysis of data on catch, fishing effort and escapement provided by the Department of Fisheries, and (2) sampling of catches and escapements and estimation of age, size, and the sex composition of the runs. The results of these assessments are becoming increasingly useful in interpreting fluctuations in abundance of the stocks.

The data are used extensively in preparation of reports required for various international treaties and other agreements. These include reports on the status and movements of stocks for the International North Pacific Fisheries Commission and the 1959 Conference on Co-ordination of Fishery Regulations between the United States and Canada.

The group also carries out special studies of salmon scales: (1) on chum salmon to distinguish stocks of various river origins and discover their distribution on the high seas for the INPFC research program, and (2) on sockeye salmon to estimate growth rates throughout the life history and to relate growth to age of maturity and survival.

(b) <u>Skeena salmon investigations</u> - studies as part of a large-scale co-operative program (between the Board and the Department) to provide precise management of the important Skeena salmon stocks. These studies form the biological basis for management of the fishery by a committee composed of the Area Director of Fisheries and the Director of the Nanaimo Biological Station. The investigations include: (1) studies of the fishery (times of passage of runs, effectiveness of the fishery under varying conditions, etc.) to provide detailed knowledge for formulation of regulations, and (2) studies of escapements (of pinks and sockeye particularly) and resultant production of young fish to assess success of regulations in providing escapements and to determine optimum levels of spawners to achieve maximum production.

(c) Lake sockeye studies - a fundamental study of the relation between young sockeye and their environment during their year of lake residence.

(d) Fraser River pink investigations - a co-operative investigation (between the United States and Canada) of the migratory movements of pink salmon in southern British Columbia and northwestern United States in connection with the Fraser River Salmon Treaty.

A. Salmon Stock Assessments

D. J. Milne

In recent years the British Columbia salmon stocks have been subjected to an increasingly heavy fishery by a large, efficient and very mobile fleet of purse-seiners, gill-netters and trollers. These boats can operate anywhere along the narrow continental shelf or in the inlets wherever fishing is allowed. In most cases they fish a mixture of stocks as well as species of salmon which renders it difficult to regulate so that only the excess crop is harvested and that sufficient spawners remain to provide optimum recruitment. The Skeena and Fraser River pink and sockeye stocks are now managed separately and sufficient research has been conducted to define these stocks by time and area of capture in relation to the spawning escapements. However for most of the remaining salmon stocks, which spawn in over 1,500 streams, it is not possible to study them in such detail. At present the best that can be done is to sample the commercial catches in the various areas and in conjunction with the catch, effort and escapement data that are supplied by the Department of Fisheries to provide an annual assessment of the changing status of stocks over broad areas of the British Columbia coast.

In 1960 the sampling was re-organized and combined to cover the catches of all species of salmon in all the substantial fisheries. For the species which mature at various ages, sockeye, chum and spring, the data are being transferred to I.B.M. cards to facilitate analysis for any need which might arise. As the series of data accumulates and more information is obtained on the escapements and the environmental conditions in both fresh water and the ocean, a better understanding of the condition of the major stocks and the effectiveness of present management practices will eventually emerge.

At present, data on the abundance and composition of the stocks are used in the preparation of reports to meet special management needs. These include reports on the status of British Columbia salmon stocks in connection with work of the International North Pacific Fisheries Commission, the United States-Canadian International Conference on the Co-ordination of Fishing Regulations and the Fraser River Pink Salmon Treaty.

In addition, special studies of scales of sockeye and chum salmon to distinguish races on the high seas and to relate growth patterns with age of return are carried out.

1. British Columbia salmon catches in 1960

D.J. Milne and
H.T. Bilton

The total commercial catch of salmon in 1960 of 77,590,000 pounds in round weight was the lowest for any year since records were started in 1910. The catches of all species were lower than catches in cycle-year periods. Although fishing was not disrupted by strikes as in 1959, drastic restrictions by regulations were again applied as in the past few years. In 1960 the gill-netters caught the highest (48.1%) and the perse-seiners the lowest (31.0%) proportion since sales-slip records were started in 1951. The only bright spots were the good catches of pink salmon in the central region (Areas 7 and 8) and of coho salmon in the Strait of Georgia (Areas 14 to 17). The sport catch in the Strait of Georgia was also good.

(a) Pink salmon. The total catch of 4,098,000 fish in 1960 was the lowest since 1946 and 40% below that made in the cycle year of 1958. Because pink salmon all mature at two years of age there are two distinct stocks occurring in odd- and even-numbered years. In recent years the fish of the odd-year cycle have been larger in average size and more numerous than those in the even years yet they both probably live and feed in the same general ocean area.

In even years pink salmon production is centered in streams of the northern British Columbia coast. The catch of these northern stocks was good in 1952, poor in 1954, fair in 1956 and 1958 and poor in 1960. Of all areas only 7 and 8 in the central region of the coast produced larger catches in 1960 than in the cycle year yet the 1958 spawning escapements in these areas were reported to be less than in 1956. The poor catches around the Queen Charlotte Islands, the Nass and Skeena Rivers and in Johnston Straits were particularly disappointing in 1960.

In odd years production is greatest in the southern part of the British Columbia coast, especially in the Fraser River. The total catch of the odd-year stock has fluctuated between 11 and 12 million fish from 1951 to 1957 but dropped to below 7 million in 1959.

The sharp drop in catch in both 1959 and 1960 suggests that unfavourable conditions in the streams or ocean have caused poor survival in the last few years. From daily observations of surface sea-water temperatures taken at lighthouses off the west coast of Vancouver Island it is apparent that above-average temperature conditions prevailed from the spring of 1957 to the fall of 1958. Thus it would appear that these exceptionally warm sea temperatures and associated phenomena such as low stream levels may have adversely affected the survival of both the 1957 and 1958 broods.

Concerning the average size of pink salmon of the even-year cycle, only those which matured in 1958 were exceptionally large at 4.9 pounds compared to the small fish of 3.9 and 4.1 pounds in 1956 and 1960, respectively. The larger fish of the odd-year cycle were of similar size in 1957 and 1959 at 5.1 pounds. When scale radii have been measured from the fish that have been sampled in the last few years, it is hoped that a better comparison will be available of the growth achieved in the ocean in each year.

(b) Coho salmon. The total catch of 2,030,000 fish in 1960 was the lowest since 1945, when records were first separated by species, and it was only 64% of the catch in the cycle year of 1957. Because virtually all coho salmon mature at three years of age after spending the first year in fresh water, this suggests that the exceptionally dry summer of 1958 adversely affected the survival during their year of stream residence.

The troll catch off the west coast of Vancouver Island of 367,000 fish was the lowest since sales-slip records started in 1951 (56% of the catch in the cycle year 1957) while that in the Strait of Georgia of 479,000 fish was the highest (160% of the cycle year 1957). This is the first time during this period that the inside catch has been larger than that caught outside. The best fishing was early in the season after the season opened on June 6 in Areas 14 and 17. The large size and growth of these fish suggests that they may have migrated from outside waters exceptionally early and may thus have escaped the outside fishery. The troll catches in the central and northern areas were below average.

Net fishing in the Strait of Juan de Fuca was restricted by closures so both the Canadian catch of 82,000 coho and the United States catch of 5,000 coho were far below those made in recent years. The gill-net catch made in the Fraser River of 57,000 fish was below average but above that made in the cycle year of 1957.

(c) Spring salmon. The total catch of 742,000 fish in 1960 was, like coho, the lowest since 1945 when records by species were first started. The troll catch off the west coast of Vancouver Island of 264,000 fish was late and ended up as the lowest in the last 9 years while that made in the Strait of Georgia of 96,000 fish was average. The troll catch off the Queen Charlotte Islands of only 15,000 fish was the lowest since the sales-slip system started in 1951.

The Fraser River gill-net catch of 125,000 fish was below average but better than that made in 1956 and 1957. The gill-net catch of fall chinook salmon made in the Columbia River was almost as poor as the record low catch made in 1959. As the spring salmon catches were generally poor along the whole coast from the Columbia River to Alaska the recent decline in the Columbia River stocks showed a marked coastwide effect this year. This is the first year since 1955 that the British Columbia troll catches have reflected this condition so markedly.

(d) Chum salmon. The troll catch of 1,837,000 fish in 1960 was the second lowest (1955 was smaller) since the fishery started in the early 1920's. The catch of 182,000 fish from the Nass River (Area 3) was higher than that in the previous two years but below the average catch of 198,000 fish for the previous 5-year period. The Skeena River catch (Area 4) of 21,000 fish was the lowest since 1955 and well below the average of 38,000 for the previous 5 years. In the central region (Areas 5 to 10) the 1960 catch of 471,000 fish was over twice as large as that made in 1959 but was still well below the average catch for the previous 5 years of 672,000 fish. The catch of 440,000 fish from the west coast of Vancouver Island (Areas 21 to 27) was slightly above the 5-year average catch of 413,000 fish. However the Fraser River catch of 67,000 fish in 1960 was the lowest since 1956 and well below the average catch of 141,000 fish for the last 5 years. In the following section under sampling the ages of these fish will be given and the success of return of some stocks will be discussed, especially those from the Nass and Fraser Rivers.

(e) Sockeye salmon. The total catch of 2,858,000 fish in 1960 was, like chum salmon, the second lowest for many years with the exception of that made in 1955. All important stocks were down, except the Fraser River where the catch was above that made in 1956. The ages and success of return of the important stocks will be discussed under the section on sampling.

In brief, the catches of salmon of all species were poor in 1960 with few exceptions. This suggests a widespread effect of unfavourable environmental conditions for survival in probably both fresh water and the sea. The exceptionally warm ocean temperatures in 1957 and 1958 and the dry summer of 1958 are no doubt important but much more analysis and field data are required before the true causes can be definitely ascertained.

2. Sampling of salmon catches for size, age, and sex composition in 1960

D.J. Milne, H.T. Bilton, E.A.R. Ball, D.W. Jenkinson and S.A.M. Ludwig

Knowledge of the age and size composition of salmon populations is essential to understand the causes of year-to-year fluctuations in the availability of salmon to the fisheries. For sockeye, chum and to some extent spring salmon there is considerable year-to-year variation in the age of maturity. For example, sockeye salmon in northern British Columbia mature mainly as 4-year-olds and 5-year-olds. Over the past 50 years, the average numbers of 4's and 5's returning from the spawning in a given brood year have been about equal. However, from any one brood year the 4-year-olds have formed as few as 3% of the total return and as many as 84%. Thus, to a considerable extent the magnitude of the population available to the fishery in any particular year is determined by the age at which the stock reached maturity. Variations in growth, especially in pinks, springs and cohos exert important effects on the yield to the fishery. Knowledge of growth is important, not only because of its direct effect on the yield to the fishery, but also because variations in growth may reflect changes in environmental conditions influencing survival.

To study variations in size and age composition, it is desirable to have series of data collected over many years. For sockeye, such data have been collected for most major producing areas for as far back as 1912. For the other 4 species annual sampling programs have begun only recently.

In 1960, for the first time, the program was re-organized to obtain representative samples for all 5 species from all the substantial salmon fisheries throughout British Columbia. Because the salmon industry is highly centralized, most of the sampling was done at Prince Rupert and Vancouver. From May to October a total of over 65,000 salmon were measured for hypural length, a preferred scale was taken from the same place on each fish for later age determinations and growth measurements. Where possible the sex of the fish was noted. The totals for each species are as follows: 8,002 pink, 17,087 sockeye, 25,736 chum, 7,253 coho and 7,837 spring salmon.

Much of the sampling data has been transferred to I.B.M. cards to facilitate analysis and storage for both present and future studies as the need arises in any particular area. In some species and areas a series of data is now available and will be referred to in the following sections while in other cases further sampling is necessary before it can be used in conjunction with other information to provide useful information on the status of the stock.

(a) Sockeye salmon

Age composition data for the 1960 sampling season are presented in Table I.

The relative success of return from any brood year can be assessed by using the ages obtained from the sampling to proportion the annual catches into the parts arising from each brood year. The total resultant catch when compared to that made in the brood year indicates how well the catches are being maintained for this particular brood year stock. Whenever possible it is better to compare the escapement in the brood year with the resultant stock produced but this involves estimating the abundance of, and sampling the escapements for age. So far this has not been possible except for Skeena River sockeye. Comparisons of brood year catches or escapements with resultant returns are shown in Tables II, III, and IV for the sockeye stocks of the 3 important northern producing areas.

i) Skeena River (Area 4). In 1960, restrictions were again applied to protect the early runs to the south end of Babine Lake, which resulted in a low catch of only 186,074 fish (36% of the average for the past 10 years) and a moderate escapement of 320,000 fish which included 46,000 fish taken by the Indian food fishery upriver. Again, as in recent years, the catch selected fewer 4_2 fish than were found in the escapement. When both catch and escapement are combined over one-half were four years of age and about one-third were five years of age. The 4-year-olds arose from the moderate spawning of 1956 which so far has reproduced poorly while the 5's resulted from the small spawning escapement in 1955 which replaced itself at a relatively high level (see Table II). The small spawnings in 1952 and 1955 and the moderate spawning in 1954 provided fair returns. However, the brood years 1950, 1951 and 1953 provided relatively poor returns, especially the slide year of 1951 when the resultant stock was less than the escapement in the brood year alone.

ii) Rivers Inlet (Area 9). The catch of 516,000 sockeye was below the average of 766,000 for the past 9 years. Although 5_2 was the most abundant age group it failed to make the resultant catch sufficient to replace the catch made in the brood year 1955 (see Table III). The poor return of 4_2's from the large catch made in the brood year of 1956 makes it appear doubtful that the 1956 brood year will be successful in replacing itself either. Thus, since 1950 the resultant catch has been smaller than that in the brood year in all years except for 1951 and 1954.

iii) Smith Inlet (Area 10). The catch of 219,000 sockeye was below the average for the previous 10 years of 297,000. The majority were 5_2's from the brood year of 1955 which like other recent years has failed to produce as large a resultant catch as that taken in the parent year. In fact only the brood year of 1951 has replaced itself in recent years (Table IV).

iv) Nass River (Area 3). In 1960 the sockeye catch of 132,943 fish was only 58% of the average catch for the past 10 years. Usually the 5_3's are the dominant age group in this area but for the first time since 1951 and the third since sampling started in 1912 the 4_2 age group predominated. This suggests that the production from the 1955 brood year was poor and that many of the 4_2's were probably bound for the nearby Skeena River. In support of the latter it should be noted that by July 10, when the Skeena fishery opened, about one-half (69,000 fish) of the sockeye catch in Area 3 had already been taken. For some

Table I. Percentage age composition of 1960 sockeye catches.

Statistical area	Location	Catch	3_1	4_1	3_2	4_2	5_2	6_2	4_3	5_3	6_3	6_4	Total samples	% females
		1000's												
3	Nass River	133	--	0.7	0.2	52.2	10.4	--	--	26.9	8.5	1.1	771	39.7
4	a) Skeena R. catch	186	0.2	--	0.3	49.3	37.3	--	0.3	5.3	7.3	--	1,111	47.1
	b) Skeena R. escapement[1]	320	0.1	--	4.6	58.3	24.4	--	0.2	4.6	7.7	0.1	943	46.7
	c) Skeena, catch + escapement	506	0.14	--	3.0	54.9	29.2	--	0.2	4.9	7.6	.06	--	--
5	Ogden-Principe	50	--	0.4	1.4	49.1	26.6	0.4	0.3	10.9	10.9	--	564	51.1
6	Whale Channel	56	--	--	1.1	44.6	30.9	0.1	0.5	11.6	11.2	--	1,002	51.6
7	Bella Bella	9	--	--	2.6	59.6	7.9	0.3	2.3	22.9	4.3	0.1	507	53.4
8	Bella Coola	87	0.4	0.1	1.6	70.8	16.6	0.2	0.1	9.1	1.1	--	1,446	54.2
9	Rivers Inlet	516	0.1	0.1	0.2	38.4	55.0	0.2	--	2.0	4.0	--	2,114	52.1
10	Smith Inlet	219	0.03	0.3	0.04	22.6	71.3	0.15	--	2.08	3.5	--	2,040	53.8
12	Upper Johnstone Strait	203	--	--	0.44	89.7	7.2	.02	0.1	2.14	0.4	--	2,227	54.4
13	Lower Johnstone Strait	44	--	--	0.3	95.0	3.1	--	0.2	1.3	0.1	--	867	49.4
23	Barkley Sound	9	--	--	--	72.2	12.0	--	--	14.5	1.3	--	640	51.4
24	Clayoquot Sound	41	--	--	--	63.3	35.4	--	--	1.1	0.2	--	315	47.4
Total catch in areas covered		1,508											14,547	
Total catch Fraser Convention Area		1,257[2]												
Total catch other areas		30												
Total B. C. catch		2,795												

1 Sampled from test-fishing catches above fishing boundary which includes Indian food fishery and escapement.
2 Sampled by the International Pacific Salmon Fisheries Commission.

Table II. Skeena River sockeye.

Brood year	Brood year esc.	Resultant Stock								% 4's	% 5's
		1954	1955	1956	1957	1958	1959	1960	Total		
		thousands of fish									
1950	449	394	193	16	--	--	--	--	603	65.3	32.0
1951	248	--	55	140	7	--	--	--	202	27.3	70.0
1952	237	--	8	438	255	8	--	--	709	61.8	35.9
1953	752	--	--	2	525	919	17	--	1,463	35.9	62.8
1954	580	--	--	--	42	596	771	39	1,447	41.2	53.3
1955	110	--	--	--	--	14	251	172	435+	57.7	39.1
1956	403	--	--	--	--	--	21	280	--	--	--
1957	491	--	--	--	--	--	--	15	--	--	--
Total		--	256+	596	829	1,537	1,060	506	--	--	--

Table III. Rivers Inlet sockeye.

Brood year	Brood year catch	Resultant Catch								% 4's	% 5's
		1954	1955	1956	1957	1958	1959	1960	Total		
		thousands of fish									
1950	1,510	345	315	--	--	--	--	--	660	52.3	47.7
1951	1,016	--	263	965	2	--	--	--	1,230	21.4	78.4
1952	939	--	--	107	129	3	--	--	239	44.8	53.9
1953	1,522	--	--	--	242	723	7	--	972	24.9	74.4
1954	575	--	--	--	1	287	320	21	629	45.6	50.9
1955	584	--	--	--	--	4	76	294	374+	32.1	78.6
1956	1,072	--	--	--	--	--	1	199	--	--	--
1957	374	--	--	--	--	--	--	2	--	--	--
Total		--	578+	1,072	374	1,017	404	516	--	--	--

Table IV. Smith Inlet sockeye.

Brood year	Brood year catch	Resultant Catch								% 4's	% 5's
		1954	1955	1956	1957	1958	1959	1960	Total		
		thousands of fish									
1950	474	118	188	--	--	--	--	--	306	38.6	61.4
1951	439	--	137	424	--	--	--	--	561	24.4	75.6
1952	342	--	--	18	27	--	--	--	45	40.0	60.0
1953	367	--	--	--	37	166	1	--	204	18.1	81.4
1954	191	--	--	--	--	57	87	8	152	37.5	57.2
1955	325	--	--	--	--	--	18	161	179+	10.1	89.9
1956	442	--	--	--	--	--	--	50	--	--	--
1957	64	--	--	--	--	--	--	--	--	--	--
Total		--	325	442	64	223	106	219	--	--	--

+ denotes incomplete returns

unknown reason, the proportion of females in the 1960 catch was exceptionally low compared to previous years.

v) Ogden-Principe (Area 5). The catch of 50,000 sockeye was below the previous 8-year average of 77,000. The 4_2's were the most abundant age group and most likely many of the fish caught in this area were bound for the adjacent Skeena River.

vi) Whale Channel (Area 6). The catch of 56,000 was much better than that in 1959 but was still below the average of 72,000 for the previous 8 years. The age compositions were similar to those from fish in Area 5 but unlike them probably few went north to spawn in the Skeena River.

vii) Bella Bella (Area 7) and Bella Coola (Area 8). The small catch in Area 7 was predominantly 4_2's and 5_3's while that in Area 8 was mainly 4_2's. These are in sharp contrast to the high proportion of 5_2's that were found in Areas 9 and 10.

viii) Johnstone Strait (Areas 12 and 13). The catch of 247,000 sockeye was below that in 1959 and as usual was composed mainly of 4-year-olds indicating that most were bound for the Fraser River area.

ix) West coast of Vancouver Island (Areas 23 and 24). These catches, taken well up the inlets, were also mainly 4_2's and were bound for spawning areas on Vancouver Island chiefly Sproat, Great Central and Kennedy Lake systems.

Thus, in 1960 the sockeye catches were well below the average of recent years in all areas sampled. In contrast to the previous two years, the 4-year-olds predominated in all areas except Rivers and Smith Inlets, attesting to the poor return of 5's from the brood year of 1955. For most areas the return of 4's was low compared to the large escapements in 1956 and will also be a failure unless many fish return as 5's in 1961.

(b) Chum salmon

The chum catches from most areas of British Columbia have been sampled only since 1958. The percentage age compositions for past years were summarized in last year's report. In 1960 a more comprehensive sampling was conducted in all areas which together made up 98% of the total British Columbia chum catch. The catches and percentage age compositions for 1960 are listed in Table V.

In the northern areas 3 and 4, the 4-year-olds again predominated but there were more 3's and fewer 5's than in the last 3 years. For the Nass (Area 3) the catches in the brood years are compared with those in the returning years in Table VI. At present the complete returns of 3-, 4- and 5-year-old fish are only available for the brood-year catches of 1954 and 1955. In both cases the resultant catches have yielded catches about twice as large as the small catches made in the parent years. From incomplete data for the brood years 1953 and 1956 the resultant catches are also above that of the parent years.

Table V. Percentage age composition of chum catches in 1960.

Statistical Area	Main salmpling location	Catch	Age composition (percent)					Total samples	% females
			2_1	3_1	4_1	5_1	6_1		
		(1,000's)							
3	Nass River	182	--	18.3	80.4	1.3	--	1,238	48.1
4	Skeena River	21	--	18.6	79.1	2.3	--	335	45.3
5	Ogden and Principe Channels	37	--	61.2	38.2	0.6	--	353	51.5
6	Whale Channel	125	--	64.0	35.5	0.5	--	1,275	48.2
7	Bella Bella	125	--	59.8	39.1	1.08	0.02	3,376	49.8
8	Namu	140	0.01	58.48	40.48	1.03	--	3,822	49.0
9	Rivers Inlet	20	--	74.2	25.4	0.4	--	1,099	57.3
10	Smith Inlet	24	--	72.2	26.7	1.1	--	812	53.8
12	Upper Johnstone Strait	333	--	42.3	56.4	1.3	--	2,603	48.8
13	Lower Johnstone Strait	203	--	41.9	57.4	0.7	--	1,626	46.0
14	Hornby Island	11	--	43.1	56.2	0.7	--	227	42.6
16	Jervis Inlet	33	--	44.7	55.3	--	--	190	44.7
17	Northwest Bay	15	--	46.6	51.7	1.7	--	176	45.5
18	Satellite Channel	14	--	59.6	38.8	1.6	--	312	52.6
20	San Juan	16	--	67.6	31.8	0.6	--	959	49.4
22	Nitinat	48	--	42.4	57.5	0.1	--	441	46.4
23	Barkley Sound	71	--	46.7	52.0	1.3	--	566	47.2
24	Clayoquot Sound	29	--	40.7	58.5	0.8	--	232	39.4
25	Nootka Sound	103	--	80.0	20.0	--	--	411	51.3
26	Kyuquot Sound	131	--	63.4	35.9	0.7	--	472	42.4
27	Quatsino Sound	58	--	91.7	8.3	--	--	304	44.7
29	Fraser River	67	--	34.6	64.0	1.4	--	1,682	42.4
		1,806						22,511	

Table VI. Nass River chums (catches in thousands of fish).

Brood year	Brood year catch	Resultant Catch 1957	1958	1959	1960	Total	% 3's	% 4's	% 5's
1952	99	26	--	--	--	--	--	--	--
1953	174	176	25	--	--	201+	--	--	--
1954	88	24	131	33	--	188	12.8	69.7	17.5
1955	68	--	22	99	2	123	17.9	80.5	1.6
1956	361	--	--	27	146	373+	--	--	--
1957	226	--	--	--	34	--	--	--	--
Total	--	226	178	159	182	--	--	--	--

+ denotes incomplete returns.

In the central region (Areas 5 to 10) the ages for 1960 departed considerably from those found in the two previous years, with 3-year-olds instead of 4-year-olds predominating in the catches. This suggests a poor production from the 1956 brood year and an improved production from 1957. The only complete returns are for the spawning in 1955. In contrast to the good returns on the Nass, the resultant catches in the central areas yielded catches much below the small catches made in 1955.

In southern catches around Vancouver Island (Areas 12-27) the 4-year-olds comprised more than 50% of most of the catches but the 3's were also important. In some areas such as off the west coast of Vancouver Island (Areas 25, 26, and 27) the 3-year-olds were most abundant.

For the Fraser (Area 29) the catches in the brood years are compared with those in the returning years in Table VII. In 1960 the catches were again predominately 4-year-old fish. Complete returns from the spawning in 1954, when the catch was large, indicate a low resultant catch, chiefly as 4's in 1958. However, the returns from 1955, when the catch was low, yielded relatively good returns as 3's in 1958 and 4's in 1959. Incomplete returns from the 1956 brood year are well above the low catch of 71,000 fish. By interpolating ages for the low catches in the years 1955 and 1956 it is obvious that the large catches made in 1952, 1953 and 1954 failed to reproduce themselves while the low catches of 1955 and 1956 have been returned with somewhat better success. It is hoped that the increase in regulatory closures in recent years will enable the stocks to return to their former level of abundance.

(c) <u>Variations in size and growth of coho salmon</u>

In last year's report the average fork lengths of coho salmon sampled during July from the troll catches off each side of Vancouver Island were given for the period 1952 to 1959. These showed that the fish caught off the west coast of Vancouver Island were consistently larger than those caught off the east coast and that usually the size has varied similarly in the two regions. In 1960 the mean fork length for outside fish of 62.1 cm was just above average while that for inside fish was 56.8 cm or much above the average for the past 8 years.

In order to determine how the difference in size of fish caught in the two regions varied throughout the life of the fish, the number of circuli were counted, the scale radii were measured and the fork lengths were calculated to the end of each year. The results are given in Table VIII for fish caught in August of 1958 and 1959 compared to those captured in June, July and August of 1960. It is apparent that the fish caught in August in outside waters are consistently larger than those caught in inside waters at each stage of life. However in 1960 the growth of the two groups of fish is more similar than in the two previous years and for fish caught in June and July it is almost the same. This suggests that some of the fish which usually remain to feed in outside waters may have migrated through Johnstone Straits early in 1960 to provide the exceptionally good fishing in Area 14 of larger than average-sized fish during June and early July. The growth in fresh water was poorest in both groups of fish in 1958 while the growth in the ocean appears to have been the best in outside waters in 1958 and in inside waters in 1959.

Much more data are required to be analysed before the variations in growth between different stocks and years can be fully assessed but in contrast

Table VII. Fraser River chums (catches in thousands of fish).

Brood year	Brood year catch	Resultant Catch							% 3's	% 4's	% 5's
		1955	1956	1957	1958	1959	1960	Total			
1952	554	(60)	(30)	7	--	--	--	(97)	--	--	--
1953	326	--	(41)	93	1	--	--	(135)	--	--	--
1954	452	--	--	19	85	1	--	105	18.1	80.9	1.0
1955	100	--	--	--	109	129	1	239	45.6	54.0	0.4
1956	71	--	--	--	--	89	43	132+	--	--	--
1957	119	--	--	--	--	--	23	--	--	--	--
Total	--	100	71	119	195	219	67	--	--	--	--

+ denotes incomplete returns.

( ) denotes estimated returns.

Table VIII. The average number of circuli (C), scale radius in mm (R) and fork length in cm (FL) at each year for coho salmon sampled in 1958, 1959 and 1960.

	Time of sampling		Outside Vancouver Island			Inside Vancouver Island		
	Year	Month	C	R	FL	C	R	FL
First year (freshwater annulus)	1958	August	17.8	.51	9.6	16.6	.47	8.5
	1959	"	19.1	.53	9.7	14.8	.43	7.6
	1960	"	19.2	.45	8.2	15.7	.39	6.9
	"	July	18.1	.43	8.0	17.3	.40	7.4
	"	June	17.5	.42	7.3	19.0	.43	7.7
Second year (ocean annulus)	1958	August	56.7	2.18	41.0	53.8	1.95	35.2
	1959	"	60.6	2.40	43.5	52.0	2.01	35.4
	1960	"	63.0	2.15	39.1	62.3	2.26	40.0
	"	July	62.4	2.22	41.5	63.1	2.10	39.6
	"	June	63.3	2.25	38.8	65.1	2.22	39.6
Third year (to time of capture)	1958	August	81.8	3.54	66.6	77.5	2.97	53.7
	1959	"	82.7	3.55	64.5	76.7	3.18	56.0
	1960	"	86.8	3.38	61.6	85.7	3.31	58.8
	"	July	83.8	3.31	61.9	85.8	3.19	58.9
	"	June	82.5	3.21	55.2	82.6	3.10	55.3

to pink salmon it does not seem likely that the three almost distinct annual stocks of coho salmon (over 95% mature in their third year) differ in growth rates.

(d) Variations in size and age of spring salmon

In last year's report the mean fork lengths of the dominant age group of 3_1 fish were compared for fish caught by troll on each side of Vancouver Island for the years 1952 to 1959. In Table IX the average for this period is compared to the means obtained from fish caught in 1960. There is a consistent difference in size between fish caught in the two regions but it is not as marked as that for coho salmon. In 1960 the fish were just below average in size in both regions and in each case the white-fleshed fish were larger than the red-fleshed fish.

The percentage age composition of the spring salmon sampled in 1960 from the troll catches made off each side of Vancouver Island and the gill-net catch made in the Fraser River are given in Table X. In last year's report the age composition for the same regions are given for the last three years. For troll-caught fish which eventually spawn in many rivers and in some cases are taken as immatures during more than one season it can only be stated that the ages of fish caught in 1960 were similar to those in previous years with the dominant age group as 3_1's. However, for the gill-net-caught fish in the Fraser River, which are all maturing fish on their spawning migration, the proportions in each age group can be related to the success or failure of definite brood years for the same general spawning stocks (Table XI).

The early migrating red-fleshed fish spawn mainly in the upper tributaries of the Fraser River system at four years of age. Many spend the first year of life in fresh water. For brood years 1954 and 1955 complete records are now available and the resultant catches have been better than those made in the parent years. For brood years 1953 and 1956, although the records are incomplete, they are or probably will be about equal to the catches made in the parent years.

The late white-fleshed fish spawn mainly in the lower Harrison River and probably in the lower part of the main stem of the Fraser River. The majority mature at four years of age after going to sea in their first year. For brood years 1952 and 1955 the resultant catches have been equal to or better than those made in the parent years but for the years 1953, 1954 and probably 1956 the returns have been lower.

Thus, on the basis of success of return of catches, it appears that in recent years the red-fleshed stocks have been replacing themselves better than the white-fleshed stocks. This is occurring despite the drastic closures during the fall season, which are designed to assist in the escapements of both chum and white spring salmon.

Table IX. Average fork lengths of spring salmon of 3 age-group sampled from troll catches off each side of Vancouver Island.

	Average for 1952-59	1960 Red	1960 White	Weighted total
West coast Fork length (cm)	67.8	66.4	69.4	66.9
East coast Fork length (cm)	65.9	65.2	66.8	65.4

Table X. Percentage age composition for spring salmon sampled in 1960.

Area	2_1	3_1	4_1	5_1	6_1	2_2	3_2	4_2	5_2	6_2	Total samples
West coast of Vancouver Is. (troll)	8.1	54.3	21.2	2.0	--	.1	4.0	8.1	2.0	.2	2,023
East coast of Vancouver Is. (troll)	16.4	41.1	25.0	1.4	--	--	6.8	7.0	2.2	.1	1,334
Fraser River (gill-net)											
Red	5.7	9.5	29.9	2.7	--	.2	7.5	30.0	14.0	.5	1,238
White	6.7	8.4	55.0	9.1	.1	--	.6	10.8	9.2	.1	993

Table XI. Fraser River springs.

Brood year	Brood year catch	Resultant catch 1956	1957	1958	1959	1960	Total
Red-fleshed fish (in thousands of fish)							
1952	87	11	2	1	--	--	--
1953	81	37	19	26	1	--	83+
1954	68	8	18	44	29	--	99
1955	61	--	5	15	44	11	75
1956	58	--	--	--	5	38	43+
1957	43	--	--	--	--	11	--
1958	86	--	--	--	--	4	--
Total		57+	43	86	79	64	--
White-fleshed fish (in thousands of fish)							
1952	27	26	1	1	--	--	28+
1953	72	20	15	7	--	--	42+
1954	79	1	10	27	14	1	53
1955	56	--	9	14	41	8	72
1956	53	--	--	1	3	31	35+
1957	35	--	--	--	--	4	--
1958	50	--	--	--	--	3	--
Total		47+	35	50	58	47	--

+ denotes incomplete returns.

3. Study of chum salmon scales to distinguish stocks

S. Tanaka, H.T. Bilton, M.P. Shepard and D.W. Jenkinson

Studies of scale characteristics of chum salmon taken from spawning grounds and coastal areas throughout the North Pacific area and on the high seas were continued. Previous reports have reviewed the results of the scale collections made in 1956 in both coastal and high-seas areas and in 1957 for those made in coastal areas. Scales collected in 1957 from 3,070 chums from the high seas and from 681 5-year-olds collected in coastal areas in 1958 have now been examined. From differences in first- and second-year circulus counts and annulus measurements of scales from over 60 areas of North America and 16 areas of Asia, an attempt was made to identify the area of origin of fish taken on the high seas in both 1956 and 1957. Because scale characteristics tend to vary between fish maturing at different ages, the present study was restricted to a consideration of 4- and 5-year-old chums arising from the brood years of 1952 and 1953 only.

In Figures 9 and 10 limits for counts and measurements for shore samples for 4-year-olds from the various shore samples taken in 1956 and 1957 are shown. From examination of the distributions of characters, it can be seen that certain groups of fish have relatively unique characteristics and can be segregated from others. For example, first half of first year (C_a) values for Siberian chums (both brood years) have limits from 8 to 15. Almost no chums from any other area have counts of less than 10. Thus, high-seas samples having significant quantities of fish with less than 10 circuli almost certainly would contain substantial numbers of Siberian chums. Similarly, only chums from British Columbia have last half of first year (C_b) values exceeding 22. Thus high-seas samples containing significant numbers of fish with C_b values exceeding 22 would almost certainly contain substantial numbers of fish originating in British Columbia.

By a simultaneous examination of pairs of characters in conjunction with an examination of single characters, some improvement in the degree of separation can be obtained. A method was devised which involved the establishment of a key in which 8 scale characters for fish taken on the high seas are compared with the same characters for fish of known origins sampled in coastal fishing areas or on spawning grounds. From these comparisons each fish taken on the high seas was classified according to the similarity of its scale pattern to scale patterns of fish originating in streams within 4 broad geographical areas: the Southeastern Region (from Oregon to central Alaska), the Northeastern Region (central, western and far northern Alaska), the Northwestern Region (here type samples were obtained almost exclusively from the Kamchatka peninsula although it is believed that fish from most Asian producing areas along the northern Okhotsk Sea and on the Bering Sea coast of the USSR would exhibit similar scale patterns) and the Southwestern Region (type samples were obtained from Hokkaido only, but it is possible that chums from the more southerly USSR producing areas may exhibit similar characteristics). In many cases, fish taken on the high seas could be assigned precisely to one of the 4 regions. In other cases it was possible only to designate that the fish originated in either of 2 or in one of 3 or even all 4 of the regions.

As a test of the method, sub-samples of fish of known origin were processed in the same way as if they had occurred among samples taken on the high seas. These tests indicated that the precise region of origin of about

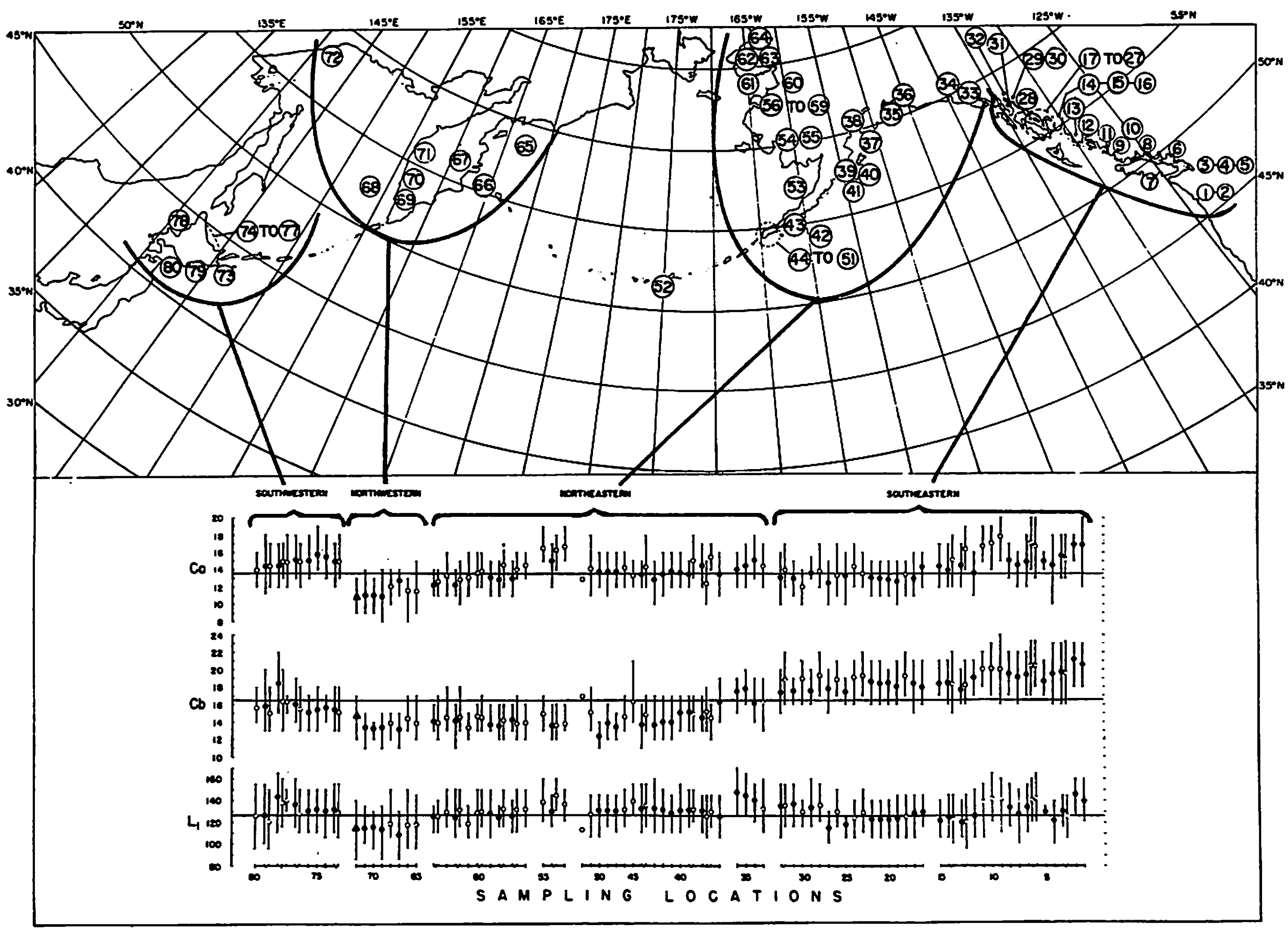


Fig. 9. Mean values and arbitrary ranges of circulus counts for the first half of the first year (C_a), circulus counts for the last half of the first year (C_b) and first-year annulus widths (L_1) for 4-year-old chum salmon collected in various coastal sampling areas. Open circles indicate values for samples collected in 1956, closed circles for samples collected in 1957 and triangles for a sample of 5-year-olds collected in the Kukhtui River in 1958.

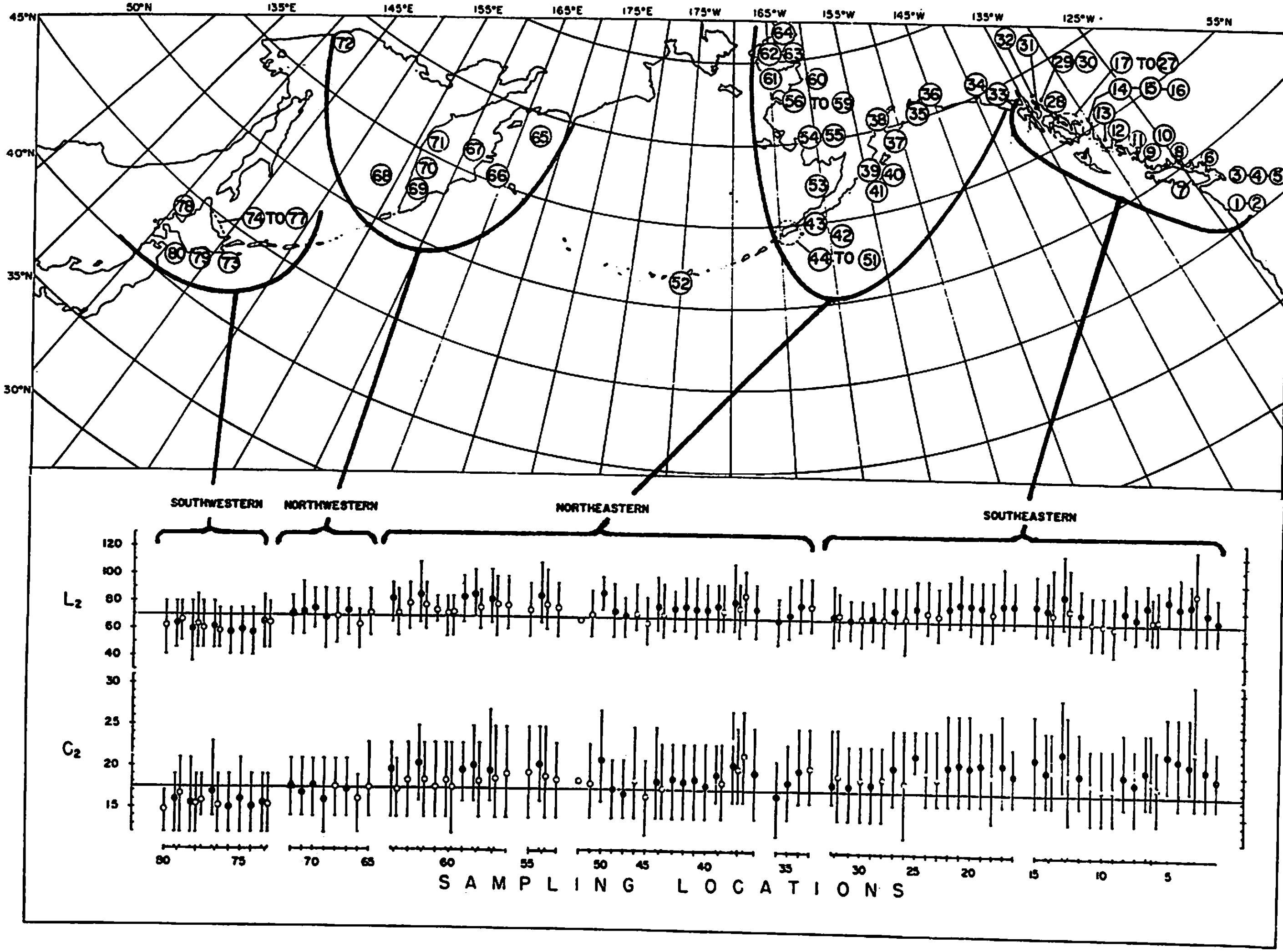


Fig. 10. Mean values and arbitrary ranges of second-year annulus widths (L_2) and second-year circulus counts (C_2) for 4-year-old chum salmon collected in various coastal sampling areas. Open circles indicate values for samples collected in 1956, closed circles for samples collected in 1957 and triangles for a sample of 5-year-olds collected in the Kukhtui River in 1958.

half the fish originating in the Southeastern Region would be recognized correctly by this method. For an additional 15%, the precise region could not be determined, but the fish would be designated as originating in either the Southeastern or Northeastern Region and could therefore be assigned as North American fish. In all but 1% of the remaining cases neither the region nor the continent of origin could be determined. In about 1% of the cases either the region or continent of origin was misclassified. Somewhat smaller percentages of fish originating in the Northeastern (northern Alaska) and Northwestern (northern Asia) Regions could be classified as to region or continent of origin (33% and 31% respectively). The number of cases in which wrong classification occurred was small (about 1% and 3% for the Northeastern and Northwestern Regions respectively). Because their scale characteristics are intermediate between those of Northwestern and North American chums, very few (around 6%) of the fish from the samples from Hokkaido (Southwestern Region) could be classified even to continent of origin. In 4.5% of the cases, the continent of origin was misclassified. Thus the methods used would be expected to provide relatively accurate identification of the region of origin of a significant proportion of those 4- and 5-year-old chums taken on the high seas which had originated in the streams of northern Asia and along the entire North American coastline. Very few of the fish originating in southern Asian chum streams would be identified.

In applying these methods to samples taken on the high seas (Fig. 11) a number of difficulties arose, stemming from the errors in classification described above and possibly from the inadequacy of sampling in certain coastal areas (especially in Asia). While these difficulties prevented determination of the exact limits of distribution of the different stocks on the high seas, the study has provided a very reasonable picture of the centers of concentration of the populations originating in all regions except the Southwestern.

As a summary, Figures 12 and 13 have been prepared from the combined data for 1956 and 1957 to show the general distribution of fish from each of the 3 regions under consideration, during the early part of the sampling season (May and June) and during the late season (July to September). The results from the 1956 and 1957 collections were quite similar. For each of the stocks, the high-seas areas in which they predominated, the areas in which they were present in lesser proportions, and the areas in which they may have been present in small proportions but where possible errors in classification make final determinations difficult, are shown.

During the early part of both years (May and June, Fig. 12), most of the fish in the samples were probably matures, some of which would already be on their way to the spawning grounds. Except for the area immediately adjacent to the British Columbia-southeastern Alaska coast (where Southeastern fish predominated), sampling was restricted to the areas westward from 165° W. Fish from northern Alaska predominated in the eastern Bering Sea and south of the Aleutians around 165° W. Northern Asian fish apparently predominated throughout most of the rest of the western ocean, except along the southern fringe of the sampling area, especially eastward from 180°. Here the proportions of fish which could not be identified were very high, suggesting the presence of stocks (either Asian or North American) with intermediate scale characters. The area over which substantial intermingling occurred lay between 175° E and at least as far eastward as 165° W. This zone of intermingling appeared to be widest near the Aleutians and to be narrower further northward in the Bering Sea. The approximate boundary separating areas where Alaskan and northern USSR fish predominated

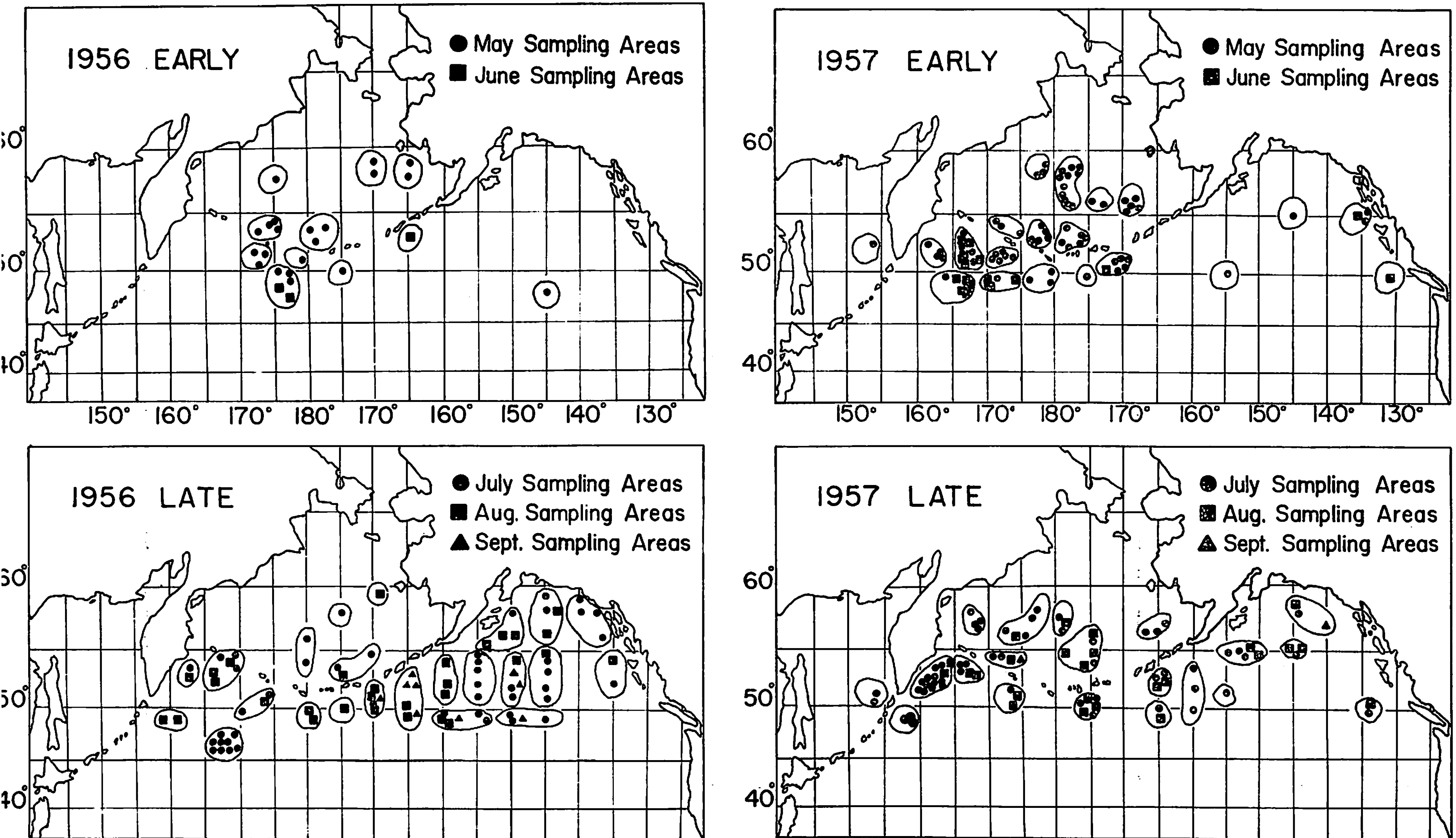


Fig. 11. High-seas sampling areas in which chum salmon used for scale analyses were collected in 1956 and 1957.

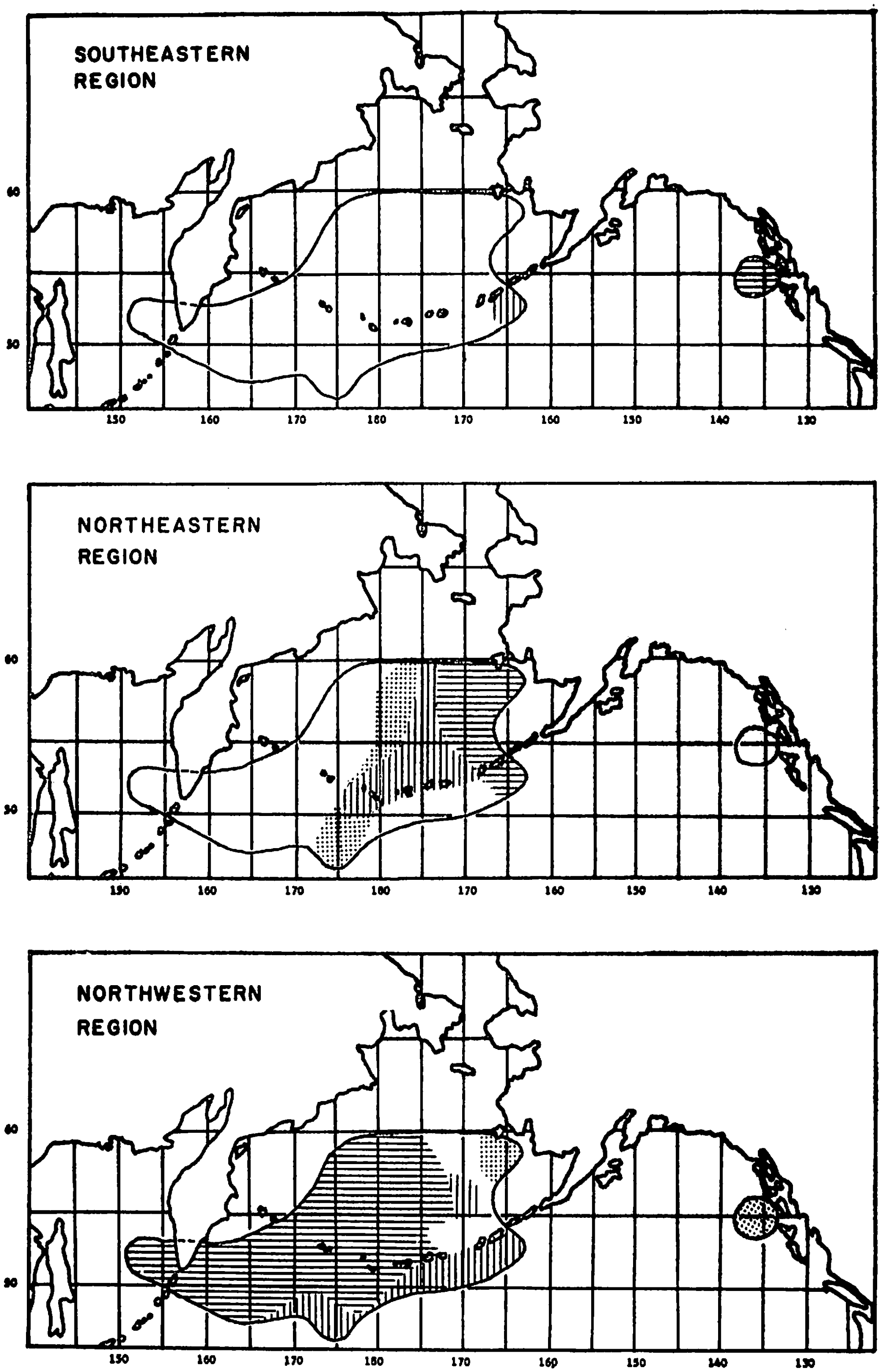


Fig. 12. Apparent distribution of 4- and 5-year-old chums originating in the Southeastern (British Columbia-southeastern Alaska), Northeastern (northern Alaska), and Northwestern (northern USSR) Regions on the high seas during May and June of 1956 and 1957. Black line encloses area sampled during 1956 and 1957. Horizontal bars indicate areas where fish from the designated region probably predominate. Vertical bars indicate where fish are probably present in smaller proportions and dotted areas indicate where fish may be present, but where errors in method prevent final conclusions. Clear areas indicate where fish from the designated regions are essentially absent.

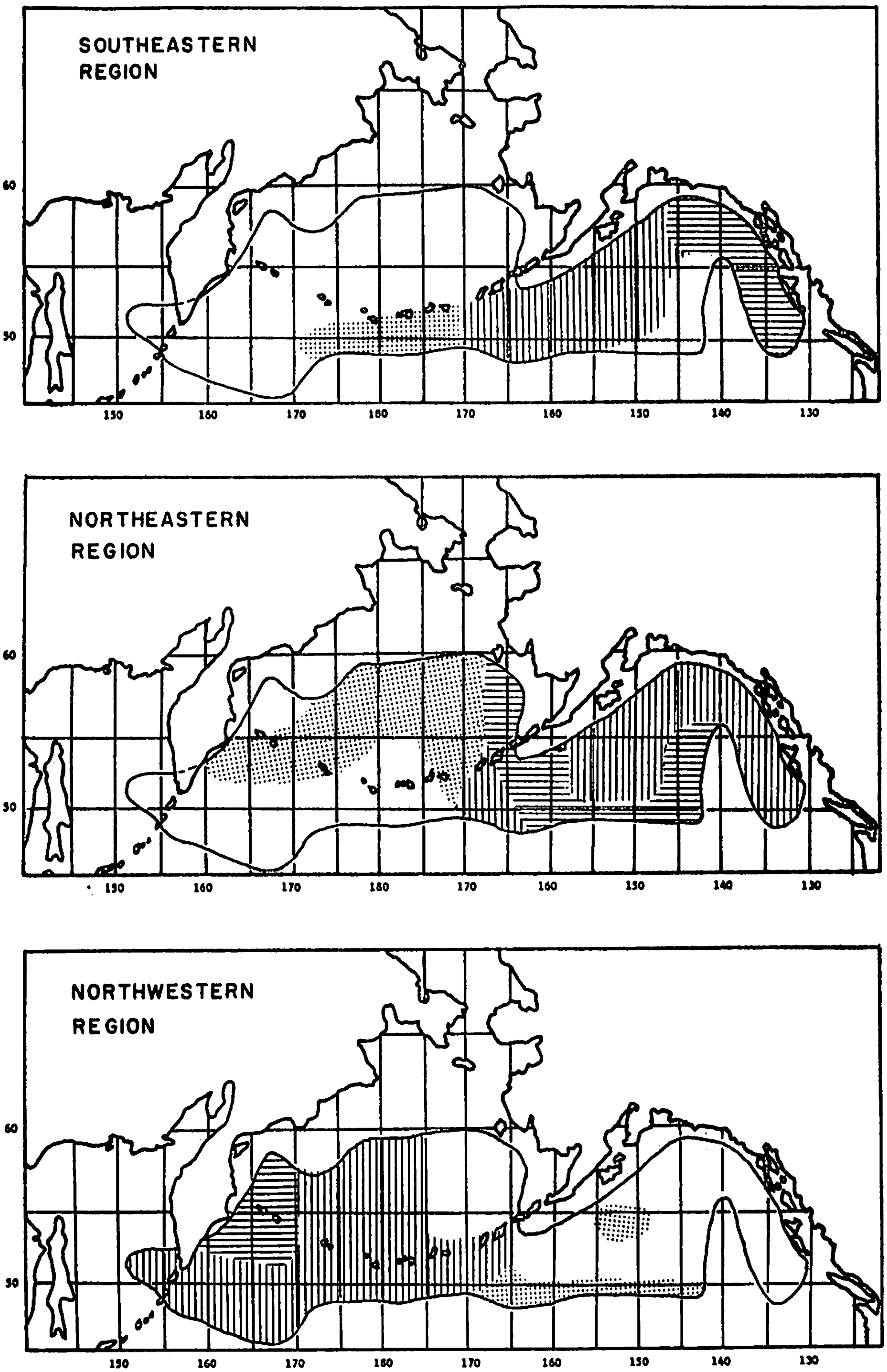


Fig. 13. Apparent distribution of 4- and 5-year-old chums originating in the Southeastern (British Columbia-southeastern Alaska), Northeastern (northern Alaska), and Northwestern (northern USSR) Regions on the high seas from July to September of 1956 and 1957. Black line encloses area sampled during 1956 and 1957. Horizontal bars indicate areas where fish from the designated region probably predominate. Vertical bars indicate where fish are probably present in smaller proportions and dotted areas indicate where fish may be present, but where errors in method prevent final conclusions. Clear areas indicate where fish from the designated regions are essentially absent.

appeared to be between 170° W and 175° W north of the Aleutians. Below the Aleutians, the presence of large proportions of unidentifiable fish makes establishment of a division line difficult. From the above considerations, in Figure 14, the approximate ranges of 4- and 5-year-old chums from North America and Asia are indicated.

Late in the season (July to September - see Fig. 13) sampling was more widespread and included a good coverage of the Gulf of Alaska as well as of the western part of the study area. As the season progressed it would be expected that mature chums destined to spawn during the summer months would rapidly emigrate from the high seas, leaving behind immature fish and populations of later spawning fish. The stocks of northern Asia are summer spawners and their distribution pattern as indicated by the scale studies, reflects their movement away from the central Bering Sea (where they clearly predominated early in the season - see Fig. 12) toward the Asian coast. The proportions of identifiable Northwestern chums were very high along the Kamchatka coast (about the same as in the early season) and considerably lower than they had been in the spring everywhere else (except for one sampling area in the Gulf of Alaska - see below). Samples throughout most of the western North Pacific and Bering Sea contained moderate proportions of Northwestern fish and large proportions of unidentifiable fish, suggesting that the residual populations there could be made up of a high proportion of late spawning southern Asian fish (which are impossible to identify because of their intermediate scale characters).

In the late part of the season in the Bering Sea, fish originating in northern Alaska (the Northeastern Region) occupied essentially the same area as they did in the early part of the season. They also formed a major part of the population in the western Gulf of Alaska. Mature fish of Southeastern origin were concentrated against the eastern shore of the Gulf, but also occurred in smaller proportions along the northern rim of the Gulf westward to about 170° W. Samples of immature fish taken immediately south of Kodiak Island in July contained a high proportion of fish with typically northern Asian scales, suggesting the possible presence of some Asian fish in this area.

It is very difficult to establish the probable area over which intermingling between North American and Asian 4- and 5-year-old fish occurred late in the summer because the actual number of fish sampled in the central North Pacific and Bering Sea areas was too small, and because of the large numbers of unidentifiable fish present in samples from this area. At this time, it is not feasible to discuss in detail the relative abundance of fish in the different high-seas sampling areas as shown by high-seas fishing. However, one general comment may be helpful. Late season catches of older chums in the mid-ocean area,as shown, for example, by the 1956 data, are usually quite poor. Catches on either side of this area remain high at least until late August. These observations suggest a division between Asian and North American mature stocks as both move toward their spawning grounds. In 1956 this division area seemed to lie between 170° W and 180°. From these considerations and study of data presented in Figure 13, in the late summer the extent of intermingling of Asian and North American 4- and 5-year-old chums (many of which are matures) is much less than that occurring in the early season. The approximate division line between areas in which one or the other predominated in 1956 and 1957 would appear to be in the general vicinity of 170° W both north and south of the Aleutians (see Fig. 14).

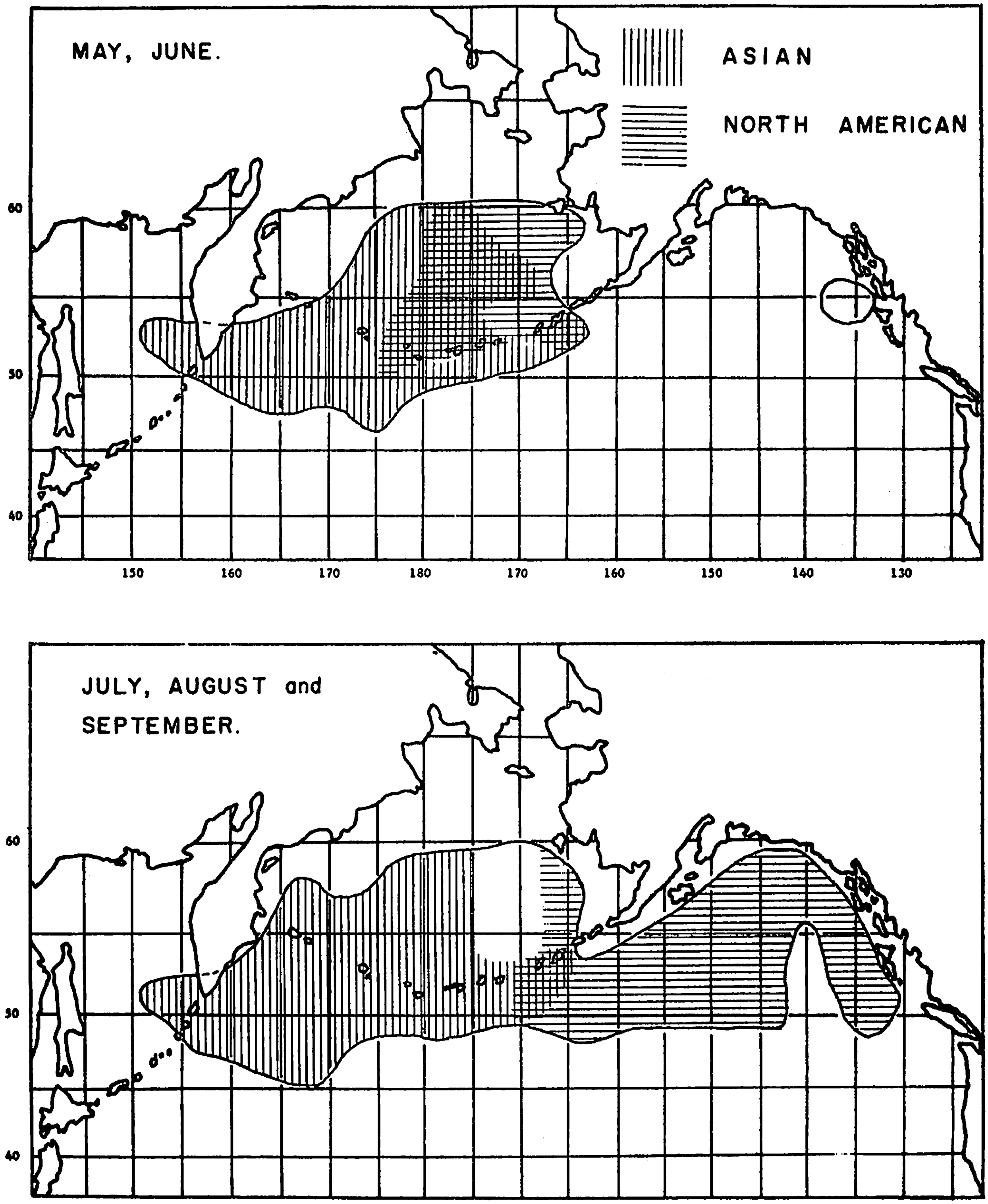


Fig. 14. Apparent distribution of North American and Asian 4- and 5-year-old chums in various high-seas areas in 1956 and 1957. Cross-hatching indicates areas of intermingling.

The study of 4- and 5-year-olds provides only a limited picture of the distribution of chums on the high seas. Especially late in the season, immature 3-year-old and younger fish form large proportions of research vessel catches. Extension of the present study to include examination of these younger fish is necessary to provide a balanced description of the distribution of stocks originating from the two continents. In addition, chum scales collected since 1957 should be examined and the results compared with those derived from the 1956 and 1957 data.

B. Skeena Salmon Investigation

J. McDonald and
F.C. Withler

Since the formation of the Skeena Salmon Management Committee in 1954, this Station has been responsible for providing the biological information required for management of the Skeena salmon stocks. This has necessitated a close examination, and the further development, of the biological principles and tools for management. The resulting information, while applied directly to the management of Skeena stocks by the Committee, may be applied more generally.

The present objective of salmon management is to provide the largest possible sustained yield. This requires fullest possible use, by the salmon, of their freshwater and marine environments. Pacific salmon reproduce in fresh water and grow mainly in the sea. Although annual variation in ocean conditions has important effects on growth and survival, it is generally conceded that the freshwater environment, and particularly the amount and quality of the spawning and rearing area available, finally limits production. Sound regulation of the salmon fishery must therefore provide the escapement which will best utilize the freshwater environment and result in the largest return.

The Skeena salmon investigations have therefore been chiefly concerned with determination of the escapement size required to produce the greatest yield to the fishery, and how to regulate fishing to provide this escapement.

(1) Determination of optimum escapements

Sockeye. Babine sockeye compose over 80% of the total Skeena run. Management of Skeena sockeye is therefore, for the most part, management of the Babine stock. In realizing its objective of providing optimum spawning escapements, the Committee was immediately faced with the problem of greatly reduced returns from the slide-affected Babine sockeye escapements of 1951 and 1952. Stringent fishing restrictions were necessary in the years of 1955, 1956 and 1957 to restore these runs to at least their former level.

At the same time, studies showed that the major part of Babine Lake was not being fully utilized by young sockeye. Because the young fish did not disperse far from the streams of their origin, better utilization depended upon re-distribution of adult escapements. Young sockeye were more dense and smaller in the northern lake basins adjacent to the large outlet spawning grounds than were sockeye in the southern lake basins which compose 90% of the total lake area. In most years the escapement to the grounds adjacent to the northern basins was sufficient to provide enough young to make best use of this limited nursery area. The amount of available spawning area adjacent to the large southern basins would finally limit use of the great potential of this part of the lake as a rearing area, but observation showed that escapements in this area were even less than those needed to fully use the streams.

Past tagging of sockeye in the fishing area and subsequent recovery of tags on the spawning grounds had shown that sockeye, proceeding to streams tributary to the southern lake basins, passed through the fishing area during the early and middle portions of the sockeye fishing season. Therefore it was possible, by appropriate regulation, to adjust the distribution of the Babine escapement and thus better use the spawning and nursery areas. Since 1956 early sockeye fishing has been restricted. As a result the proportion of the total Babine escapement (and resultant young sockeye) using the main lake area has been increased.

Since 1955, the Babine sockeye escapement has been restored to about its pre-slide level, and in 1958 and 1959 the escapements approached the apparent optimum required for best use of the spawning and nursery areas. The effect of the near optimum escapements in 1958 and 1959, together with better distribution of spawners and their young, has resulted in a gratifying increase in the numbers and size of young fish produced. (See next section - "Lake Sockeye Studies").

<u>Pinks</u>. Intensive study of Skeena pink stocks began in 1956. Prior to this time, little was known of the escapements to the major spawning grounds or the timing of individual runs through the fishery. Extensive taggings and surveys have since provided a working knowledge of these runs for management purposes.

Analysis of past catch statistics revealed that spawnings in years of abundance more often resulted in large returns than did spawnings in years of scarcity. It was also evident that the existing stock level was far below that which produced the large catches prior to 1931.

Observations in major producing streams support this conclusion. Since studies began in 1956, fry output has been roughly proportional to the abundance of parent escapements, suggesting that recent escapements have been well below the capacity of the spawning grounds to produce young pinks.

(2) <u>Regulation of the fishery</u>

Tentative regulations designed to provide desired escapements are established half a year in advance of the main fishing season. To establish such regulations it is necessary to know the times that different runs pass through the fishery, the likely abundance of the returning runs, and the effectiveness of the probable fishing fleet in exploiting them. During the fishing season, the regulations can be changed to adjust for deviations of existing conditions from those that were expected.

The greatest problem in establishing regulations in advance of the season is predicting the likely abundance of the runs. At present the best advance indication of the abundance of the returning runs is the abundance of young fish which went to sea. Recent studies have shown, however, that survival in the sea may vary greatly from year to year and, in the case of sockeye, that the age of return may also vary. These fluctuations make precise prediction difficult. To improve prediction, factors associated with these variations are being investigated. These studies show that for sockeye, marine survival and age of return are related to growth both in fresh water and in the sea. Thus, knowledge of the size of young sockeye going to sea, and that of "jacks" which return a year or two in advance of the main body of the run, will assist in prediction of the total return. With information on the abundance of the run, data on the times of passage of runs through the fishery (from past tagging experiments) and on the efficiency of the fishery (from study of catch and escapement statistics) are then used to establish tentative regulations to provide the desired division between catch and escapement.

During the season, detailed comparisons of catch figures with immediate estimates of escapement (derived from test fishing above the fishery), permit assessment of the effectiveness of regulations. Adjustments can then be made as the abundance of the run or the effectiveness of the fishery demands.

1. The 1960 Skeena salmon catch and escapement

J. McDonald
and K.V. Aro

The escapements of sockeye and pink salmon needed to return these stocks to their former relatively high level, and ultimately to provide the greatest possible sustained return to the fishery, can only be provided by close regulation of the fishery. To regulate for the escapement needs of each species and of each major stock comprising the total run of each species is complicated by a considerable degree of intermixing within the fishing area and by the ability of the fleet to catch a large proportion of the fish present in the area in a very short time. A record of the catch and escapement to major spawning and nursery areas provides a means of assessing the effect of the regulations on the stocks.

The Skeena Salmon Management Committee, when recommending the 1960 regulations for sockeye and pinks, considered the following:

(a) The need to increase the sockeye escapement to the under-used spawning streams tributary to the large nursery area of the southern portion of Babine Lake was still evident. Sockeye which spawn in these streams pass through the fishing areas from mid-June to mid-July.

(b) The total Skeena sockeye run, which would be composed of 4-year-olds from the 1956 spawning and 5-year-olds from the 1955 spawning, was expected to be small. The 1955 spawning was the poorest on record for the Skeena and was expected to provide a total return of less than 200,000 5-year-olds. The 1956 spawning was moderate in number and, in the Babine watershed, well distributed over the spawning grounds. It was expected that approximately 500,000 or slightly more sockeye would return from this run as 4-year-olds in 1960. These expectations indicated that, even if the 1960 sockeye were not fished, the numbers returning would be adequate only for a good escapement.

(c) The 1960 Skeena pink run, which was returning from the moderate seeding and resultant fry production of the 1958 run was expected to number about 2,000,000.

(d) The fishing industry had faced in the past few years and would face again in 1960 hardships imposed by small sockeye runs brought about by the Babine River rock-slide. Various representatives of the industry had pointed out that very poor prospects were in sight for the 1960 British Columbia salmon runs generally and had expressed concern that severe regulation of the 1960 Skeena salmon runs would work undue hardship on the industry.

Bearing the above considerations in mind the committee recommended the following regulations for the 1960 Skeena salmon fishery:

(a) That fishing for sockeye commence on July 10, by which time some early-run sockeye would have passed the fishing area.

(b) That for the 3 weeks from July 10 to July 31, 2 1/2 days per week fishing be permitted to harvest the middle season sockeye.

(c) That from July 31 to August 28, 3 days per week fishing be permitted to harvest the expected moderate run of pinks. It was borne in mind that heavy fishing to harvest early-run pinks might jeopardize the late-season sockeye escapement which would be passing during the last week of July and the first week of August.

As fishing progressed, it became apparent that the sockeye run was even smaller than expected, and was especially small in the early portion of the season. Figure 15 shows, for the Skeena Gill-net Area, the numbers of days fishing recommended by the Committee prior to the season, the actual number of days fishing allowed each week, the weekly number of gill-net boat deliveries, and the estimated weekly total abundance of sockeye and pinks (catch plus escapement estimates derived from test fishing above the upriver commercial fishing boundary). The diagram illustrates that the escapement of sockeye was small prior to the commencement of sockeye fishing on July 10. During the last three weeks of July and the first week of August the run remained small, and about 45% of the sockeye entering the Skeena Gill-net Area were caught. During the second and third weeks of August when fishing was reduced to 2 days per week about 20% of the small numbers of sockeye present were caught. The total catch of sockeye in the Skeena Gill-net Area amounted to 186,000 pieces.

The escapement was also small, amounting to about 320,000. Of these, 263,000 entered the Babine-Nilkitkwa watershed. This was one of the smallest escapements to Babine since counts began in 1946. The spawners were well distributed over the Babine spawning grounds, with slightly over half entering streams tributary to the under-used southern basins. Water conditions appeared favourable for spawning. Escapements to other Skeena sockeye spawning areas were lower than average.

The 1960 Skeena pink run was one of the poorest on record. The total run, slightly in excess of 500,000, was not even as great as the parent escapement. The return of pinks was also poor in most other areas of British Columbia and southeastern Alaska, strongly suggesting that the young from the 1958 spawning encountered extremely unfavourable ocean conditions for growth and survival. Figure 15 illustrates the weekly abundance of pinks in the Skeena Gill-net Area and the division of the stock by week into catch and escapement upriver. It became apparent by the end of the first week of August that the pink run would be very small. Consequently, additional 24-hour closed periods

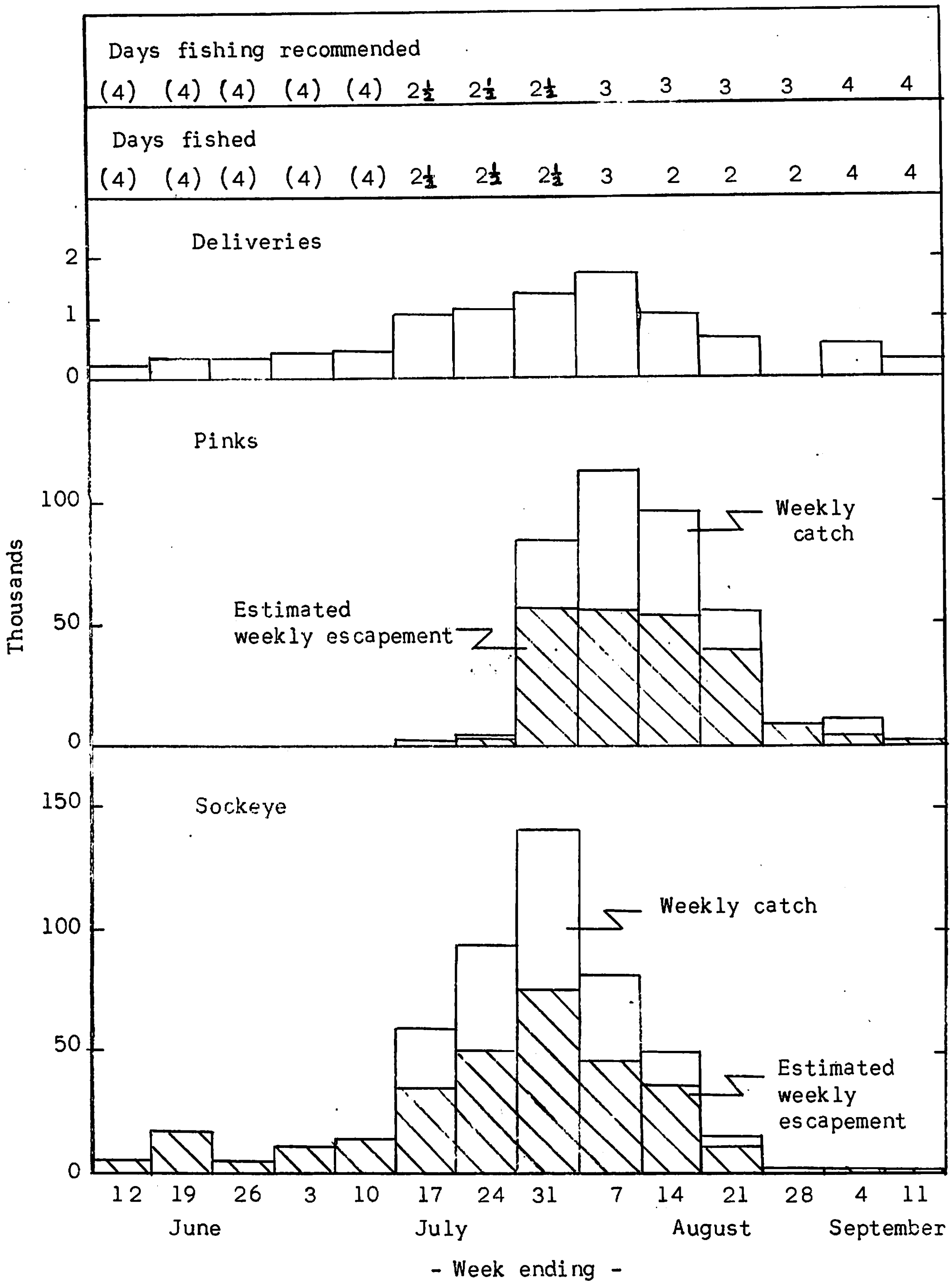


Fig. 15. Catch, escapement (based on test-fishing catches), and fishing effort (boat deliveries by week), Skeena sockeye and pinks, 1960. Days fishing in brackets refer to days when spring salmon nets only were permitted.

were recommended by the Committee during the second and third weeks of August in order to provide additional spawners. A complete closure was recommended for the same purpose during the week ending August 28. The total catch of pinks in the Skeena Gill-net Area was 170,000. An additional 100,000 Skeena-bound pinks probably were taken in Ogden Channel.

The total escapement was 273,000, one of the lowest recorded on the Skeena River. Some 215,000 spawned in tributaries of the Skeena River or in the river itself, while 58,000 spawned in coastal streams adjacent to the Skeena Gill-net Area. The effect of the fishery on the early part of the pink run was reflected in the small escapements to the Kispiox and Kitwanga Rivers. The closures later in August permitted a somewhat larger (111,000) escapement to the Lakelse River.

The 1960 Skeena gill-net catch of spring salmon was about 19,000, which is below average for the period since 1950. The escapement to the Bulkley, Morice, Kispiox, Lower Babine, and Khyex Rivers were reported by Department officers to be light, and to the Kitsumgalum and Bear Rivers to be average. The runs to the Ecstall River and Johnson Creek were reported to have been better than in the cycle years.

The 1960 gill-net catch of coho salmon in the Skeena area was approximately 36,000, which is slightly over half the 1950-58 average. The escapements to the Bulkley, Bear, Kitsumgalum and Kitwanga Rivers and to the streams tributary to the Skeena estuary were reported to be light and to the Morice, Babine, and Lakelse Rivers of medium intensity.

The 1960 Skeena gill-net catch of chums was about 21,000 pieces, which is less than half of the 1950-59 average. The escapements to the streams in the Skeena-Lakelse area and to the streams tributary to the Skeena estuary were reported to be light.

2. <u>Escapement indices from test fishing</u>

K.V. Aro and S. Tanaka

Estimates of the escapement of sockeye and pink salmon throughout each season since 1955 have been obtained from the catches of these species in standard gill-net drifts above the upriver commercial fishing boundary. These estimates, together with catch statistics, permit an assessment of seasonal and annual changes in the rate of removal by the fishery.

The seasonal patterns of test-fishing catches have been compared with those of the escapements to the spawning grounds. The comparison has shown that throughout each season the test-fishing catches were generally proportional to the escapement. An index of the escapement as indicated by test fishing catches has been derived for each season by summing the average daily test-fishing catch per hour and dividing this sum into the total escapement to areas upriver from the test-fishing site. The indices for the years 1955 to 1959 are shown in Table XII.

Table XII. Test-fishing indices and escapement abundance for Skeena pinks and sockeye, 1955 to 1960.

Year	Sum daily catch/hr* Sockeye	Sum daily catch/hr* Pink	(1,000's fish) Total escapement Sockeye	(1,000's fish) Total escapement Pink	Escapement per daily catch of 1 fish/day Sockeye	Escapement per daily catch of 1 fish/day Pink
1955	377	1,672	125	987	333	584
1956	834	522	441	202	530	387
1957	769	1,929	485	868	632	451
1958	1,203	1,149	884	556	735	484
1959	1,111	1,909	854	1,383	769	724
1960	407	195	313	215	770	1,104

*Adjusted to correct for differences in efficiency of boat skippers.

There has been considerable variation in the indices for sockeye and pink escapements during the six years of test fishing. Sources of variation include:

(a) Differences in efficiency of nets. During the early part of the 1955 season, a standard commercial sockeye net was used instead of the special graded mesh nets used later in the season and in subsequent years. The commercial net, having considerably more surface of a mesh size suitable for catching sockeye than the experimental net was much more efficient at catching sockeye. For this reason, the test-fishing index for sockeye in 1955 was much lower than in subsequent years. Comparisons of the areas of the two nets composed of sockeye catching mesh indicate that the commercial net would be expected to catch about twice as many fish as the experimental net. Correcting for this difference for 1955 sockeye, the "escapement per daily catch of 1 fish/day" index in Table XII should be corrected to 510, much closer to values for the other 5 years.

(b) Differences in efficiency of skippers. As outlined in previous reports, it has been found that since 1956, there has been a consistent difference in catching efficiency between the two skippers averaging about 30%. This difference has been accounted for in preparation of Table XII.

(c) Effects of environmental factors. The effects of a number of environmental factors including time of day, wind velocity and direction, cloud cover, tide level, amount of debris in the river, number of seals in vicinity of net on test-fishing catches were examined. It was found that none exerted consistent effects except the stage of the tide. Test-fishing sets are made only on slack tides. When tide levels were very low (below about 5 feet), it was found that test-fishing catches increased markedly. This suggests that at very low tides, when much of the Skeena River at the test-fishing site dries up, the fish are concentrated more in the deep channel where test fishing is conducted.

(d) Effects of net saturation. The data in Table XII suggest that the indices are higher in years when escapements were large than when they were small (excepting data for 1960). This in turn suggests the possibility that the catching efficiency of the nets may decrease as they become increasingly filled with fish. To correct for the effects of such net saturation, a number of theoretical conditions were considered and tested by application to the actual test-fishing catch data. The situation that seemed to apply best to the test-fishing data was based on the assumption that each fish caught in the net frightens away a set proportion of those subsequently reaching the net. The following equation represents the relationship between catch and the relative abundance of fish under these circumstances:

$$qN = \frac{e^{ac} - 1}{at}$$

Where q = efficiency of empty net

N = number of fish reaching the net

a = proportion of fish reaching net repelled by a catch of one fish in the net

c = catch of fish in net

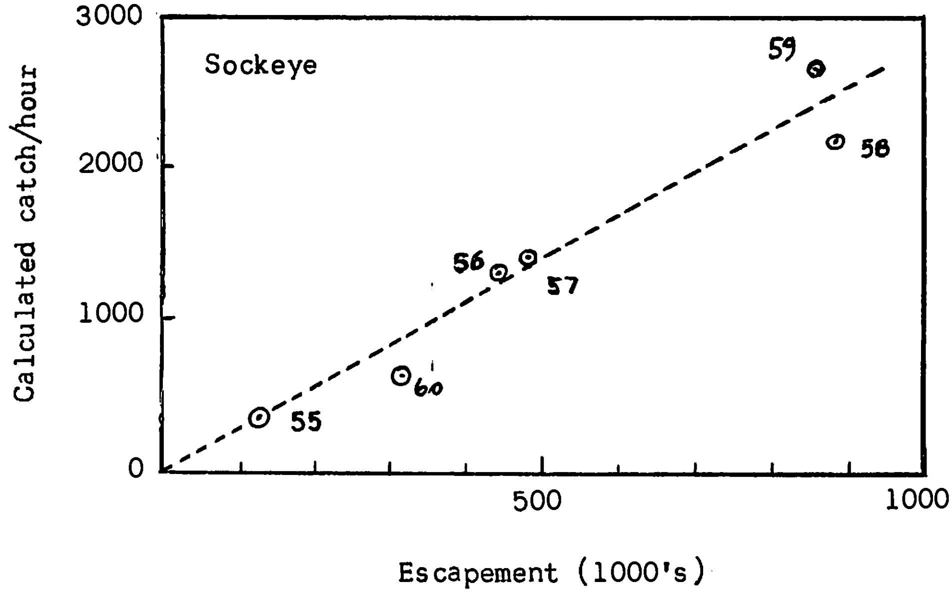
t = time

Application of this formula to test-fishing catch data throughout each season provided weekly escapement indices that paralleled the changing abundance of escapements revealed by later spawning ground counts closer than did indices derived from uncorrected data.

Even with such sources of variation, test fishing has provided a reasonably reliable index of the abundance of the escapement. In Figure 16, escapement indices derived from test fishing, corrected for the various effects noted above, are compared with estimates of escapements observed on the upriver spawning grounds. The test-fishing indices vary closely in proportion to the actual escapements. From the graphs it can be seen that deviations from expected abundances of escapements are about as great at low levels of abundance as at high, indicating that the percentage error in the test-fishing indices likely is greater when the run is small.

3. Babine fence counts in 1960 F. P. Jordan

Babine Lake is the largest producer of sockeye in the Skeena system. The escapement to Babine in past years has constituted over 80% of the total escapement to the Skeena. Operation of a counting fence on the Babine River has provided an accurate record each year since 1946 (except in 1948 when the fence was inoperative) of the abundance, timing and of the length, sex and age composition of the run. Counts have also been made of all other species of salmon and steelhead trout ascending past the fence. These data have been of particular importance since 1951 in assessing the effects of the partial block to migration by the Babine River rock-slide and the success of measures taken



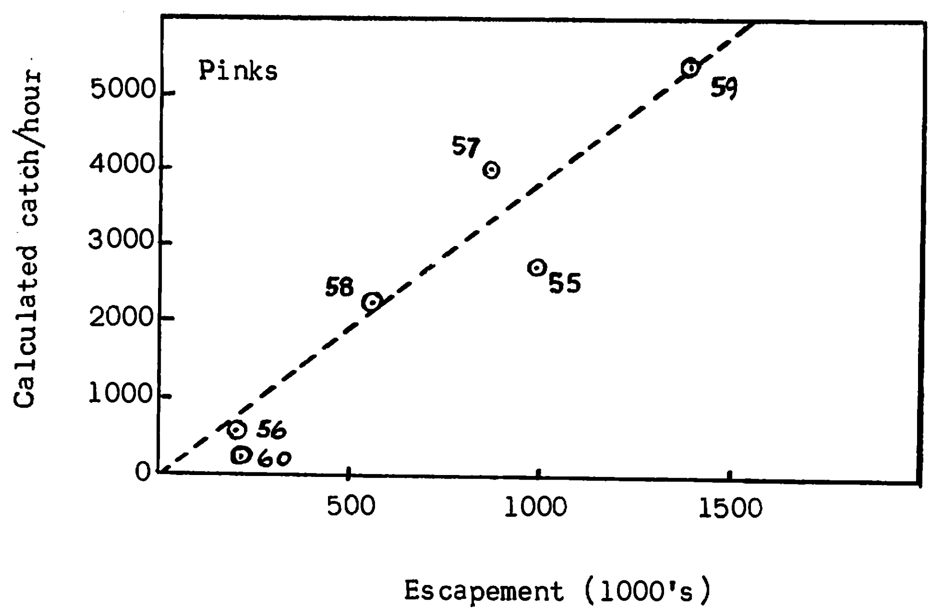


Fig. 16. Comparison of test-fishing escapement indices with escapement estimates based on spawning ground counts and estimates for 1955 to 1960.

by the Skeena Salmon Management Committee toward rehabilitation of the slide-affected stocks.

The numbers of the five species of Pacific salmon which were counted in 1960 are compared in Table XIII with counts made in the other years of operation:

Table XIII. Counts of salmon passing the Babine fence.

Year	Sockeye		Spring	Pink	Coho	Chum
	Large	Jack				
1946	444,551	31,154	10,528	28,161	12,489	18
1947	261,460	261,101	15,614	55,421	10,252	7
1948*	650,000					
1949	461,139	47,993	7,433	13,663	11,938	5
1950	364,356	179,302	6,838	38,728	11,654	7
1951	141,415	11,042	2,778	50	2,122	0
1952	349,011	27,936	5,915	2,706	10,554	1
1953	686,586	28,028	8,353	1,108	7,648	17
1954	493,677	9,745	5,925	4,604	3,094	66
1955	71,352	30,624	3,528	2,151	8,947	3
1956	355,345	18,164	4,345	2,691	9,250	3
1957	433,149	50,162	7,509	25,865	4,421	15
1958	812,043	30,769	8,274	6,600	7,606	8
1959	782,868	31,920	9,597	56,766	10,947	20
1960	262,719	49,396	2,855	4,876	6,794	6

*Total sockeye estimated from comparison with stream surveys and fence counts of other years.

The run in 1960 of 262,719 "large" sockeye was smaller than average. The count began on July 12. The daily count rose to a peak of 18,130 large sockeye on August 7. The early peak is characteristic of most years and consists of early-running fish to the smaller streams at the south end of the lake. Following the peak, the run declined and rose again to a second peak of 10,211 large sockeye on August 27. This portion of the run is mainly composed of fish which spawn in the Upper and Lower Babine and Fulton Rivers. Following the second peak on August 27, the run declined until only 118 large sockeye were counted on September 28. Fence operations were then discontinued. The run of spring salmon was less than average. During the early part of the season the run consisted mainly of "jacks", while later, the run was predominantly composed of large fish. Since spring salmon spawn below as well as above the fence, the count represents only a portion of the total Babine River run. The pink salmon run was about average for even-year cycles following the rock-slide. As is the case for springs, some pinks spawn below the fence. The coho run was a return in a cycle year of the 1951 slide-affected run. The runs in this cycle have shown a steady improvement from the count of 2,122 in 1951. A few chum salmon again reached the Babine fence.

To examine the composition of the 1960 Babine sockeye run, 1% of the previous half-day's fence count was sampled twice daily for length and sex. In addition, sampling was carried out to determine the proportion of the large fish which were "normal", net-marked, or injured.

Females in the 1960 sockeye run outnumbered the large male sockeye as in all other years with the exception of the slide years 1951 and 1952. The 1% sample indicated that 55.7% were females and 44.3% were males. As shown in Table XIV, these figures are about average for the 1946 to 1960 period.

Table XIV. Percentages of male and female sockeye passing the Babine fence.

Year	% male sockeye	% female sockeye
1946	43.52	56.48
1947	45.56	54.44
1948	--	--
1949	40.99	59.01
1950	43.74	56.26
1951	51.88	48.12
1952	58.90	41.10
1953	44.15	55.85
1954	39.72	60.28
1955	47.16	52.84
1956	48.62	51.38
1957	49.00	51.00
1958	39.38	60.62
1959	39.56	60.44
1960	44.30	55.70

Sampling to determine the condition of large sockeye showed that 9.9% had net marks, 5.1% had other injuries and 85% had no injuries or net marks. These figures were similar to those obtained in past years, with the exception of 1951 and 1952 when many slide-damaged fish were observed. A comparison with sampling in previous years of fence operation is shown in Table XV.

Table XV. Condition of sockeye passing the Babine fence.

Year	Normal	Net-marked	Injured
1946	--	--	--
1947	84.5	11.35	4.2
1948	--	--	--
1949	86.9	6.22	6.8
1950	84.2	12.34	3.5
1951	51.6	18.33	31.1
1952	69.2	1.00	29.9
1953	93.0	4.27	2.7
1954	89.3	8.26	2.5
1955	87.2	6.12	6.7
1956	94.2	4.27	1.5
1957	90.2	8.26	1.5
1958	83.5	13.91	2.6
1959	91.5	4.17	4.3
1960	85.0	9.88	5.1

"Jack" sockeye, as well as the large male and female sockeye, were smaller than average in 1960. In Table XVI, their average size in 1960 is compared to that observed in previous years.

Table XVI. Average length, in centimetres, of sockeye in the proportionate samples.

Year	Large males	Jacks	Females
1949	61.5	37.4	59.9
1950	57.7	38.3	57.1
1951	60.1	38.9	58.4
1952	58.9	38.3	57.7
1953	62.4	38.6	60.3
1954	66.6	38.3	63.0
1955	55.7	38.2	57.9
1956	58.1	36.0	57.1
1957	57.6	37.8	57.0
1958	61.6	38.5	59.4
1959	62.3	37.4	60.4
1960	55.6	36.5	55.2

The average egg content in 1960 was calculated to be 2,915 eggs per female. Based on the number of females estimated to have survived the Indian fishery above the fence (138,391), the potential egg deposition at Babine was approximately 403 millions.

4. Babine Lake sockeye smolt output

J. McDonald

Knowledge of the number, size, and age composition of smolts emigrating each year from Babine Lake provides a measure of the production from parent escapements of known size and distribution. The abundance of smolts may also provide advance indications of the number which will be available to the fishery, two or three years later.

Estimates of the smolt output have been made annually since 1951 through a marking and recovery program. Smolts were marked and released near the lake outlet. The abundance of the smolt run was estimated from the proportion of marked fish among those captured further along the migration route.

Observations since 1958 have shown that significant numbers of smolts leave the lake at about the time of ice-breakup and before the usual mark and recovery program had begun. The small size of these "early" smolts, together with results from tagging, suggests that they were mainly from the adjacent Nilkitkwa-North Arm nursery area. The main body of smolts which followed were larger in size, and came mainly from the more distant main lake basins. This recent information suggests that the estimates of the smolt output in years prior to 1958 included only the population emigrating from the main lake basins rather than from the Babine Lake system as a whole. The data for the earlier years are being re-examined and attempts will be made to revise the estimates for the years prior to 1958.

In 1958 and 1959 estimates of the number of "early" smolts were based on net catches and school counts, whereas the main runs of smolts were estimated by use of the conventional mark and recovery method. Extension of the mark and recovery program in 1960 permitted, for the first time, an estimate of the total smolt migration in this way.

From May 3 to June 26, 1960, 71,305 smolts were tagged and released. Of the 655,381 smolts examined three miles downstream from the tagging site, 987 were tagged, giving a tagged to untagged ratio of 1:664 and a seasonal recovery of 1.38% of the tagged fish. When adjustments were made to account for a calculated tagging mortality, the estimated smolt output was 45 million. The "early" run was in the order of 15 million and the "late" run in the order of 30 million.

The estimated smolt output and the survival from egg to smolt for the brood years 1956 to 1958 are shown in Table XVII.

Table XVII. Potential sockeye egg deposition, estimated number of smolts and survival from egg to smolt, Babine Lake.

Brood year	Potential egg deposition	Year smolts migrated	Estimated number smolts	Survival egg to smolt
	(millions)		(millions)	(percent)
1956	523	1958	22	4.2
1957	653	1959	39	5.9
1958	1,543	1960	45	2.9

The smolt output from the 1958 brood stock was the largest yet estimated from the Babine system. Although the output was large, the data indicate that the survival from egg to smolt was lower than that resulting from the spawnings of 1956 and 1957.

5. Growth and age of return in Skeena sockeye

H.T. Bilton and J. McDonald

Skeena sockeye mature mainly as 4- and 5-year-olds. The proportion of the stock maturing as either 4's or 5's varies greatly from brood year to brood year, creating a major problem in attempts to forecast the likely abundance of the run in any one year. Work on other species suggests that in some cases age of maturity may be associated with the rate of growth. To investigate this possibility for Skeena sockeye, recent data on age of maturity, size and growth rates as deduced from scale measurements have been examined. Although these studies are in a preliminary stage, two promising leads have appeared.

(a) Size of "jack" sockeye and age of return. Although most Skeena sockeye mature as 4- and 5-year-olds, some also mature as 3-year-olds or "jacks". The latter, which are almost exclusively male fish, are too small to be taken to any extent in the Skeena fishery. Since 1946, annual counts and length measurements have been made of jack sockeye entering the Babine Lake system (the main Skeena sockeye producing area). The average size of jacks has varied from year to year from as low as 36.0 cm to as high as 40.6 cm. In Figure 17, the proportions of returning runs that came back as 4-year-olds and 5-year-olds are compared with the average size of jacks for brood years since 1943. The results indicate that for a given brood year, when jacks were small, the proportion of the stock returning as 4-year-olds tended to be small, whereas when jacks were large, the stock tended to return predominantly as 4-year-olds. Statistically, the correlation coefficient for this relationship (+0.72) is highly significant. Thus it would appear that when growth is relatively good early in the sockeye's life, the fish tend to return to spawn at an earlier age than when growth is slow. This relationship offers a means of predicting, a year in advance, the likely proportions of the run that will subsequently return as 4's and 5's. Thus, from knowledge of the average size of jacks appearing in 1960, it should be possible to determine whether the progeny of the 1957 brood will return mainly as 4-year-olds in 1961 or as 5-year-olds in 1962. Data for future years will permit further assessment of the reliability of this relationship.

(b) Growth in fresh water and the age of return. The foregoing section suggests that growth rates early in the life history of the sockeye may have important effects on the ultimate age of maturity of the fish. To examine whether or not the growth rate during the year spent in fresh water affected the subsequent age of maturity, scales of young sockeye smolts emigrating from Babine Lake and of adults returning two to three years later to the commercial fishery were examined.

Among smolts emigrating from Babine Lake, there was a very strong relationship between the size of the fish and the number of rings or circuli on their scales. As an example of this, Figure 18 shows the relationship between circulus counts and body length for smolts leaving Babine Lake in 1956. On the scales of returning adults it is possible to recognize the part of the scale laid down in fresh water and thus to count the number of fresh-water circuli and to

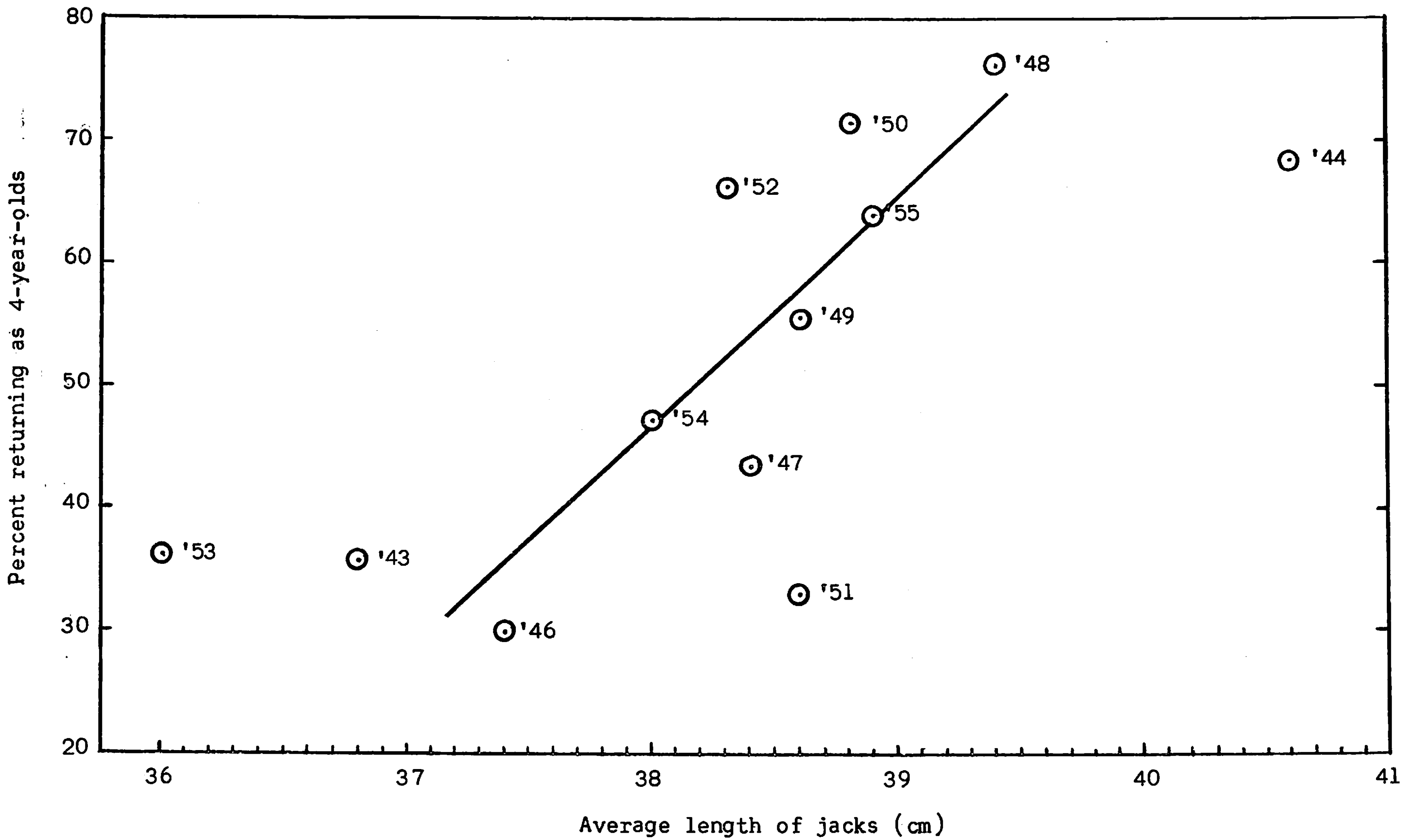


Fig. 17. Relation between age of return and size of jacks for the brood years 1943 to 1955 in Skeena sockeye.

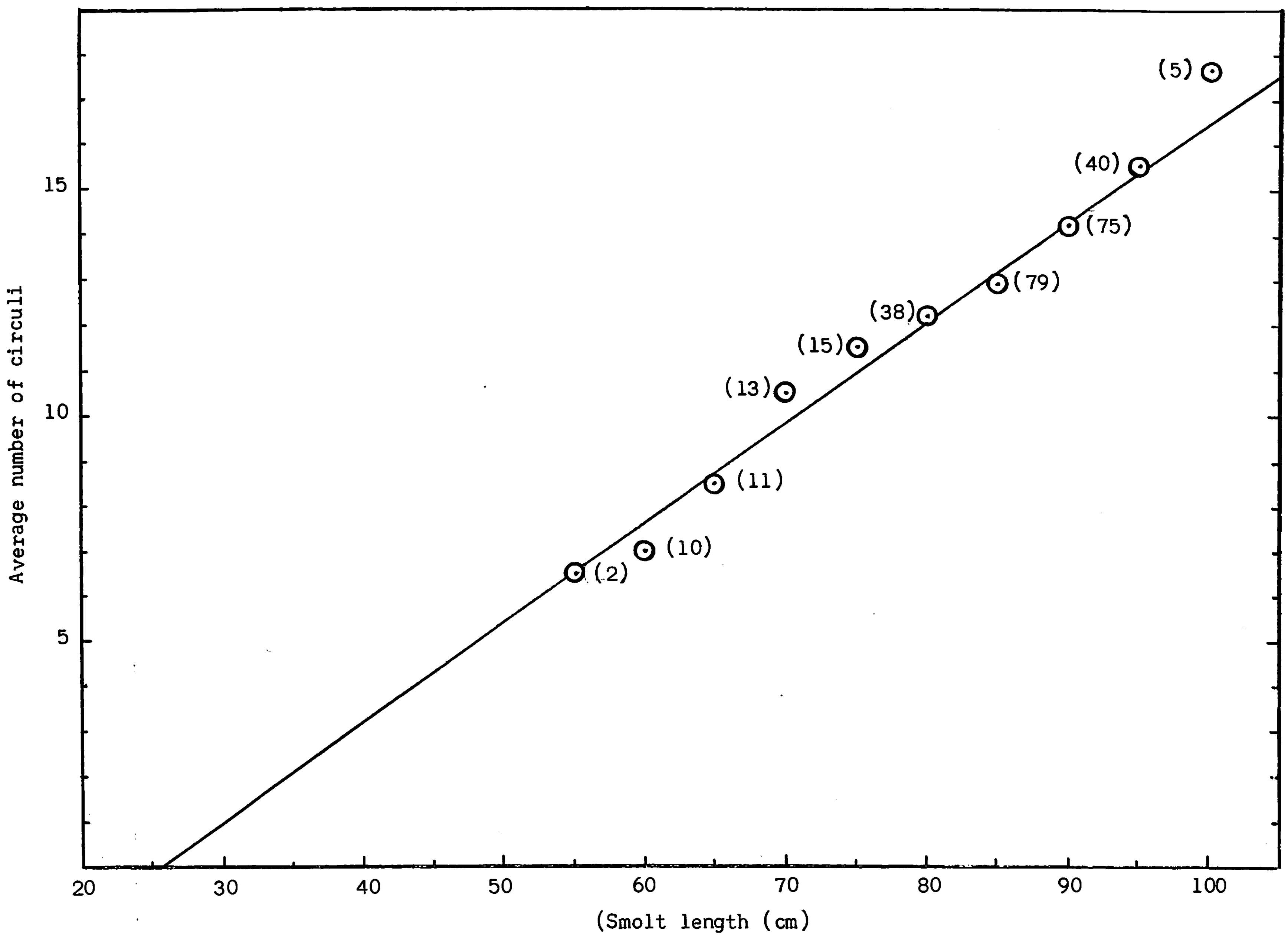


Fig. 18. Relationship between circulus count and body length for smolts emigrating from Babine Lake in 1956. (Figures in brackets indicate number of specimens used to compute values for each point.)

determine the approximate size of the fish as it left fresh water two to three years before. Examination of scales of 4-year-old and 5-year-old fish originating in the brood years from 1952 to 1955 shows that, in most years, 4-year-olds exhibited much higher circulus counts than did 5-year-olds (see Fig. 19). This in turn suggests that in any given year, the small smolts tended to mature at an older age than did the large ones. For the last brood year studied (1955), however, the difference in circulus counts was very small, suggesting that in this case factors other than freshwater growth were exerting important effects on the age of maturity.

These studies are continuing and will be extended to examine the relative importance of growth in fresh water and in the sea in determining the age at which Skeena sockeye mature and return to spawn.

6. The 1960 Skeena pink salmon escapement

J. McDonald

Officers of the Department of Fisheries carry out annual surveys of Skeena spawning areas to estimate escapement size. In recent years, where more detailed information is required for management, these surveys have been supplemented by ground and air surveys, tagging and recovery procedures, and fence counts by Fisheries Research Board personnel. For the most part, this additional work has been confined to the relatively large spawning areas and escapements. These produce the major portion of the Skeena pink salmon and it is in these areas where accurate estimates of the number of spawners are the most difficult to obtain.

In 1960 the escapement to the Kispiox River was estimated by a tagging and recovery program. Fences were operated on the Lakelse, Kitwanga, and Babine Rivers. The escapements to other areas were estimated by the Department of Fisheries stream surveys. The estimated total escapement in 1960 and in other recent years is given in Table XVIII.

Table XVIII. Estimated escapement of Skeena pink salmon, 1955 to 1960.

Place	1955	1956	1957	1958	1959	1960
Kispiox River	540,000	75,000	360,000	66,000	650,000	45,000
Kitwanga River	125,000	35,000	160,000	158,000	250,000	27,000
Lakelse River	175,000	75,000	140,000	262,000	185,000	122,000
Babine River	5,000	3,000	27,000	10,000	77,000	7,000
Bear River	6,000	Nil	15,000	Nil	20,000	Nil
Skeena River	10,000	5,000	50,000	50,000	150,000	10,000
Others	119,000	10,000	113,000	10,000	54,000	5,000
Coastal Rivers	78,000	75,000	105,000	116,000	95,000	45,000
Total	1,058,000	278,000	970,000	672,000	1,478,000	261,000
Total upstream of test-fishing site	987,000	202,000	868,000	558,000	1,383,000	215,000

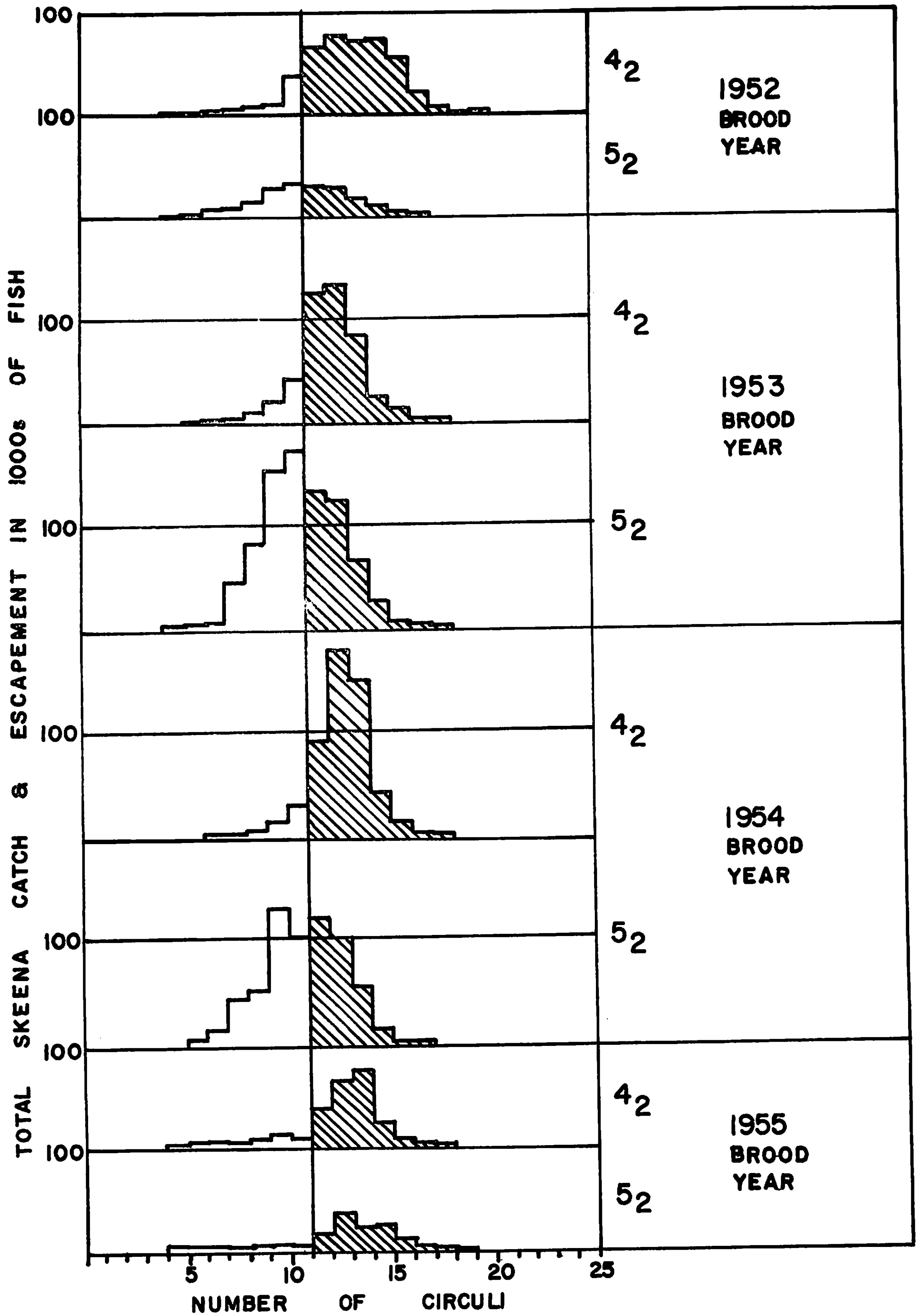


Fig. 19. Freshwater circulus counts for 4_2 and 5_2 sockeye collected from the Skeena River catch and escapement for the years 1956 to 1960.

The 1960 escapement was about 2/5 of that in the parent year and was comparable in size to the escapement in the cycle year of 1956. The escapements in 1956 and in 1960 were probably as small as any which have occurred since the beginning of the fishery. In 1960, the greatest decrease from the brood year occurred on the Lakelse and Kitwanga Rivers and on the main stem of the Skeena River, although in the latter instance estimates of the numbers of spawners are less firm. The escapements to the Kispiox and Babine Rivers were about 3/4 of those in the 1958 brood year.

7. Freshwater survival from the 1959 pink salmon escapement — J. McDonald

Estimates of the number of spawners and the abundance of resulting seaward migrating fry have been obtained from several large spawning areas tributary to the Skeena River each year since 1956. These data provide information on survival in fresh water (egg to fry) and, together with information on the catch, indicate survival in the sea (seaward migrant to returning adult). The purpose of this work is to determine the escapement size required to produce the greatest yield to the fishery, and secondly, to develop means of predicting the likely number of adults returning from escapements and fry outputs of known abundance.

Method of estimating fry output. A standard method of trap-netting for pink fry was developed in 1956 and used from 1956 to 1959 on the Lakelse, Kitwanga, and Kispiox Rivers. Nets with openings 2 ft. wide and 1 ft. deep were operated at the surface of the rivers. Nets were fished at a number of stations across each river at frequent intervals during the period of fry migration. The average number of pink fry captured per hour during each period of operation was used to calculate indices of the annual fry output from each river.

Experimental trap-netting carried out in 1958 and 1959 indicated that the vertical distribution of the migrants at the trapping sites varied from river to river depending upon the depth of water. This work also showed that the vertical distribution may change diurnally and therefore daytime catches were not directly comparable to night-time catches. This new information clearly showed that fry catches in the standard net would only provide a very gross indication of changes in fry abundance and that the indices obtained from one river were not comparable to those obtained on another.

Because of these shortcomings, the method was revised in 1960 to account for changes in the vertical distribution of the migrants and to provide an estimate of the fry output from each river in absolute terms. A vertical column of nets, each with an opening 6" x 12", was used. This net column was capable of capturing fry from top to bottom in each river. These traps were fished at various stations across each river throughout the fry migration. The total number of fry migrants was calculated from the average catch per hour and the proportion of the cross sectional area of the river 'covered' by the nets.

Egg to fry survival, 1959-1960. Data on the estimated number of parents, egg deposition, fry output, and survival from egg to fry are given in Table XIX.

Table XIX. The estimated number of parents, egg deposition, fry output and survival from egg to fry, 1959-1960.

River	Estimated number parents	Estimated egg deposition	Estimated fry output	Survival egg to fry
		(millions)		(percent)
Lakelse	185,000	167	30	18
Kispiox	650,000	585	132	23
Kitwanga	250,000	225	34	15

Comparative data of the survival from other escapements and spawning grounds of this size are not available. However, the survivals observed on the Skeena tributaries are high compared to averages recorded over a number of years at Port John, B. C., and McClinton Creek, B. C. They are comparable to the survival observed in "good" years at the other two locations.

In 1959, the total pink salmon escapement to the Lakelse, Kitwanga, and Kispiox Rivers was over one million or about 2/3 of the total escapement to the Skeena system, including coastal streams within the Skeena Gill-net Area. Conditions for survival in the 3 rivers examined were probably better than those on most other streams as the discharge of the Lakelse, Kispiox, and Kitwanga Rivers is stabilized to a considerable extent by their relatively large drainage systems and lakes near their headwaters. The probable survival from egg to fry from other areas must therefore be considered below that recorded on the rivers examined. If it is assumed that the survival in the other stream was about 2/3 that recorded on the three major spawning areas, then the total fry output from the Skeena in 1960 would be in the order of 265 million.

C. Lake Sockeye Studies

W. E. Johnson

1. Young sockeye in Babine Lake

Distribution and abundance throughout the lake system. Because of rather limited dispersion from their natal streams, the distribution of young sockeye throughout the complex Babine lake nursery area (Fig. 20) is largely governed by the distribution of the parent spawners to the various tributary spawning grounds. In this respect, the Babine system can be divided into two general regions: (1) the areas north of Halifax Narrows (Nilkitkwa Lake and the North Arm of Babine) which serve the young produced by the late-running fish which spawn on the outlet Babine River grounds, and (2) the lake areas south of Halifax Narrows which accommodate the young from earlier-running fish which spawn on the grounds tributary to these areas. In the first region there is a small lake area (10% of the total) with a large amount of spawning ground; that is, the size of the nursery area is the factor limiting further sockeye production. In the second region, the opposite situation prevails - there is an extremely large lake nursery area with tributary spawning grounds of limited capacity.

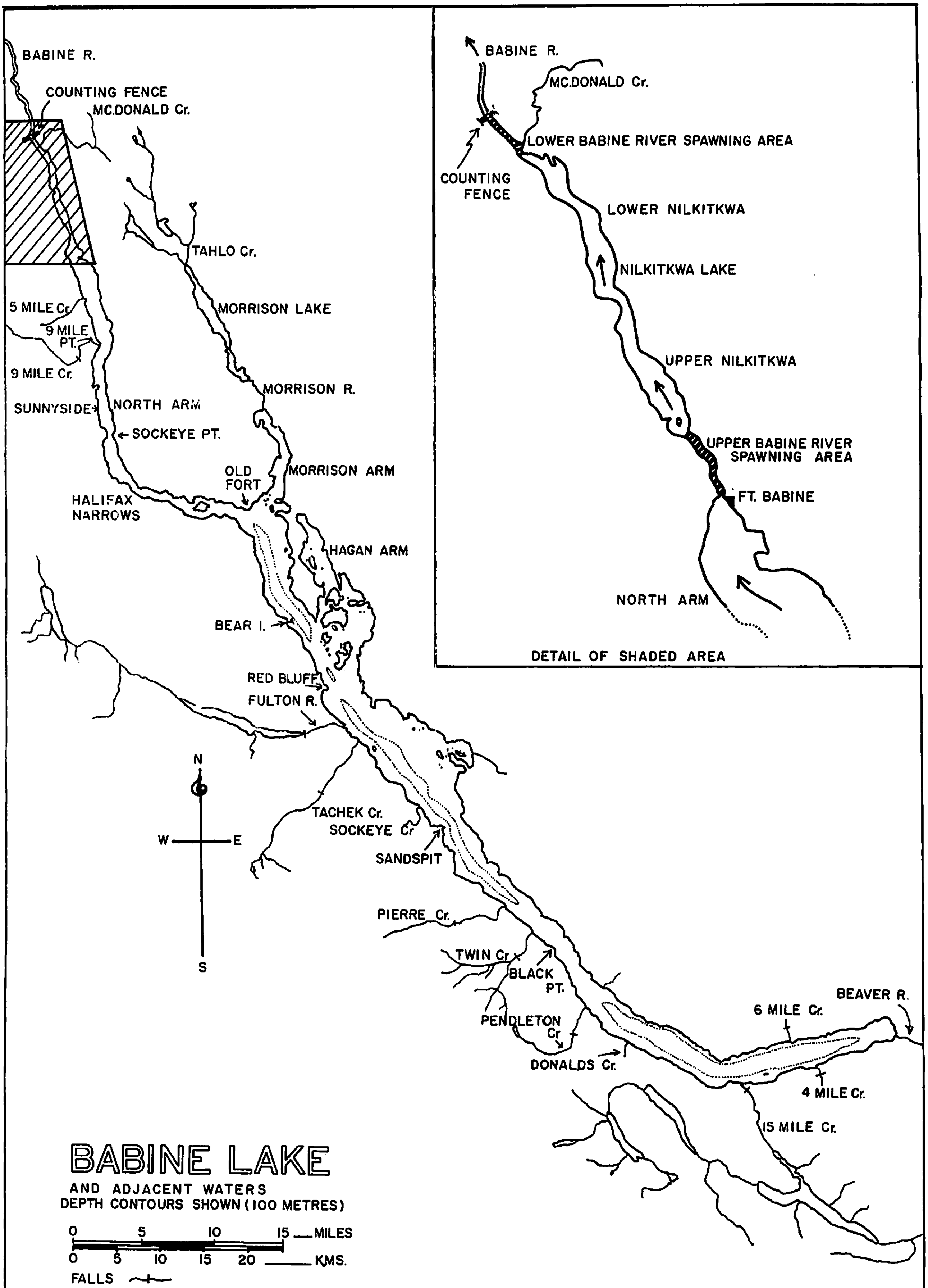

BABINE R.
COUNTING FENCE
MC.DONALD Cr.
TAHLO Cr.
MORRISON LAKE
5 MILE Cr.
9 MILE PT.
9 MILE Cr.
MORRISON R.
SUNNYSIDE
NORTH ARM
SOCKEYE PT.
OLD FORT
MORRISON ARM
HALIFAX NARROWS
HAGAN ARM
BEAR I.
RED BLUFF
FULTON R.
N
W
E
S
TACHEK Cr.
SOCKEYE Cr
SANDSPIT
PIERRE Cr.
TWIN Cr.
BLACK PT.
PENDLETON Cr
DONALDS Cr.
6 MILE Cr.
BEAVER R.
4 MILE Cr.
15 MILE Cr.
BABINE R.
MC.DONALD Cr.
LOWER BABINE RIVER SPAWNING AREA
COUNTING FENCE
LOWER NILKITKWA
NILKITKWA LAKE
UPPER NILKITKWA
UPPER BABINE RIVER SPAWNING AREA
FT. BABINE
NORTH ARM
DETAIL OF SHADED AREA
BABINE LAKE
AND ADJACENT WATERS
DEPTH CONTOURS SHOWN (100 METRES)
0 5 10 15 MILES
0 5 10 15 20 KMS.
FALLS

Fig. 20

Prior to 1955, in all the years for which we have escapement records, more than half (and up to 86%) of the Babine sockeye were later-running fish which spawned on the outlet spawning grounds. As a result, the majority of young sockeye produced in those years utilized the limited lake nursery areas north of Halifax Narrows, and the resulting smolts produced in many of these years must have been quite small in size. Since 1956, regulation has served to achieve a better distribution of spawners by protecting the earlier-running fish which spawn south of Halifax Narrows. As shown in Table XX, this policy has achieved a better distribution of young sockeye. With this change towards greater numbers of young south of Halifax Narrows, their mean growth rate has been increased and smolts of greater mean size are being produced. As past studies of sockeye have indicated that large smolts enjoy a better rate of ocean survival than do small smolts, it is expected that the greater number of large smolts produced at Babine will result in a higher overall rate of sockeye production.

In 1960, the estimated total number of young sockeye in the lake system (progeny of the 1959 spawning) was comparable to that of 1959 (progeny of 1958 spawners). Also, the mean size of fish north of Halifax Narrows was slightly larger in 1960 than in 1959. This indicates that the smolt output in 1961 will be comparable to the record smolt run of 1960 and that the smolts will be of slightly greater mean size. If this proves true, then there will be no evidence of any adverse effect of the large 1959 lake population on the second successive large lake population of 1960.

<u>Growth rate of young sockeye salmon</u>. During their one year of lake residence in the Babine system young sockeye attain most growth in the first few months, that is, during the period of summer thermal stratification. For example, fish weighing 0.2 grams when entering the lake as fry in mid-June attain 4.5 grams by mid-October, but weigh only about 5.5 grams when emigrating from the lake as smolts the following spring. Observations of the growth rate of under-yearling sockeye, their abundance, and the abundance of their zooplankton food in the various lake basins of this system in the years 1956 to 1959 provide a basis for comparing mid-June to mid-October growth rates under a wide range of conditions. Near-surface water temperatures for this period have been roughly comparable throughout, and there are no known genetic differences involved; thus, growth rate is believed to have been largely determined by intraspecific competition and food abundance. The results strongly support this belief.

Using logarithmic scales throughout, Figure 21 presents graphically the relationship of growth rate to food abundance and intraspecific competition. Figure 21a implies a general direct relationship between growth rate and zooplankton abundance over the range shown, Figure 21b shows the growth rate is increasingly depressed by intraspecific competition after population densities exceed approximately 7,000 fish per hectare (3,000 per acre).

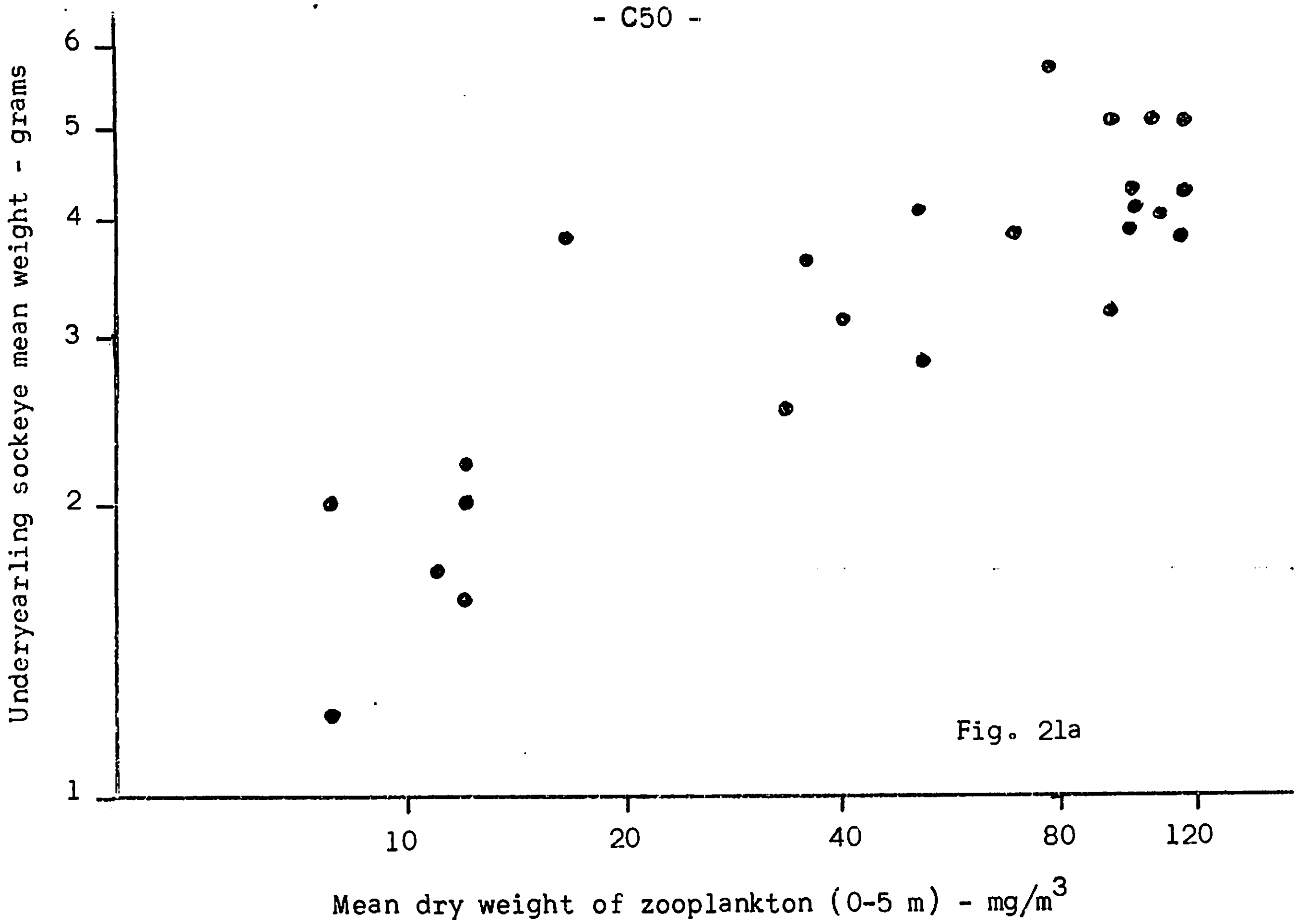
At a glance it appears that there is a simple explanation of the relationship between growth rate, competition and food abundance, i.e. that with an increasing number of young sockeye present an increasing reduction of the food supply is brought about resulting in an increasing reduction of the growth rate. Although cropping of the zooplankton by large populations of young sockeye is obvious in much of these data, critical examination (beyond the scope of this brief report) does not verify such a simple explanation of growth-competition-food relations based on food abundance alone. Detailed examination suggests there is an effect of competition on growth rate which is expressed independently

Table XX. Distribution and size of young sockeye in the Babine Lake system

Lake Region	Number of adult sockeye spawning excluding "jacks" (thousands)	Estimated number of age-0 sockeye in late August (millions)	Approximate mean weight of age-0 sockeye in mid-Oct. (grams)
	1954	1955[b]	
North of Halifax Narrows	256.3	38.2 to 52.9	1.5
South of Halifax Narrows	185.6	7.1 to 19.3	4.0+
Total	441.9	45.3 to 72.2	
	1955	1956	
North of Halifax Narrows	19.2	2.0	3.8
South of Halifax Narrows	27.8	3.1 + (7.4)[a]	4.0+
Total	47.0	5.1 + (7.4)[a]	
	1956	1957	
North of Halifax Narrows	119.5	26.5	3.3
South of Halifax Narrows	148.9	34.8 + (22.3)[a]	4.0+
Total	268.4	61.3 + (22.3)[a]	
	1957	1958	
North of Halifax Narrows	188.2	45.0	2.4
South of Halifax Narrows	202.8	46.5 + (20.0)[a]	4.0+
Total	391.0	91.5 + (20.0)[a]	
	1958	1959	
North of Halifax Narrows	270.0+	66.0	2.7
South of Halifax Narrows	290.0+	85.1 + (20.0)[a]	4.0+
Total	560.0+	151.1 + (20.0)[a]	
	1959	1960	
North of Halifax Narrows	290.0+	62.0	3.0
South of Halifax Narrows	300.0+	86.0 + (20.0)[a]	4.0+
Total	590.0+	148.0 + (20.0)[a]	

[a]Additional millions of age-0 sockeye believed progeny of "kokanee".

[b]1955 data from very limited sampling, so estimates only roughly approximate - probably much too low.



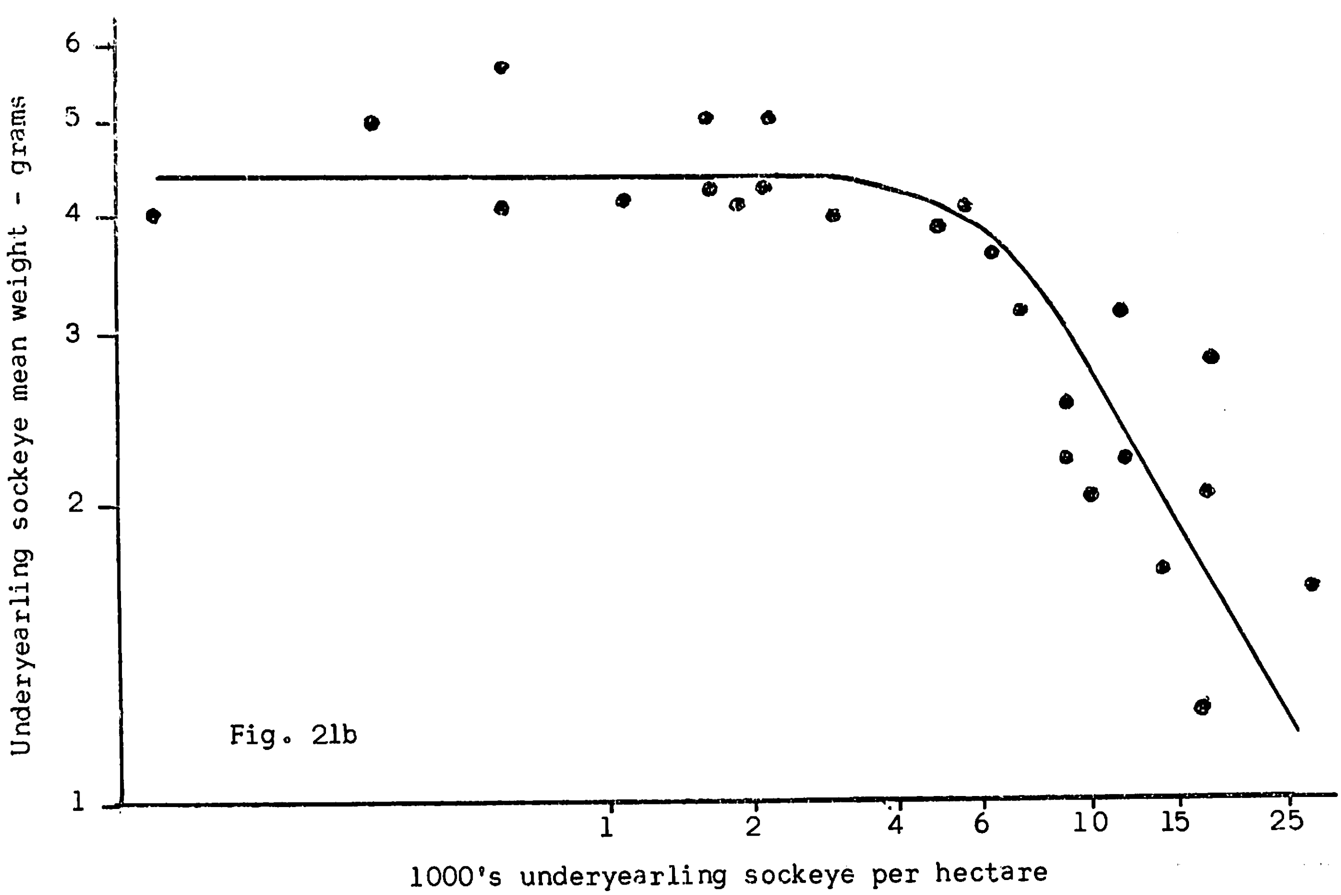


Fig. 21. Density and size of young sockeye in the Babine Lake system.

of absolute food abundance. In spite of the complexities of the mechanisms involved, the rather well-defined relation between growth rate and population density as shown by the solid line in Figure 21b can serve to evaluate the potentials of this lake nursery area.

Capacity of the Babine system as a sockeye producer. The curve in Figure 21b demonstrates the growth rate of young sockeye which may be expected at various levels of population density. In an earlier study at Cultus Lake, Foerster has shown that there is a direct relationship between smolt size and subsequent survival rate to maturity. Evidence that this relationship might hold generally is available from recent research on sockeye in Alaska. Combining the curve of Figure 21b and Foerster's relationship between smolt size and survival rate, Figure 22 describes the relationship between lake population density per unit area and the likely numbers of returning adults per unit area. No units are given for the likely number of returning adults as we cannot reasonably apply the same survival rates found by Foerster for Cultus Lake sockeye. However, for consideration of this general relationship we need only assume that there is a direct relation between smolt size and survival.

The relationship shown by Figure 22 follows the law of diminishing returns. With the progressive addition of more units of production (young sockeye) there is an increase in total production (returning adults) up to a point where the addition of further units of production results in a decrease in total production. The critical point (where production is at a maximum) corresponds to a late-August lake population of approximately 10,000 young sockeye per hectare (4,050 per acre). At this population density young sockeye would attain a size of about 2.5 grams by mid-October and emigrate as smolts of about 3 grams mean weight. For such optimum or maximum production, then, the Babine Lake system would require an evenly distributed late-August young sockeye population of 4,050 per acre or a total of the order of 500,000,000 - which would give a smolt output of roughly 200,000,000.

This estimation of the maximum potential is based only on the potential of the lake nursery area for rearing of smolts. In the Babine system there are insufficient spawning grounds to produce naturally the numbers of fry required, and achievement of such a maximum production would of course require large-scale fish culture techniques as yet unproven.

In considering the practicable potential of this sockeye-producing area, we must again make the broad separation into those regions located north and south of Halifax Narrows.

The region north of Halifax Narrows is characterized by having large-capacity spawning grounds (the Babine River above and below Nilkitkwa Lake) in relation to the lake nursery area available. With this situation the ultimate potential of the lake area can be realized and the problem becomes one of providing an escapement of the proper size to these outlet spawning grounds. Escapements of the order of 250,000 to 300,000, as provided in 1958 and 1959, appear to be of the proper magnitude.

The region south of Halifax Narrows is characterized by the opposite situation. An extremely large lake nursery area is available in proportion to the capacity of the tributary spawning grounds. The problem of attaining the highest natural production of sockeye from this region is then one of providing escapements which will make fullest possible use of the available spawning

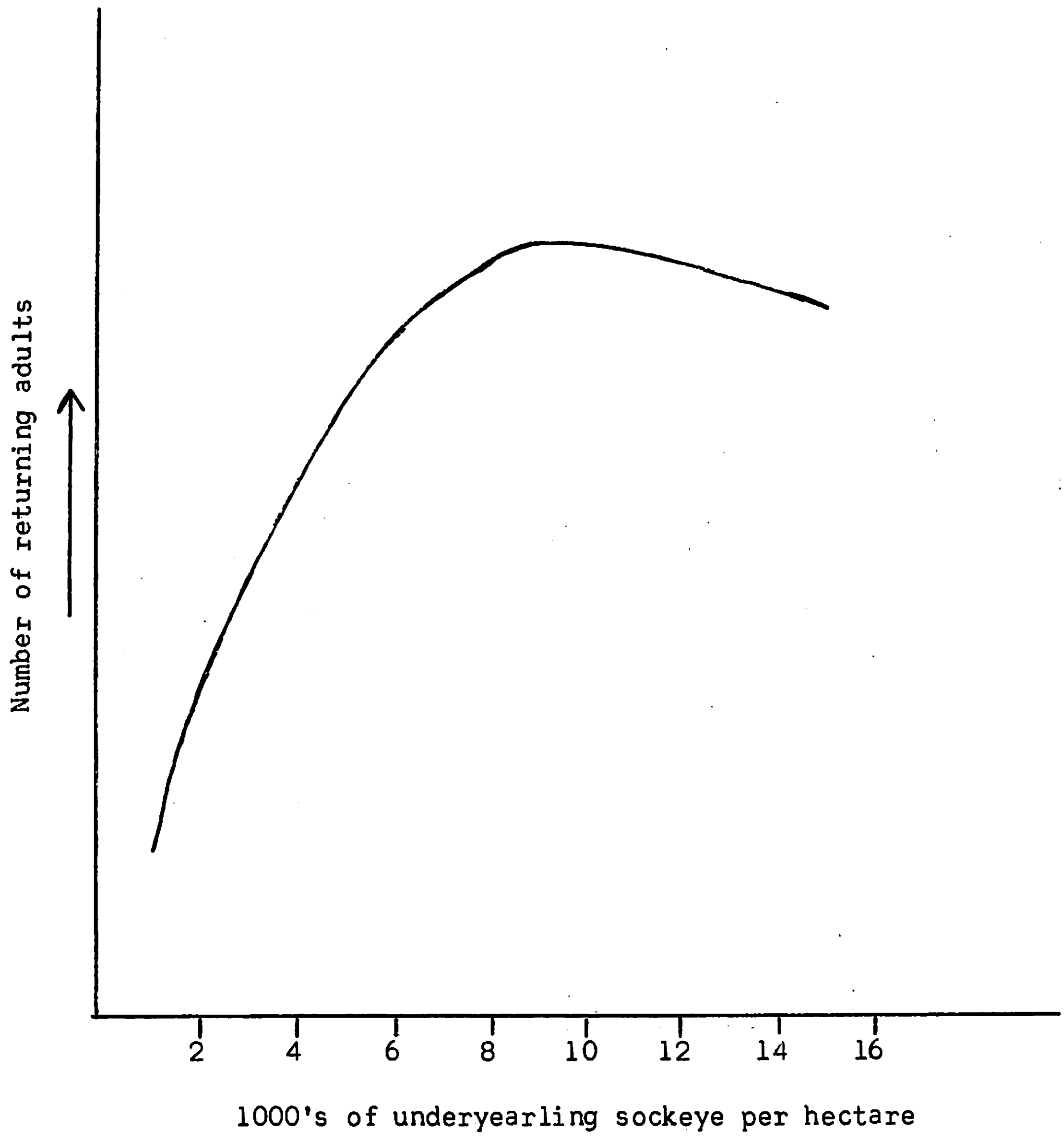


Fig. 22. Density of young sockeye and probable numbers of returning adults per unit area.

grounds. Such has been the aim of recent regulations and the large escapements of 1958 and 1959 have approximated this ideal.

2. Depth distribution of sockeye and other lake fishes

An attempt to study the vertical distribution and diurnal vertical migrations of fish in Babine Lake was made during the 1960 season using special monofilament gill-nets. It was hoped that these nets would fish efficiently during daylight hours as well as at night and thus serve as a means of better interpretation of echo-sounding records. Unfortunately, this did not prove to be the case in the rather clear waters of Babine Lake: catches were very small, especially during daylight hours, and of course there is the chronic enigma of how to interpret negative results, prevalent in any passive fishing method such as gill-netting. Also, there were problems involved in the handling of large, deep gill-nets by hand from small boats, especially in sets at great depths and in cases where nets were tended frequently during a 24-hour period. Nevertheless, these gill-net catches, together with results of gill-net fishing carried on in the previous two years, do seem to indicate some probable features of fish distribution and diurnal movement vertically in the light of what is seen with echo-sounding gear.

The following applies to the period of summer thermal stratification of the lake:

Sockeye fingerlings. Sea-scanar studies have shown that during daylight hours, sockeye fingerlings appear to be distributed throughout the 0-20 foot depth range but with greatest concentration centering about a depth of about 10 feet. In the evening twilight there is a mass movement toward the surface with a maximum near-surface concentration occurring in the early moments of darkness. After dark a dispersion over a greater depth range occurs - possibly a slow settling proceeds through the night. Soon after dawn the typical daylight distribution is again assumed. The smallest meshed gill-nets were received too late in the season to permit a full testing. However, the few sets made in late October did not contradict the findings; fingerlings were taken only at night and nearly all at depths less than 25 feet.

Kokanee (of age group II and older) were taken readily in all parts of the Babine system in offshore, near surface sets. Daytime catches were mainly in the depth range 0-30 feet, with highest catches in the 10-15 foot interval. Night catches were spread over a greater depth range (0-60 feet) but highest catches were very near surface (0-10 feet). This suggests the probability of a vertical distribution and diurnal vertical migration pattern similar to that of the closely related sockeye fingerlings.

Rainbow trout rarely have been caught at depths greater than 30 feet. Most were taken in the 0-15 foot interval. This is true for both day and night catches.

Lake trout (char) have been taken at various depths down to 170 feet. Daytime catches have all been from depths greater than 50 feet. Overnight sets have taken considerable numbers at shallower depths, especially in the range 10-50 feet.

Ling were taken primarily at depths greater than 70 feet and as deep as 180 feet. Only 3 specimens were taken in shallower sets (in the 50-70 foot range).

Whitefish. The few taken in daylight sets were from the 50-100 foot depth range. Those taken in overnight sets were nearly all in the 0-50 foot range.

Peamouth and squawfish were taken only in overnight sets and nearly always at depths less than 30 feet. These two species were taken most commonly in the shallower regions of the lake system (Nilkitkwa Lake, North Arm, Morrison Arm and Hagan Arm) and only rarely in offshore sets in the main basins of Babine. Largest catches were associated with areas of shallow mean depth or with inshore areas.

3. Serum proteins of kokanee and anadromous sockeye

Mr. Ian Carlson, graduate student at the University of British Columbia, has carried out a program of study of the blood serum proteins of Babine sockeye and kokanee using electrophoretic techniques. He has evaluated the specificity of protein constituents of the blood of both anadromous sockeye from various Babine spawning grounds and kokanee from various spawning grounds and various parts of the lake. Results are now in preparation for presentation.

4. Surveys of two potential sockeye producing areas

In earlier geological times some of British Columbia's major sockeye producing lakes (notably Owikeno and Long Lakes in the Rivers and Smith Inlets areas) were inlets of the sea. This fact suggests that sockeye producing lakes might be produced artificially by damming of inlets. One question that this possibility raises is whether or not suitable conditions for rearing sockeye could be provided in a reservoir consisting of a layer of fresh water overlying one of sea water.

Sakinaw Lake. In its recent history Sakinaw Lake has had intrusions of salt water at higher tides. Such intrusions are believed to have been infrequent in recent years - more information of the exact history is being sought.

A visit was made to Sakinaw Lake on April 29, 1960. Temperatures and water samples for salinity determination were taken at a central station at various depth intervals down to the maximum depth possible with the gear used. The depth to bottom at this station is unknown. Table XXI lists the resulting data.

The data are sufficient to show that this lake is one in which a surface freshwater layer overlies a deep reservoir of stagnant salt water. The uniform low salinity and the temperature structure to a depth of approximately 80 feet could be typical for a wholly freshwater lake in this region. The increase in temperature and salinity below this depth shows the presence of an underlying reservoir of salt water heavily laden with hydrogen sulfide and devoid of oxygen.

Table XXI. Temperatures and salinities, Sakinaw Lake, April 29, 1960.

Sample No.	Depth feet	Salinity ‰	
1	0	0.12	
2	0	0.12	
3	20	0.12	
4	20	0.12	
5	50	0.12	
6	50	0.12	
7	80	0.12	
8	100	0.52	H_2S present
9	100	0.57	"
10	120	1.12	"
11	120	1.12	"
12	150	6.08	"
13	250	10.81	"
14	250	10.83	"

Sample No.	Depth feet	Temperature °C
1	3	12.50
2	6	12.12
3	9	12.08
4	12	11.96
5	15	11.89
6	18	11.00
7	21	8.80
8	24	8.55
9	30	8.18
10	39	7.50
11	45	7.20
12	51	6.51
13	57	6.10
14	66	5.62
15	81	5.51
16	87	5.51
17	90	5.53
18	102	5.69
19	108	5.97
20	114	6.19
21	120	6.27
22	132	6.50
23	160	7.15

Fishing for young sockeye salmon was carried out by tow-netting and using high explosives. A total of 57 young sockeye of four age groups were taken:

Age Group	No. of fish	Mean weight - grams
0+	31	0.22
1+	12	6.80
2+	11	26.20
3+	3	54.60

These fish appeared normal in every respect. The numbers taken, for the small amount of fishing effort expended, suggests that the young sockeye population is fairly substantial.

It appears that Sakinaw Lake, with its underlying reservoir of salt water, serves quite satisfactorily as a nursery area for young sockeye salmon.

Wyclees Lagoon. Wyclees Lagoon, between Smith Inlet and Long Lake, is a body of water which receives regular intrusions of salt water at higher tides. Observations were carried out there during the period August 17 to 20, 1960.

Temperatures and water samples for salinity determinations were taken at various depths at a central station where depth to bottom was 210 feet (64 m). The data are listed in Table XXII. It is obvious that this lagoon has no layer of fresh water - only a superficial layer of lower salinity water which probably varies considerably depending on the influx of fresh water from Long Lake and of salt water from Smith Inlet. The intrusion of salt water from Smith Inlet is greater and more frequent than we had earlier anticipated.

Fishing for 3 days was carried out by means of tow-netting and gill-nets. Only 9 young sockeye were caught: all were of age group 1+ and they had a mean weight of 6.8 grams. It appears that this lagoon does not serve to any extent as a nursery area for sockeye salmon.

Table XXII. Temperatures and salinities, Wyclees Lagoon, August 18, 1960.

Depth	Salinity	
m	‰	
0	1.38	
5	17.61	
10	21.07	
15	23.13	
20	23.76	
30	24.27	H_2S
40	24.46	"
50	24.65	"
60	24.67	"

Depth	Temperature
m	°C
0	20.1
3.8	19.0
4.3	18.0
4.9	17.0
6.1	16.0
7.7	15.0
9.0	14.0
11.0	13.0
20.0	12.7
40.0	12.7
60.0	12.7

D. Fraser River Pink Salmon A. S. Hourston

In 1957 Canada and the United States ratified a Protocol to the existing Fraser River Salmon Treaty to bring the management of the pink salmon fisheries in the Fraser Convention waters under international control. Under terms of this agreement, the International Pacific Salmon Fisheries Commission was charged with scientific investigations and promulgation of regulations for the pink salmon fisheries in the Convention area. In addition, the two countries agreed (Article VI of the Protocol) to conduct "a co-ordinated investigation of pink salmon stocks which enter Convention waters for the purpose of determining the migratory movements of such stocks".

Pink salmon which enter Fraser Convention waters approach either from the north through Queen Charlotte Strait or from the south through the Straits of Juan de Fuca. In the coastal waters between Queen Charlotte and Juan de Fuca Straits, the runs destined for the Fraser system itself intermingle with runs bound for Canadian streams adjacent to Queen Charlotte and Johnstone Straits, Discovery Passage and the Strait of Georgia and with runs bound for streams in the State of Washington, mainly in the Puget Sound area. The problem posed by the Protocol involves determining the times of passage of the different populations through the various Canadian and American fishing areas, and estimating the contributions of the individual runs to the fisheries.

To investigate this problem, a co-operative international program was developed by a co-ordinating committee composed of representatives of Canada (the Director, Pacific Area of the Department of Fisheries and the Director of the Board's Nanaimo Station), the United States (officials of the Washington State Department of Fisheries) and of the International Pacific Salmon Fisheries Commission. The program, carried out in 1959, involved large-scale taggings of pink salmon along the northern and southern approaches to the study area and subsequent recovery of tagged fish in commercial fisheries and on the spawning grounds. In addition a more or less complete census of the populations involved was obtained through the collection of catch statistics for individual fisheries and through special programs to estimate the abundance of spawning escapements.

In general, each of the 3 groups undertook responsibility for those portions of the joint program carried out in their areas. Tagging along the northern approach was conducted by the Fisheries Research Board who tagged almost 22,000 pink salmon, mainly in the upper Johnstone Strait area. Pink salmon entering via the southern approach were tagged at Salmon Bank (14,000), Point Roberts (10,000) and West Beach (4,000) by the Salmon Commission and in Admiralty Inlet (3,000) by Washington State. The Canadian agencies undertook responsibility for recoveries from the Canadian commercial fisheries while the Salmon Commission undertook the major responsibility for recoveries by the United States fishermen. Catch statistics and estimates of spawning escapements to individual streams were gathered by each of the 3 agencies in their own study areas (i.e. by the Salmon Commission for the Fraser Convention area, by the Fisheries Research Board and the Department of Fisheries for Canadian waters outside the Convention area and by Washington State for United States waters outside the Convention area.

The results of this extensive program are still being analysed. All basic data have been exchanged between agencies and a sub-committee of technical personnel of the 2 countries and the Salmon Commission has completed the preliminary collation of the tag recovery data, catch statistics and spawning ground information. In all some 33,000 tags were recovered, over 400,000 pink salmon were examined on spawning grounds and daily catch statistics by gear were recorded for 33 individual fisheries. The Salmon Commission has undertaken primary responsibility for analysis of the collated data on pink salmon using the southern approach and the Fisheries Research Board has done likewise for fish using the northern approach. The present summary is confined to preliminary results of the latter analysis.

The 1959 catch in the overall study area was the poorest in recent years (Table XXIII). Of the total catch of over 7 million pinks, 2,450,982 (33%) were taken in the 17 fisheries in Canadian waters north of the Convention area (Table XXIV, Fig. 23). The bulk of this catch (68%) was taken by seiners operating in the Johnstone Strait-Malcolm Island area.

Table XXIII. Catch of pink salmon in the study area, 1953-1959 (odd-year cycle only).

Study area	1953	1955	1957	1959	Average
Canadian fisheries outside Convention waters	5,131,715	3,182,850	4,420,081	2,450,982	3,796,407
Canadian Convention waters	3,962,584	4,062,060	2,603,796	2,297,512	3,231,488
U.S. Convention waters	4,957,188	4,697,058	2,780,970	2,442,929	3,719,536
U.S. fisheries outside Convention waters	1,036,824	515,972	356,795	183,970	523,390
Total	15,088,311	12,457,940	10,161,642	7,375,393	11,270,821

Analyses of the spawning ground escapement data have not yet been finalized, but preliminary estimates are available for all runs. In the Canadian study area, surveys were conducted by Board and Department personnel. Abundance of 9 of the 10 largest runs (Fig. 24) was estimated by tagging and recovery programs on the spawning grounds (Table XXV); the escapement to the Keogh River was estimated by a counting fence. Estimates for most of the other 75 streams in the Canadian study area were derived from visual surveys. However fence counts were obtained on 2 of these streams and tagging and recovery programs were conducted on 7. The total escapement to Canadian streams north of the Fraser River was estimated at slightly over 1 million fish. Over two-thirds of these fish spawned in 4 rivers (Skwawka, Indian, Glendale and Squamish) and nearly 90% in the 10 rivers listed in Table XXV. Overall escapements to the Fraser River system and to United States streams were estimated at 1,077,000 and 540,000 respectively.

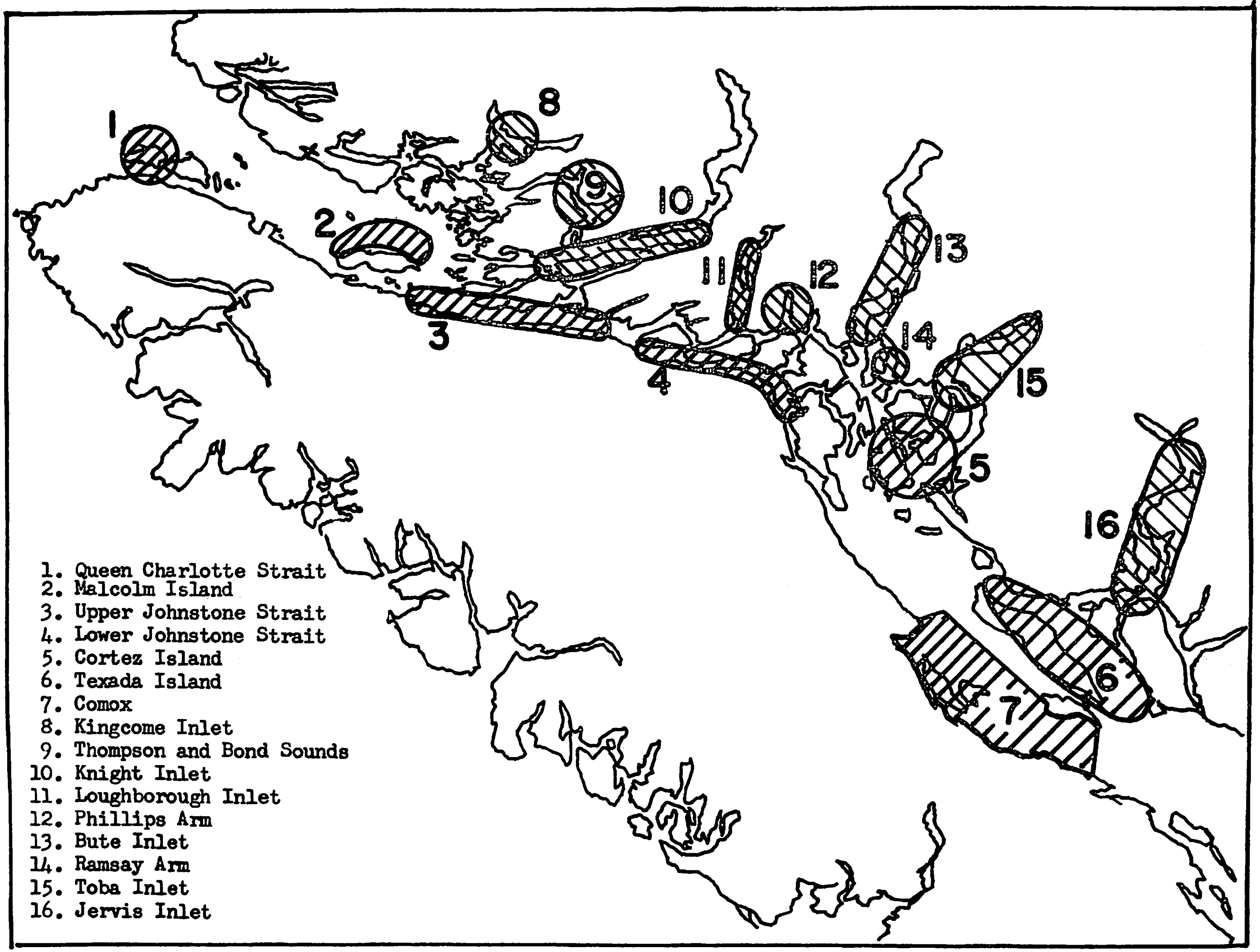


Fig. 23. **Fishing areas in the Canadian study area in 1959.**

Table XXIV. Summary of 1959 commercial pink salmon catches in the Canadian study area by location and gear.

Region	Catch Fish	Per cent of total catch	Per cent catch by gear		
			Seine	Gill-net	Troll
Queen Charlotte Strait	167,551	6.8	*	1.4	98.6
Malcolm Island	512,751	20.9	64.1	3.1	32.8
Upper Johnstone Strait	945,989	38.6	90.5	8.4	1.1
Lower Johnstone Strait	530,850	21.7	92.4	6.5	1.1
Cortez Island	1,288	.1	*	33.9	66.0
Texada Island	26,498	1.1	64.9	28.4	6.7
Comox	6,189	.3	.8	4.4	94.8
Kingcome Inlet	5,261	.2	49.5	49.7	.8
Thompson and Bond Sounds	54,948	2.2	99.0	1.0	--
Knight Inlet	65,036	2.7	3.1	92.5	4.4
Loughborough Inlet	333	*	--	100.0	--
Phillips Arm	2,601	.1	7.2	92.8	--
Bute Inlet	7,044	.3	1.2	74.0	24.8
Ramsay Arm	1,120	*	5.8	94.2	--
Toba Inlet	17,963	.7	--	100.0	--
Jervis Inlet	105,533	4.3	98.3	.9	.8
Howe Sound	27	*	--	81.5	18.5
	2,450,982	100.0	75.7	9.5	14.8

* Less than 0.1%.

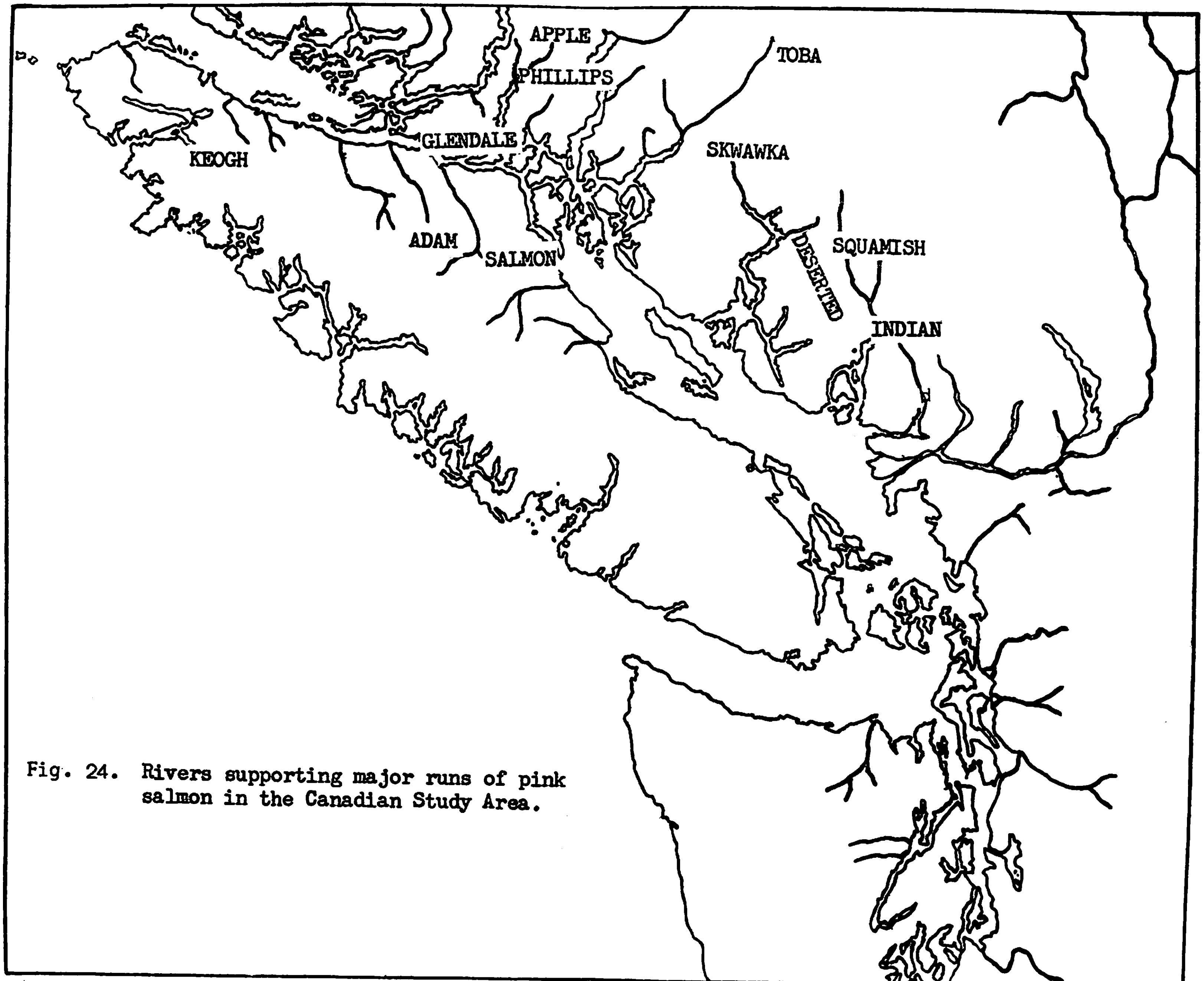


Fig. 24. Rivers supporting major runs of pink salmon in the Canadian Study Area.

Table XXV. Escapement estimates for pink salmon spawning runs in the Canadian study area in 1959.

Stream	Escapement estimate
Skwakwa and Deserted Rivers	255,000
Indian River	175,000
Glendale River	175,000
Squamish River system	100,000
Adam River	40,000
Toba River system	40,000
Phillips River	35,000
Keogh River	26,000
Salmon River	25,000
Apple River	20,000
Total	891,000
Total remaining 75 streams	134,000
Grand total	1,025,000

The tagging program was designed to determine the destinations, migration routes, times of passage and exploitation rates of the pink salmon runs entering the study area. Substantial numbers of recoveries from the Johnstone Strait taggings were made in all important Canadian streams adjacent to and south of the main Canadian fishing area, including the Fraser River (Fig. 25), indicating that appreciable numbers of fish from each of these stocks migrated through Johnstone Strait on their way to the spawning grounds in 1959. However, the proportion of each run tagged varied from stream to stream. The number of tags recovered per thousand carcasses examined was relatively low in the most northerly streams both on the mainland and on Vancouver Island, increased to a maximum in the central part of the Canadian area and decreased again moving southward to the Fraser (Fig. 26). Thus it would appear that some of the fish bound for the more northerly streams had diverged from the main migratory route before reaching the tagging area. On the other hand, the decline in numbers of tags per thousand carcasses in the southern streams can be attributed to the fact that many of the spawners in these streams had entered the study area through the Straits of Juan de Fuca and thus were not intercepted by the Canadian tagging boats. This conclusion was verified by the Salmon Commission tagging program at Salmon Bank which indicated that an appreciable portion of the early run along the southern approach was destined for these streams. Preliminary examination of the recoveries on the spawning grounds indicates that, with respect to time of passage through the fisheries, the runs may be divided into eight categories (Fig. 27).

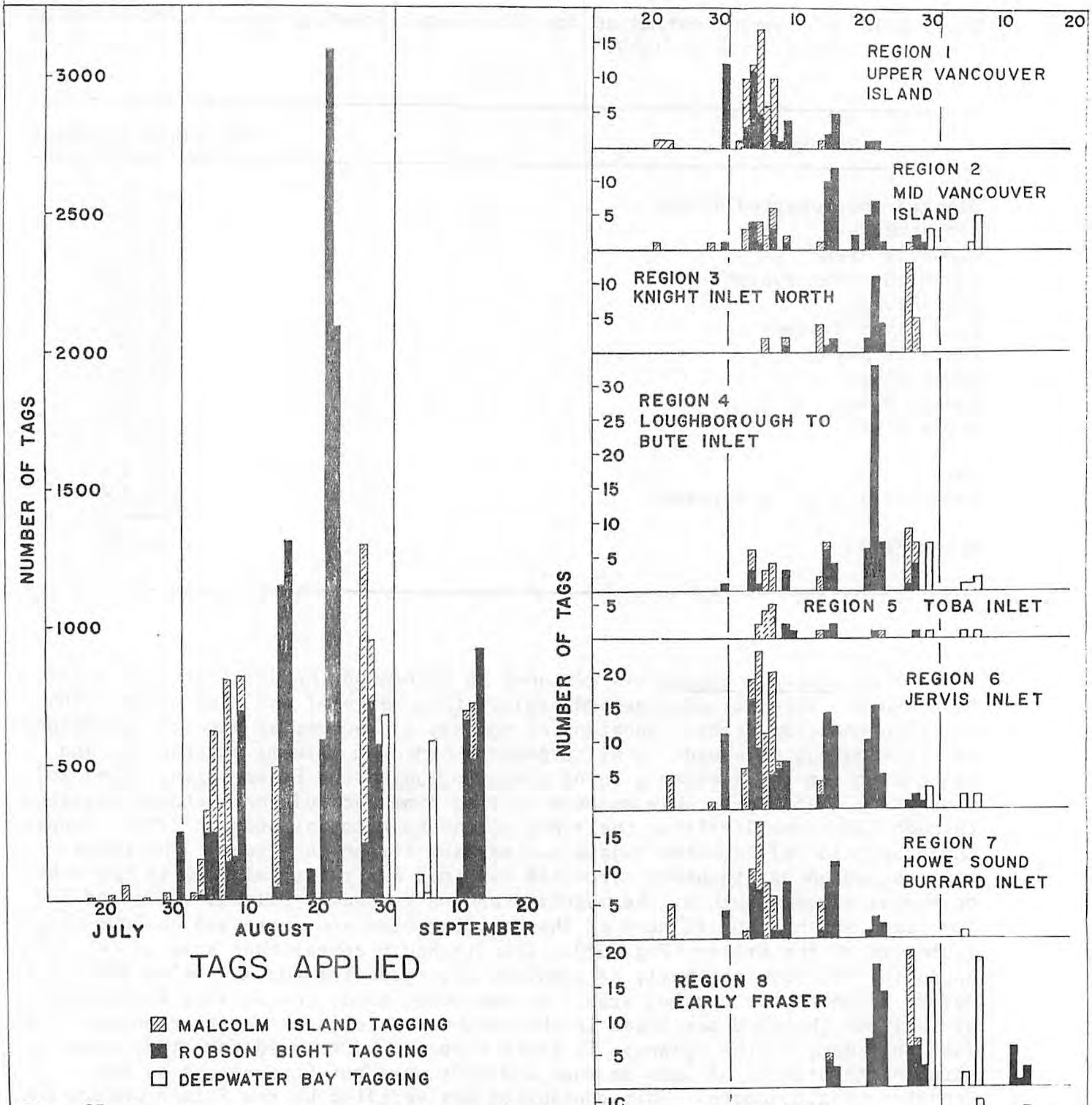


Fig. 25. Tagging and recoveries, by week of tagging, of fish tagged in upper (Malcolm Island, Area 12-4), middle (Robson Bight, Area 12-5) and lower (Deepwater Bay, Area 13-2) Johnstone Strait in each of 8 regions containing runs of similar migratory patterns. (Partial sample of recovery only).

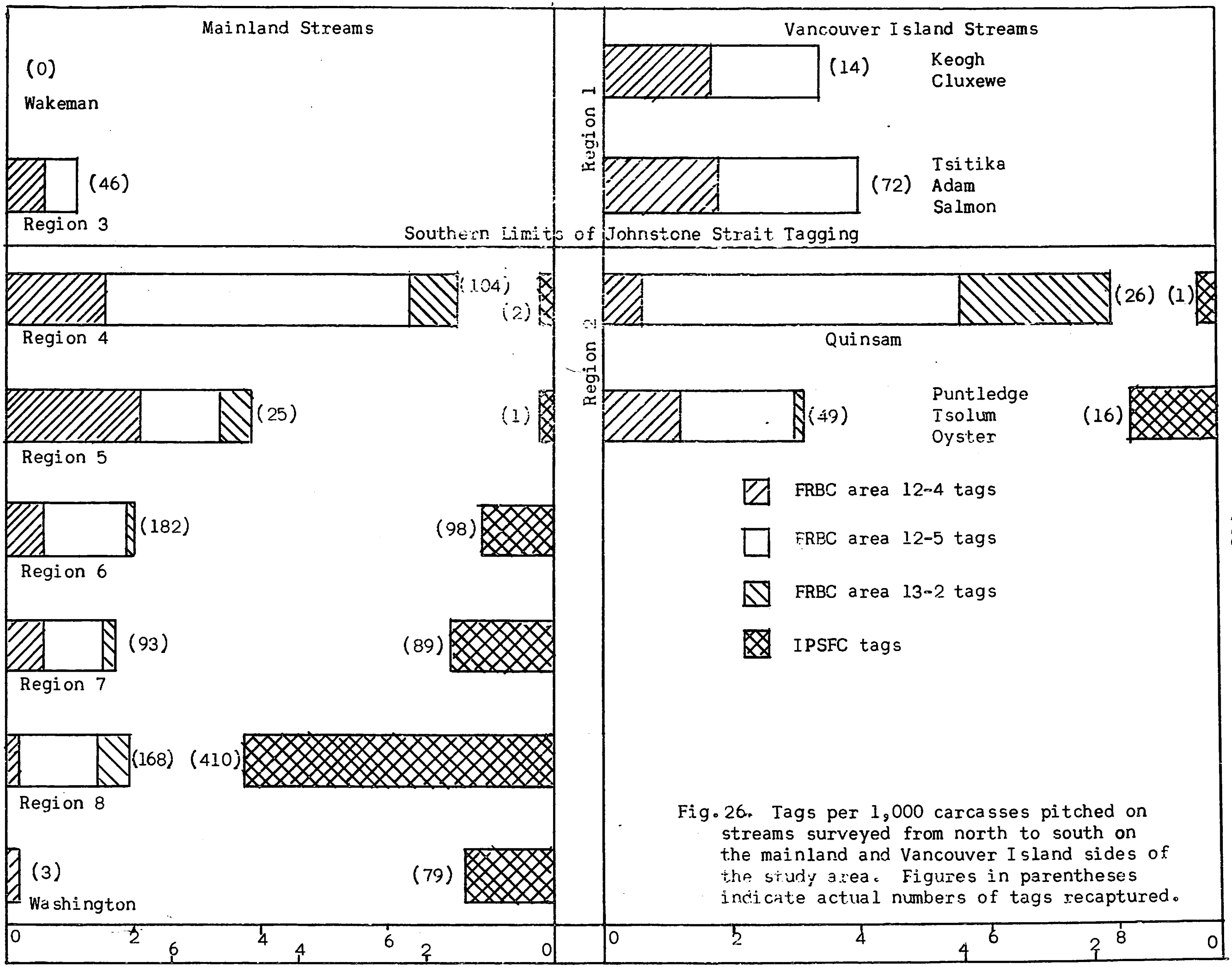


Fig. 26. Tags per 1,000 carcasses pitched on streams surveyed from north to south on the mainland and Vancouver Island sides of the study area. Figures in parentheses indicate actual numbers of tags recaptured.

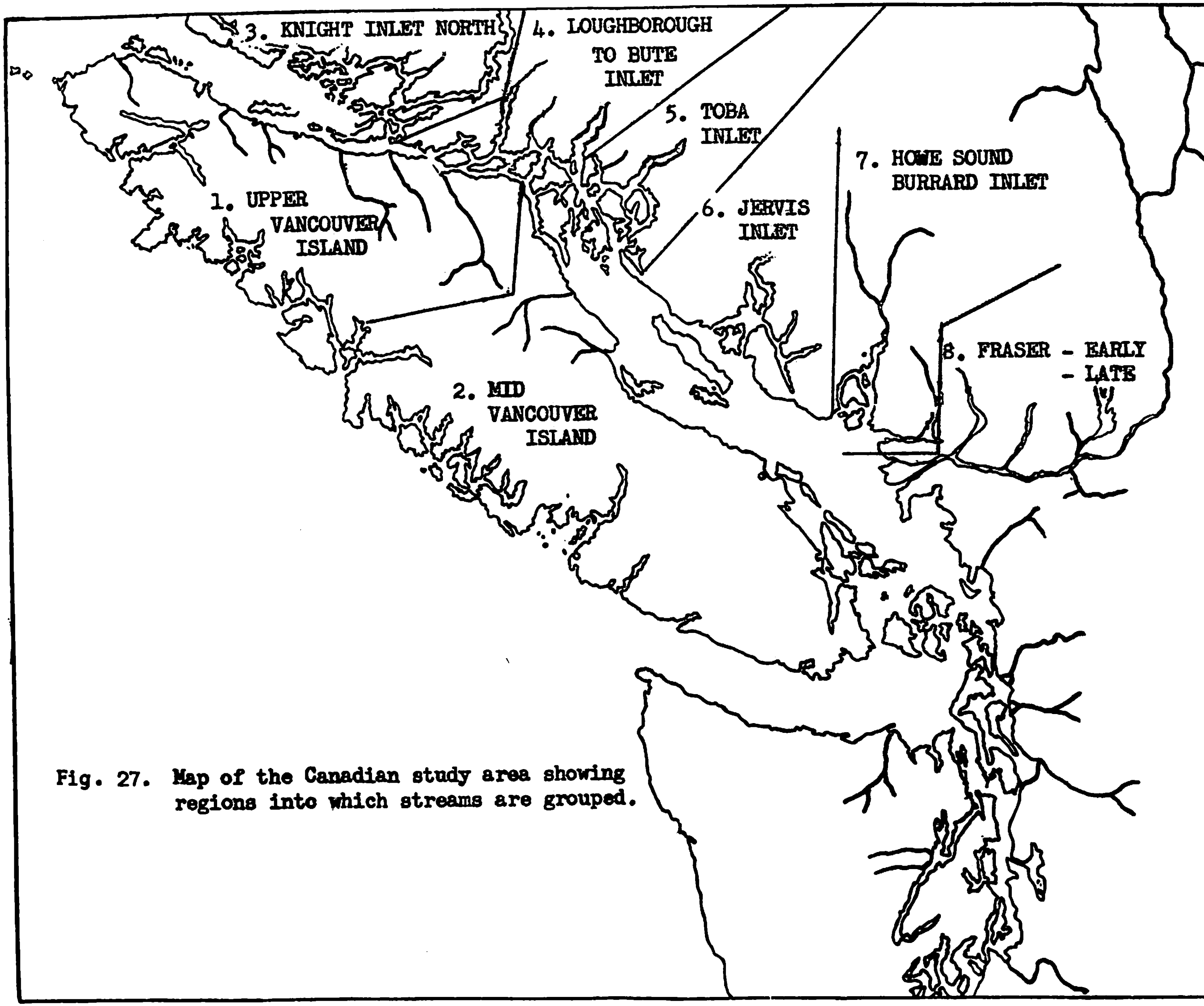


Fig. 27. Map of the Canadian study area showing regions into which streams are grouped.

Region 1 - Upper Vancouver Island (Keogh, Cluxewe, Tsitika and Adam Rivers) - very early runs.

Region 2 - Mid-Vancouver Island (Quinsam, Oyster and Puntledge Rivers)- middle season runs.

Region 3 - Knight Inlet and north (Kakweiken, Waterfall, Glendale, and Ahnuhati Rivers) - late runs.

Region 4 - Loughborough to Bute Inlet (Phillips, Apple and Stafford Rivers) - middle and late runs.

Region 5 - Toba Inlet (Quatam, Brem and Toba Rivers) - early runs.

Region 6 - Jervis Inlet (Skwawka and Deserted Rivers) - early and middle runs.

Region 7 - Howe Sound and Burrard Inlet (Squamish and Indian Rivers) - early runs.

Region 8 - Fraser system - late runs.

During the first third of the season (to August 16) tagging was conducted throughout the northern Johnstone Queen Charlotte Strait fishing area (Fig. 25). It is probable that during this period all runs passing through the fishing area were well tagged. Good recoveries were made on all the early-run streams on upper Vancouver Island (Region 1), and on the mainland south of Bute Inlet (Regions 5, 6 and 7), a few recoveries were made on the middle runs (Regions 2 and 4) and almost no recoveries in the late-run streams of the Knight Inlet area (Region 3) and the Fraser (Region 8).

At the peak of the season (August 17 to 23), tagging was restricted entirely to Robson Bight in the center of the main fishing area. During this week runs tending to diverge from the main migration route north of the Robson Bight area (Regions 1 and 3) were tagged much less intensively than those migrating to areas south of Robson Bight. During this period recoveries of tags in all early and middle areas south of Robson Bight (Regions 2, 5, 6 and 7) declined, with the exception of Jervis Inlet (Region 6) which remained the same as the previous week. Those in late or middle and late areas (Regions 4 and 8) increased.

From August 24 to 30, tagging was again extended throughout the upper Johnstone-Queen Charlotte Strait fishery, probably providing a good coverage of all runs present. By this time, runs to the early streams on Vancouver Island (Region 1) and on the southern mainland (Regions 5, 6 and 7) were essentially over; only a handful of recoveries were made at the tail end of the stream surveys on these creeks. Recoveries from runs to the late streams in Region 3, and the so-called early Fraser runs were large during this period, and recoveries from Regions 2 and 4 were still appreciable in number.

During the week August 31 to September 6, storms restricted tagging to the lower end of Johnstone Strait. Consequently, runs to Regions 1, 3 and 4 would not be adequately tagged. However, tagging in the preceding week indicated that the runs to Region 1 were essentially over, and that the run to Region 4 was declining, whereas the runs to Region 3 were still present in some numbers. South of the tagging site the "tail ends" of runs to Regions 2, 4, 5, 6 and 7 were still present but the majority of the recoveries were made in the Fraser River, with the early runs still predominating.

In the last week of tagging, from September 7 to September 13, most of the tags were applied at Robson Bight, but some tags were also applied north of Malcolm Island. The only stream recoveries from this tagging were made in the Fraser system, mainly on the late-run streams, indicating that the runs to the other Canadian streams were over by this time.

Thus, during the early part of the 1959 season (to August 20) almost all pink salmon approaching the study area from the north appear to have been destined for Canadian streams north of the Fraser River. About 45% of the Johnstone Strait catch was taken during this period. During the remainder of August, when 17% of the season's catch was taken, appreciable numbers of Fraser River fish were also present. After the beginning of September, the fish passing through Johnstone Strait were practically all destined for the Fraser River. Thirty-eight per cent of the Johnstone Strait catch was taken during this period. At no time did pinks of United States origin appear in any numbers along the northern approach. Groups of runs to other Canadian streams showed similar but less marked differences in timing. These differences in times of passage through Johnstone Strait should permit regulation of the Johnstone Strait fishery according to the individual requirements of the separate runs and is therefore of great potential value in the management of these runs.

STUDIES ON SALMON PROPAGATION

F.C. Withler

1. Experimental hatchery investigations

R.A. Bams and F.C. Withler

There is an increasing need to develop techniques to introduce salmon runs to new areas, to augment temporarily runs which have been depleted to low levels by natural catastrophe or by over-fishing, and, possibly, to maintain indefinitely runs in areas suitable in other respects but lacking spawning area. The enhanced survival of eggs to the fry stage attainable in hatcheries (90% as compared to around 10% in nature) has commended their use as a propagation tool for many years. In spite of the apparent advantage arising from better survival to the fry stage, however, the adult returns from hatchery-reared fry have seldom been more than that to be expected from the equivalent number of eggs spawned naturally, and usually less.

No satisfactory reason for the higher mortality of hatchery-reared fry over that of natural fry has been demonstrated. However, W. S. Hoar's work in 1955 on the behaviour of fry when exposed to unnatural environmental conditions may offer some explanation. He found that pink fry which had never schooled preferred a cover of stones and avoided bright light; after brief schooling (as would be induced in conventional lighted hatchery troughs) they swam above the cover of the stream bottom, in bright light. Further, chum fry which had swum as a school in one direction in a circular trough for as little as 10 minutes tended to maintain this behaviour when re-released into the trough hours later.

The experiments suggested that normal behaviour responses of fry could be distorted by the unnatural conditions imposed by conventional hatcheries. Such modified responses might account for the higher mortality of hatchery fry by, for example, making them vulnerable to predators, or by delaying or preventing the onset of migration and feeding.

With this background, it was decided that an experiment should be conducted in which fry would be raised and released under as natural conditions as possible:

(a) The developing eggs would be subjected to a temperature regime similar to that of their stream of origin.

(b) The hatched eggs (alevins) would be subjected to natural light and temperature conditions at the terminal stage of development, prior to release.

(c) The fry, as much as possible, would be provided easy access to the stream at the stage they would normally migrate. (Experiments conducted by M. P. Shepard in 1956 had shown that fry would swim up and out of deep darkened containers of upwelling water at the same stage of development as fry migrating in nature).

To meet these conditions it was decided to establish the experimental facilities on a stream which supported a natural run, to use the water of that stream in which to incubate the eggs, to incubate the eggs and allow the fry to release themselves in darkness, and, in the first experiments at least, to use pink salmon whose 2-year life cycle meant that results would be obtained quickly.

Kleanza Creek, tributary to the Skeena River, was chosen for the site: the run appeared to be of a size which would permit taking all of the eggs from the spawning run, the total number of adults surviving from the liberated fry could be estimated because the rate of exploitation of Skeena pinks was better known than for other pink producing areas, and the stream's water was suitable for hatchery use in that it was free of mud and silt and relatively stable.

Conclusive results from the Kleanza experiments are not yet available. Operational and other difficulties have prevented wholly satisfactory fry liberations. Perhaps most important of these difficulties has been the underestimation of the abundance of the Kleanza run - in no year since the beginning of operations in 1957 has the spawning run been sufficient to provide enough Kleanza eggs alone for a large-scale liberation. The Kleanza eggs employed have each year been supplemented with greater numbers of eggs taken from the larger Lakelse and Kitwanga pink runs. Whether these latter fry return to Kleanza Creek or to their streams of origin is not known. Furthermore, because they originate from stocks whose early temperature environment differs more or less from Kleanza Creek, it has been difficult to ensure that their development to the fry stage parallels that of Kleanza spawn.

Treatment of the Kleanza stocks and the supplementary egg collections are reviewed briefly:

(a) The 1957 brood. The Kleanza hatchery and collecting facilities were completed in time to take only a portion of the eggs from the 1957 Kleanza pink spawning run. The 0.57 million Kleanza eggs taken were supplemented by 1.36 million eggs collected from the later-spawning Lakelse run. Breakdowns in the new pumping system and failure of the Lakelse eggs to develop rapidly enough in the cold Kleanza water caused severe losses during early incubation. Some 0.345 million Kleanza fry emigrated from the hatchery earlier than expected, but released themselves satisfactorily; the 0.325 million Lakelse fry emigrated from the hatchery more than a month later than the Kleanza fry and long after the normal Kleanza migration time. Even so, most Lakelse fry escaped with prominent yolk sacs still attached.

In 1959, a total of 1,200 adults returned to Kleanza Creek. These represented a survival rate from fry to returning adult of only 0.18% (or, if the abnormal Lakelse fry are omitted from the calculation, 0.35%) compared to an approximate average in nature of 1.5%. For the 1957 brood, then, the survival of hatchery-reared fry was only one-tenth to one-fifth that in nature.

(b) The 1958 brood. Only 0.34 million eggs were obtained for the hatchery from the small 1958 Kleanza run. These were supplemented with 1.32 million Lakelse eggs, whose development was accelerated by eyeing them in the warm water of Lakelse Lake before transporting them to Kleanza. Both the Kleanza and Lakelse fish survived the winter relatively well, and the Lakelse fry reached the migrant stage at about the same time as the Kleanza fish. A total of 1.4 million fry released themselves in April, 1959, only slightly earlier than anticipated. Their behaviour pattern before and after release appeared normal - they released themselves mostly during the day, hid in the gravel during daylight hours in the stream, and moved rapidly downstream and out of Kleanza Creek during the early hours of darkness.

Their return in 1960 amounted to only about 600 adults. These represented a survival of 0.043%, which, even if adjusted for the low return to the

Skeena River in general in 1960 (1/4 of the expected return) amounts to only 0.17%. This figure again compares unfavourably with an average return of 1.5% for natural migrants.

(c) The 1959 brood. Only 0.40 million eggs were obtained from the small 1959 Kleanza run. These were supplemented by 8.80 million eggs from the nearby Kitwanga run, which were transported to the hatchery. The first eggs obtained at Kitwanga proved extremely sensitive to handling. In all, some 3.2 million were lost during transport, incubation and release. In the spring of 1960 some 6.0 million fry were liberated. Of these more than 50% showed more prominent yolk sacs than natural fry and are therefore thought to have released themselves too early. This fact, in spite of a total release greatly in excess of that for the 1957 and 1958 broods, is likely to depress the size of the return in 1961 below what might have been expected from a satisfactory release. (Too late to be useful in the 1960 liberation, it was discovered that by limiting the time of release to the period of the day when the stream water was coolest only the most advanced fry would escape from the release troughs. Future releases will be better controlled by taking this behaviourism of the fry into account.)

(d) The 1960 brood. Although a large egg take at Kleanza Creek and at Kitwanga River had been planned in 1960, the phenominally poor return of pinks to the Skeena River in 1960 curtailed the operation to the extent that only the 0.2 million Kleanza eggs available were taken. These were eyed in the Kleanza hatchery, then shipped to Nanaimo for experimentation and to Robertson Creek on Vancouver Island where they were planted in a specially prepared spawning channel by the Fish Culture Development Branch. Curtailment of the 1960 Kleanza operation was taken as an opportunity to examine the degree to which straying into Kleanza Creek by spawners bound for other Skeena tributaries might distort interpretation of the return of adults from hatchery liberated fry. Accordingly, it would be expected that no pinks will return to Kleanza in 1962 if no straying occurs.

Table I summarizes the number of eggs collected, the number of fry released, and the number of returning adults for each year since 1957.

Table I. Summary of experimental hatchery operations at Kleanza Creek.

Year of egg take	Number of eggs taken				Number of fry released				Number of adults returned
	Kleanza	Lakelse	Kitwanga	Total	Kleanza	Lakelse	Kitwanga	Total	
	(1,000's)				(1,000's)				
1957	570	1,360	0	1,930	345	325	0	670	1,200
1958	340	1,320	0	1,660	300	1,100	0	1,400	600
1959	400	0	8,800	9,200	300	0	5,700	6,000	..
1960	200	0	0	200	0	0	0	0	..

Hatchery experiments on sockeye. An important factor in choosing pink salmon for the initial tests of modified hatchery techniques was their short life span, which meant that results could be obtained quickly. Since pink fry migrate directly to sea after emergence, there is little opportunity to observe their survival after liberation, and the factors affecting it. Sockeye on the other hand spend one or more years in a lake before migrating to sea and therefore are more readily observed for at least a year following release; in the early stages after migration out of the stream they can usually be seen close to the lake shore and at later stages can be caught readily by townetting, a technique developed by W. E. Johnson at Lakelse Lake in 1955. R. E. Foerster's work on Cultus Lake sockeye suggested that hatchery fry suffered the extra mortality soon after liberation.

During 1960, preparations were made to repeat the hatchery experiment conducted at Kleanza Creek on sockeye salmon at Lakelse Lake, employing those indicated improvements in technique already developed. Lakelse Lake supports a run of sockeye whose eggs could be accommodated entirely in a hatchery of similar capacity to that of Kleanza. Much is known about the Lakelse sockeye stock from observations made during the 1944-48 Skeena salmon investigation and subsequently. During the winter of 1960-61 trailers to accommodate the hatchery equipment and personnel have been built and are now being installed at Scully Creek, a small, stable sockeye producer tributary to Lakelse. It is proposed to test the collecting, holding, incubating, and release facilities during 1961-62 by collecting eggs from a part of the 1961 Lakelse run and rearing them through to liberation.

Laboratory studies of fry behaviour. In addition to direct field observation of the results of modified hatchery techniques, laboratory experiments on the behaviour of fry were resumed during the fall and winter of 1960-61. These experiments, although limited in scope by available facilities, have indicated that:

(a) movements of sockeye fry in gravel are directed both by gravity and the direction of water flow within the gravel,

(b) fry raised on open screens reach the swim-up stage earlier than fry raised under similar conditions but on screens with one layer of gravel, and

(c) a substantial period of time may elapse between the time the swim-up stage is reached and the period of main migratory activity.

Even these preliminary observations emphasize the need for extensive experimentation to define the conditions required for successful artificial propagation.

2. Stream salmon investigation

W.P. Wickett

Water movement in spawning gravel of lakes

Information has been gathered on the movement of water 10 inches inside the gravel along the shore of Great Central Lake, Vancouver Island, during the course of the calibration of the Mark 7 standpipe.

Instrument. The accuracy of the instrument was tested in a steel barrel of pea gravel. The instrument's tubes were connected through the side of the barrel above the gravel surface allowing five inches of water over the gravel. A water hose was connected to the centre of the barrel bottom. The permeability of the gravel was found to be 25,000 cm/hr from the discharge rate of 69 cc/sec in the 2-inch line under a 1-inch head. The area of the gravel cylinder was 2,300 sq. cm.

(1) Discharge of water up through barrel = 135,000 cm^3/hr

$$\text{Nominal velocity} = \frac{Q}{A} = \frac{135{,}000\ cm^3/hr}{2{,}300\ cm^2} = 59\ cm/hr$$

Peizometer difference between surface and 10 inches in gravel = .024"

$$\text{Nominal velocity} = KS = 25{,}000\ cm/hr \times \frac{.024''}{10''} = 60\ cm/hr$$

(2) Discharge of water up through barrel = 42,000 cm^3/hr

$$\text{Nominal velocity} = \frac{Q}{A} = \frac{42{,}000\ cm^3/hr}{2{,}300\ cm^2} = 18\ cm/hr$$

Peizometer difference between surface and 10 inches in gravel = .006"

$$\text{Nominal velocity} = KS = 25{,}000\ cm/hr \times \frac{.006''}{10''} = 15\ cm/hr$$

The agreement is very good considering the difficult field conditions of the test.

The greatest source of error in calculating velocity is the determination of the gradient "S", since the lake-standpipe head differences are frequently limited to a few thousandths of an inch. A well-trained and careful operator is required. There is a possibility of eliminating the necessity of a skilled operator using pressure transducers according to Mr. Pirart. A much more portable instrument would result as well.

Observations

A. Three sources of water movement in the gravel have been found and a fourth suggested by Mr. Boyd of the Fish Culture Development Branch.

(1) Changes in lake level cause a movement of water into the gravel aquifer back of the shore.

(2) Outflowing water is found at definite points. In the few positions (redds) tested, a temperature difference between lake and ground water was found.

(3) Waves with a period of 2 minutes cause movements of water up to 140 cm/hr for a few seconds. The 20-minute seiche that persists in Great Central Lake probably causes water movement but the peizometer differences may be too small to observe. Further careful measurements are needed.

(4) The use of dye has shown cold water moving down through surface gravel in a direction parallel to the lake bottom slope. The Mark 6 standpipe, if equipped with a water-proof or pressurized motor, could be used by a diver to record such flows. Seiches may also induce currents parallel to the gravel surface.

B. Permeability of areas "most likely" spawned and unspawned. Guided by a spawning intensity map provided by the Fish Culture Development Branch, permeabilities were sampled along 1,300 feet of shore. The spawned area was along the 60-foot depth contour. The unspawned area was taken along the 40-foot contour. In the spawned area the range was 550 to 20,000 cm/hr, median value 3,700 cm/hr. In the unspawned area the range was 47 to 75,000 cm/hr, median 1,465 cm/hr. These rates are significantly different.

The temperature was above 10°C at depths shallower than 55 feet in August when the survey was made. Spawning fish may be avoiding warm water as well as finding groundwater emerging at depths of equal density. Further profitable studies can be made.

C. Emergence of groundwater above areas of low permeability. Water was found to emerge above an area of low permeability. Outflow was missing in the area below. Salmon had spawned in this shallow area of outflow and had not used the area below. A further survey of the area will be made this spring.

In the preliminary studies to date, outflowing water appears to be associated with the salmons' choice of spawning sites but there appears to be sufficient movement of water in the gravel to suggest that eggs can be incubated in any permeable gravel locations.

Transfer of pink salmon to Newfoundland

The transfer of several million eggs planned for 1960 was postponed because of the failure of the spawning runs in Skeena tributaries from which the eggs were to be taken. The next transplant needs to be at a high level (5 million +) if the ocean survival is to be assessed.

Freshwater production of coho smolts

The fishing pressure on coho salmon has been increasing in recent years. Total catches have remained fairly constant for the past ten years. It is desirable to inquire into (1) the capacity of streams to rear coho salmon, (2) the number of spawners necessary to use the streams to capacity, and (3) the relation of the present numbers of coho to the indicated maximum.

An analysis of adult and smolt counts at Hooknose, Nile, Waddell, and Minter Creeks indicates that (1) 20 smolts per 100 square yards of stream are produced, being 1% of eggs deposited, (2) one pair of spawners per 120 square yards of stream gives the maximum number of smolts from these streams.

A small stream, Chef Creek, 50 miles north of Nanaimo has been known to be very productive of underyearlings over the past 15 years. It has a steady summer flow and is easily fenced. Counts of adults and smolts combined with electrofishing of the stream will give a measure of production. An adult count of 833 was made between October and January. This is approximately 19 adults per 120 square yards of stream. Underyearlings have been found during the winter under cutbanks and logs. They were well fed with oligochaetes.

It is planned to make as detailed a study as recources permit of the aquatic and terrestrial food, cover, predators, winter areas, fecundity, movement within streams, digestive rates, homing, and disease. During the present year, the staff are becoming acquainted with the available gear and type of data to be gathered.

Conditions for the incubation of salmon eggs in streams

Work this year has been confined to publication and conferences with other scientists. A reading of the literature indicates two points of additional interest:

(1) Pink salmon eggs need water temperatures above 5.5°C in the pre-eyed stage but apparently stocks do better when the winter temperature drops and remains much lower.

(2) Gravel will be most permeable if the ratio of the diameters of the largest and smallest particles does not exceed 5.

3. Studies on salmon production at Port John

F. Neave and R.C. Wilson

Pink and chum salmon

Annual records of the spawning populations of salmon and of the output of young fish in Hooknose Creek have been maintained since 1947, with the exception of the 1959 escapements. Long-term records are essential for determining the effects of population-size on freshwater survival and for establishing whether there is interaction between the odd- and even-year lives of pink salmon. These are problems of great importance in the general theory and practice of salmon conservation. During the years of observation there has been no obvious downward trend in the pink and chum population levels of Hooknose Creek - a situation which contrasts with results obtained on some other streams on which weirs have been operated. On the other hand, the combined spawning populations of these two species have fluctuated from 1,891 to 34,738 in different years.

Among the conclusions which have been reached from observations on this wide range of population sizes are:

(a) The percent survival from eggs deposited to outgoing fry, although varying from about 1% to 17% in different years, is similar for the two species in a given year.

(b) The two species should be regarded as a single unit in considering the effects of population-size on survival.

(c) A very rapid increase in fry output accompanies increase in size of spawning populations up to a level of some 10,000 spawning fish. Above this level, fry output is irregular but has never numerically exceeded the output obtained from smaller populations.

(d) Predation by other fish (especially coho smolts and sculpins) is relatively heavier on small fry populations than on large ones and therefore tends to hinder the "come-back" of stocks which have been depressed to a low level.

Information is now required on (a) the level of fry output that could be attained by elimination or control of predators, (b) the kind of mortality (compensation, depensatory or independent) which takes place after the fry reach the sea, and (c) the possible detrimental effect of heavy egg deposition on the survival of eggs deposited in a subsequent year.

Output of fry in 1960. The potential deposition of eggs in Hooknose Creek in 1959 is not known since (for the first time since establishment of the field station in 1947) the counting weir was not operated. From observations made on the stream after the peak of the spawning run it was evident that the run, as expected, was small. Outgoing fry in the spring of 1960 numbered 204,000 pinks and 177,000 chums. This probably represented a relatively high survival for a parent population of small size.

Adult escapement and egg deposition in 1960. While the pink salmon escapement of 3,165 fish was not small in relation to the long-term average, it was much less than the expected return from the 745,000 fry which left the stream in 1959. Poor runs of pink salmon were widespread in 1960 and pointed to higher than average natural ocean mortality. It is believed, however, that fishing intensity on the Hooknose Creek fish was also higher than usual. The chum escapement of 1,287 fish is assumed to represent the survival of most of the 1957 fry run of 70,000, plus a portion of the 1958 fry run of 136,000. Although the number of fish returning in 1960 was small, it undoubtedly represented a higher percent survival than the pink salmon escapement.

Figures recorded for the two species were:

Species	Number of adults	Percent females	Average egg-content	Potential deposition	Loss of eggs by retention (%)
Pink	3,165	54.47	1,676	2,792,000[a]	1.16
Chum	1,287	49.73	2,704	1,676,000[a]	0.85

[a] Does not include eggs of 58 pink females and 20 chum females which were taken for egg counts or otherwise died unspawned.

Sockeye

In recent years the possibility has been investigated of promoting more rapid growth and of obviating the high mortality associated with fry and smolt stages in fresh water by transfer of newly emerged fry to the low-saline water at the mouth of Hooknose Creek. The fry-migrants produced in 1955 to 1959 from the chief spawning ground of the watershed (Tally Creek) were treated in this way. All smolts leaving the watershed since the beginning of these experiments have been marked by fin-clipping in order that the returning adults could be distinguished from those resulting from the transferred fry.

In 1960 the adult escapement comprised 185 sockeye, of which only 20 were unmarked. Since unmarked fish have constituted only a small proportion of the escapement in any year, it is evident that the transfer of fry has not hitherto produced favourable conditions for survival and it was therefore not carried out in 1960. Smolts were marked, however, because of the possibility of returns from a relatively large transfer of fry (135,000) released in 1959.

Sockeye smolts at the Hooknose Creek weir in 1960 numbered 15,161, of which 15,011 were released to sea after removal of both ventral fins.

The sockeye fry output from Tally Creek in 1960 was 85,552, of which all but 318 passed alive into the lake. This is a larger production than the average of recent years but the percent survival which it represents is not known, since the spawning population was not counted in 1959.

Coho

Coho smolts leaving Hooknose Creek in the spring of 1960 numbered 5,945. Since the estimated egg deposition in 1958 was 425,100, the survival was 1.40%. In the seven years from 1954 to 1960, the annual output of smolts has varied only from 4,513 to 6,756. This may indicate that the escapements are large enough to permit full utilization of available territory and food supplies.

The adult escapement in the autumn of 1960 consisted of 117 females, 103 large males and 284 jacks. The potential deposition was estimated to be 263,500 eggs.

4. Young salmon in the sea

R. R. Parker

Available evidence on the sea life of pink and chum salmon suggests that the young fish suffer high mortalities during the first months spent in the ocean, after migration from the rivers and streams. Mortality rates during the pelagic phase, after these first few months, appear to be much lower. If these observations are true, conditions during early sea life are important in determining the stocks' final abundance as adults returning to spawn.

To date little is known of the mechanisms which bring about the heavy mortality in the early sea stage. A field program has been initiated this spring in association with the Port John field station where conditions are favourable for observing the dispersion of pink and chum fry from a measured output into the sea. About half the seaward migrants from Hooknose Creek have been marked, and some success in tracing their movements and growth in the nearby coastal waters has already been achieved. The ultimate objective of this study will be the determination of the relationship between the many varying environmental conditions and the survival of young salmon.

An important aid to the study would be a reliable method of measuring survival of the fry. To date no more suitable method than marking the fry by amputation of certain fins or combinations of them has been devised. Preliminary experimentation with marked and unmarked fry held under laboratory conditions with a predator was begun early this spring. The results are reported below.

Laboratory experiments on the survival of marked vs. unmarked fry

It has been noted by Dr. Pritchard at McClinton Creek and Mr. Hunter at Hooknose Creek that pink salmon fry marked by fin amputation do not survive to maturity as well as the unmarked members of the population. This higher mortality rate does not appear to be associated strongly with the extent of wounding or the after-effects of at least careful handling, but rather with lowered survival generally for a period of time that may equal the remaining life span. When expressed as instantaneous rates, the McClinton Creek marked pinks suffered a mortality rate 1.31 to 1.42 times that of the unmarked fish (4 experiments). The correspondong factor for Hooknose Creek pinks was 1.5%. These ratios indicate a consistent marking effect.

A preliminary series of experiments to determine the bases of the marking effect was conducted in the laboratory. An aquarium containing 100 marked (adipose and right ventral) and 400 unmarked pink fry was used, into which an 8-inch rainbow trout was introduced to serve as a predator. A control aquarium containing equal numbers of marked and unmarked fry at the same density as the experimental lot was set up. Unmarked fish were anaesthetized and handled in the same manner as marked fish. The experiment was repeated four times. A summary of results is as follows:

Experiment number	Degrees of freedom	Chi-square	Probability	Ratio i_m/i_u
1	1	1.858	0.18	1.37
2	1	1.305	0.26	1.29
3	1	2.571	0.11	1.42
4	1	1.501	0.22	1.31
Total	4	7.235	0.13	
Pooled	1	7.002	$<.01$	1.35
Interaction	3	0.233	0.96	

Each experiment by itself was not significant; the probabilities of obtaining similar results by chance are well above the 5% level. The pooled data, however, indicate a total selectivity that is highly significant. Furthermore, interaction χ^2, indicates homogeneity within the experiments, i.e. the results are consistent. The mortality rate ratios are also consistent with the field observations. Thus the effects of marking on survival may be duplicated and studied in the laboratory.

These empirical and experimental observations may find explanation in the following hypothesis: that mutilation of the fish simply makes it appear different than the unmarked population in the eyes of its enemies. Hence the predator is able to follow an individual without the confusion presented by an aggregation of identical fish. In this manner the predator may be slightly but significantly more successful in capturing the marked individual as compared to the unmarked. This hypothesis and other details of factors underlying predator selectivity should be further investigated. Such a study is a necessary step toward evaluation of marked fish returns.

EXPERIMENTAL STUDIES ON PHYSIOLOGY AND BEHAVIOUR OF SALMON - J.R. Brett

Research in this field is designed to give basic information on the functional capacities, maturation processes, tolerance levels and normal behaviour patterns of migrating salmon as a basis for determining their ability to withstand changes in freshwater environment, particularly those resulting from hydroelectric dams and pollution. Since the problems are complex and broad in nature, the research has been set up on a broad front, dealing with the normal variation which accompanies the physiological and behavioural aspects of migrating salmon. Once the normal variability has been reasonably established, it will be possible to examine the effects of imposed stress, simulating possible changes which could occur in the salmon's freshwater environment.

In certain avenues, this stage has now been reached; in some others it is imminent. Of the five species of salmon, four have been successfully brought into the laboratory and records made of spawning behaviour. This year two stocks of sockeye were held for between two and three months, reaching maturity in a very healthy state. It has been shown repeatedly that, in the special tank facilities provided, these captive fish will spawn readily, producing healthy fry. Ability to handle and transport adults has been refined to the point where time and distance are no longer hazards. A combination of waterproof canvass bags, sponge-padded tanks, reduced temperature and adequate oxygenation has made it possible to bring salmon to the laboratory for study from any accessible corner of the province, should the occasion arise. Knowledge of how to take repeated blood samples, to display organs radiographically, the qualitative characteristics of maturation proteins, the sustained swimming speed of sockeye, some of the cellular and disease characteristics, and, in the young, the tolerance levels to a number of toxic compounds under varying environmental conditions has enhanced the ability of the research group to examine and assess functional problems of salmon. It is this sort of growth in understanding which is the immediate aim of the research.

The large flume in Robertson Creek was brought into use for the first time. Initial studies on swimming performance of adult sockeye provided measures of fatigue levels, and, in an unanticipated way, displayed the devastating effect of the fungus, Saprolegnia. The need for still more refined exercising cages was apparent to enable more exacting studies, including extended periods of sustained performance. Such a cage has been designed and will undergo tests in the forthcoming season.

The field camp at Stamp River Lagoon near Great Central Lake was in operation from April to October, servicing the field and flume studies. Underwater efforts to photograph habits of migrating salmon were rewarded by colour film records of movement and crowding of adults in relation to such obstacles as turbulent water and irregular bottom topography. These technical achievements will be gradually expanded and shifted to include studies on the four fishways in the Stamp River area.

Increased evidence was obtained for the possible celestial orientation of migrating young sockeye by a combination of experimental tests and direct observation. This important aspect of behaviour will be examined more intensively for two more seasons, meanwhile considering the possibility of similar experiments with adults. In this combined approach of field and laboratory testing, fundamental requirements for effective migration and survival are being established.

1. Swimming studies on adult sockeye J.R. Brett and C.T. Shoop

The objectives of this research are: 1) to study the energy demand of swimming; 2) to determine maximum sustained swimming speeds; and 3) to observe behaviour under different velocity conditions. A start on this program was made during June and July when construction of the Robertson Creek flume was completed. Samples of 15 fish, captured in the Great Central Lake fishway, were placed in pens with imposed velocities of 0, 0.4, 0.7, 1.5, 2.3, 2.7 and 2.8 ft/sec.

Complications arising from intense fungus infection from naturally occurring *Saprolegnia* at prevailing high temperatures (65°-72°F) curtailed the studies on the energy demand of swimming. However, it was possible to maintain 5 females for 10 days at the velocities of 1.5 ft/sec and less, and for 16 days at the 0-velocity (up-welling water). The maximum distance swum was about 280 miles.

Maximum sustained swimming speeds for 100 hours included 2.5 ft/sec and may be up to 2.9 ft/sec for uninjured or uninfected fish. At such elevated temperatures this was quite a remarkable performance. Prior to these tests, there had been considerable speculation on the rest requirements of salmon, and a belief that bursts of swimming not only characterized behaviour but were a physiological requirement. This latter is only true for "fatigue velocities", in excess of approximately 3 ft/sec. It is now apparent that lesser velocities can be maintained 24 hours a day without cessation, for a number of days at least, covering distances equivalent to 50 miles per day. In one instance, two sockeye were still swimming after covering 175 equivalent miles in 3 1/2 days.

Although great effort was put into the design of the exercise pens to force the fish to swim at imposed rates, the masterful detection of water movement by the salmon brought out various flaws in the apparatus. These served to demonstrate interesting phenomena. At high velocities which would normally be fatiguing, if permitted, salmon can glide in surface waves with no more than the effort of keeping fins appropriately spread; by fanning the pectoral fins forward and down they can "grip" small irregularities on the bottom and readily hold against the current; slight reductions in velocity caused by corners or invisible obstacles were used and guarded as protected territory. Many clear indications of the diverse use and function of the fins could be had by studying the performance at each velocity. The activity in quiet water appears to be equal to swimming at about 0.2-0.3 ft/sec from a study of tail-beat frequencies.

From this first endeavour much profitable research can be seen. In particular the devastating effect of the omnipresent *Saprolegnia* attacking and spreading from the slightest injury, and promoted by warm water, points to the need for increased attention to this problem. Any factors contributing to slight injuries, such as those which are present in the Alberni system (gill-net fishery, Indian fishery, Stamp falls and fishway, Sproat falls and fishway, Great Central Lake dam and fishway) can be expected to kill fish before spawning if fungus gets started. Five days was sufficient time at 68° ± 2°F to be lethal in captivity. For a run which spends nearly 3 months in fresh water prior to spawning, ample time is present despite lower temperatures to eliminate the injured fish. A study of injuries observed on fresh-run fish captured in the Great Central Lake fishway showed 50% to 60% with some sort of damage. Any factor contributing to increased freshwater temperature (such as large reservoirs, irrigation systems, etc.) can be expected to promote fungus invasion and destruction.

Excellent opportunity was presented for the study of swimming and the use which salmon made of different patterns of water. A modified pen has been designed and will be ready for next spring. The pen has a complete surface, plexiglass viewer, a dome for housing a movie camera, and a grid pattern on the floor. By mounting the pen with rollers on tracks along the edge of the flume, it will be possible to move it forwards or backwards as desired in the low and high velocity water which the inclined plane produces within the flume.

These modifications will also permit a considerably improved facility for the study of fatigue. By establishing the relation between swimming speed and time to fatigue (preliminary curve obtained this year), it will be possible to impose "degrees" of fatigue and study the physiological consequences. For this it is proposed to equip the field camp with modest laboratory facilities for processing blood or other fractions related to the identification of fatigued states.

Behaviour studies will be given further consideration. At present it is difficult to assess the significance of the captive behaviour. Considerable difference occurred between the pens. Within a few hours of captivity, aggressive territorial defence was set up by at least one or two fish. This may be a result of the confined quarters. However, it was so rapid in fish which had undoubtedly been schooling or closely grouping prior to this that it may be present in naturally confined areas of streams or fishways in a manner hitherto unsuspected. Further study of this phenomenon, and of the competing for areas of reduced velocity when swimming actively or involved with fatigue conditions, is indicated.

Finally, it seems entirely possible with the experience and knowledge of handling and treating fish, gained in this first major effort, to carry out the energy studies on swimming. Some limited indications can be expected from this year's samples, as yet not fully processed.

2. Tolerance studies and environmental factors — D.F. Alderdice

A major consideration underlying the conducting of toxicity studies has been the evaluation of the response of young salmon to a toxicant considered as a primary stressor, and the changes in the response which are produced by variations in environmental factors as ancillary stressors.

The purpose of this consideration is that of defining the limits to which types of environmental variation can occur without placing salmon in jeopardy. The environmental domain in many instances cannot be regarded as a simple phenomenon. Single factor analyses of the response of fish to an environmental variable may provide insight into unique functional abilities of the animal, but deny knowledge of possible serious interactions in more complex situations.

Studies designed to investigate type problems may be initiated in the field. Their innate complexity, however, justifies their more rapid elucidation by laboratory techniques. This has required the study and application of new techniques in experimental design in order to bring the relative truths of the laboratory study more closely into correspondence with absolute field situations.

Studies were initiated on kraft oxidized weak black liquor, as a primary stressor, since this material would not only provide information on the biological effects of an industrial process of high pollution potential, but also allow the elucidation of new procedural requirements. Under experimental conditions, the liquor proved to be relatively innocuous from the point of view of toxicity *per se*, although its use provided ample proof in justifying the consideration of deleterious effects resulting from the imposition of additional environmental factors. The use of oxidized black liquor as the primary stressor, therefore, has been discontinued in favour of another compound.

Kraft weak oxidized black liquor. The resistance of coho smolts to acute levels of kraft weak oxidized black liquor varies considerably according to the levels of ancillary variables concomitantly impressed on the test animals.

The domain examined included salinity, temperature, and oxygen concentration between the levels of 0 and 22.5‰S, 7 and 17°C, and 3.0 and 8.0 ppm O_2, respectively. The following generalizations are indicated from the data:

1. Increase in oxygen concentration over all levels of temperature and salinity effect increases in resistance time.

2. Decrease in temperature over all levels of salinity and oxygen concentration increases resistance time to an apparent optimum at or below 7°C.

3. There is an optimum salinity at approximately 10‰S over all levels of temperature and oxygen concentration, at which resistance is maximal.

The following tentative conclusions are drawn, based on the waterborne waste products of the mill studied.

1. The toxicity of full-bleach effluent appears to be related to its black liquor content.

2. Black liquor content of the full-bleach effluent is normally low, and where it is, toxicity of the effluent appears to be a minor consideration.

If effluent is present in the aquatic environment, the adherence to conditions which will provide for optimum levels of associated environmental variables should provide the most acceptable compromise for young salmon. Based on responses to black liquor:

3. Resistance times in fresh water over all tested levels of temperature and oxygen concentration are very strongly depressed, suggesting that effluent should not be discharged into fresh water (e.g. rivers).

4. Resistance times are optimal in waters of medium salinity over all levels of temperature and oxygen concentration, suggesting that discharge of effluent into coastal waters would effect the best compromise.

5. Resistance times are strongly depressed at oxygen levels below saturation values over all levels of salinity and temperature. Since effluent has a considerable oxygen demand, it should not, therefore, be discharged into regions where a net oxygen deficit can occur through lack of circulation or exchange.

Kraft unbleached effluent. Dosage-mortality assays have been conducted on kraft unbleached effluent fractions prepared by the Pollution Investigation for determination of those fractions whose potency provides the toxicity of the unbleached effluent.

Tests were conducted on *Daphnia pulex* at 20°C in series of three replicates of six dosage levels for twenty-three fractions. Test fractions were adjusted to pH 10, that of the initial whole unbleached effluent, and corrections for mortality in the controls were applied by Abbott's formula.

In those cases where it was necessary, control solutions were made from *Daphnia* culture water subjected to the procedures involved in producing the corresponding unknown fractions.

Daphnia were used in place of fish in this preliminary study because of the difficulty of producing sufficient quantities of all fractions to enable their being tested against fish.

Bacillus thuringiensis. A commercial formulation of *Bacillus thuringiensis* ("Thuricide") was tested in 1960 by the Department of Agriculture on an experimental basis to evaluate its potential use in spray programmes against forest defoliating insects. The material was tested in its field formulation to evaluate possible toxic effects on young coho salmon.

In an oil wetting-agent formulation, Thuricide proved to be toxic to the test fish. Factorial examination of formulation ingredients indicated that the oil carrier and Thuricide components contributed significantly to the toxic effects.

Compared with DDT, the usual agent used in budworm control programmes, the tests indicated that Thuricide has only about one-thirtieth the potency of DDT for young salmon. This is the first alternative material to DDT, tested at this Station, which has indicated promise of limiting indiscriminate aquatic damage resulting from such spray programmes.

3. Biochemistry of maturation

W.E. Vanstone

A qualitative study of the changes in the plasma proteins of coho salmon, as separated by zone electrophoresis on filter paper, from an early age to spawning and death has been completed. Attempts to secure quantitative results were not successful since a pure race of fish was not examined and it was found that the relative amounts of certain protein fractions varies between races of coho.

No sex differences were apparent prior to gonadal development. The protein patterns from laboratory-reared and wild yearling fish were similar and need not be discussed separately. Plasma from pre-smolt yearlings contained five protein fractions, rather than four as reported previously, which in order of decreasing mobility have been designated 1, 2, 3, 4 and 5. Lipids were associated with fraction 2. Fraction 1 was absent from the plasma of coho smolts but it reappeared shortly after the fish entered salt water.

Plasma electropherograms obtained from prepuberal 2-year-old coho which had spent a year at sea were qualitatively similar to those obtained from pre-smolting yearlings. However, fraction 5 in all samples examined was more distinct at this stage and may be similar to γ-globulin in other vertebrates.

Other than a progressive increase in fraction 5, electropherograms of plasma obtained from maturing, spawning and spawned-out 2 1/2-year-old males were similar to those of immature fish of either sex. By contrast a sixth plasma protein fraction appeared with the onset of maturation in the female. This sixth fraction, fraction 6, which was also associated with lipid staining material, had the same mobility as fraction 4 and was admixed with it. The resulting mixed fraction was designated fraction 4 + 6. Fraction 6 is probably a mixture of lipovitellin and lipovitellenin complexes in transit to the developing ova. This fraction, together with its associated lipid, disappeared from the plasma at about the same time that the eggs were released from the ovarian tissue. It was absent from spawning or spawned-out fish.

In oviparous vertebrates each period of egg production is associated with profound changes in blood chemistry of the female. The blood changes include increased concentrations of certain proteins (of fraction 6, above), lipids, vitamins and minerals and these changes are considered to be related to the mobilization of these compounds for egg formation. Several investigators, working mainly with birds, have shown that in addition to the normal puberal changes which, as in the mammal, are related to endocrine activity, similar and even greater increases in these serum constituents result from estrogen treatment of egg-laying vertebrates of either sex or of castrates. A preliminary study on the effect of estradiol monobenzoate on some serum constituents in migrating adult sockeye has been completed.

Migrating adult sockeye salmon, which would have normally spent three months in the lake before spawning, were captured at the Great Central Lake dam near Alberni, British Columbia and transported to the laboratory at Nanaimo where 10 fish, 5 of each sex, were arbitrarily placed in each of 2 identical tanks containing constantly flowing fresh water. The fish in one tank received 4 daily injections of estradiol monobenzoate while the fish in the second tank received 4 daily injections of hormone suspending agent.

There was no significant difference in total body weight between the four groups of fish, and estrogenization had no effect on gonad weight, ratio of gonad weight to total body weight or egg diameter.

Estrogenization resulted in a highly significant decrease in the hematocrit of both male and female salmon, and increased the serum levels of total protein, total lipid, neutral lipid, total cholesterol, free cholesterol and lipid phosphorus. There was no significant difference in the hematocrit or serum levels of these constituents between control male and female salmon.

Maturing female fish had higher serum calcium and protein phosphorus levels than males and both these constituents were significantly increased by exogenous estrogen.

The results indicate that the effects of estrogen on the serum constituents of sockeye salmon are similar to those obtained in other egg-laying vertebrates.

Methods for determining plasma volumes in salmon and for characterizing salmon lipids are being actively investigated. A study of the biochemistry of the parr-smolt transformation is to be undertaken.

4. Diagnostic studies of stress and disease G.R. Bell

Work is continuing on the transaminases of salmonids, with the aim of determining the value of serum enzymes as diagnostic agents of tissue damage and that of tissue transaminases as indicators of metabolic shifts. Existing methods for measuring several transaminases have been suitably modified and both serum glutamic-oxalacetic (SGOT) and tissue glutamic-pyruvic transaminases have been found in coho salmon and rainbow trout. The most convenient method of measurement involves the use of linked enzyme systems which result in the oxidation of reduced diphosphopyridine nucleotide, a reaction which is followed spectrophotometrically. The reversibility of the SGOT has been demonstrated and the optimum pH range of the system is 8-9. The SGOT continues to function up to at least 35°C; its upper limit has not yet been determined. SGOT will not transaminate D-aspartate, the "unnatural" isomer of the amino acid but the transaminase appears to function normally even in the presence of the inhibitor deoxpyridoxine at 4×10^{-3}M. Failure of the inhibitor to act indicates that this transaminase has a qualitatively or quantitatively different cofactor requirement from that of mammals and bacteria or that the deoxypyridoxine must be activated by tissue enzymes. The cofactor (vitamin) requirement of coho SGOT is now being examined.

Assessment of the diagnostic value of SGOT levels in salmonids has been hindered by the failure of orally administered carbon tetrachloride to cause liver damage. Other techniques and chemicals are being tested.

Further development of radiographic techniques, especially injection of radiopaque media into the dorsal aorta, has lead to the photography of major portions of the circulatory system of salmon. Data concerning the circulatory system are of fundamental importance to the physiological studies of metabolism.

Disease. A study of apparent bacterial "kidney disease" in cultured pink salmon (*O. gorbuscha*) has been completed. The disease is characterized by the presence of visible lesions, pustules, and necrotic areas in and on the major internal organs, particularly the kidney. Externally, however, most of the affected fish appeared normal. Both sexes were equally sensitive to the disease and there was no significant difference ($p > 0.5$) between the weights and lengths of healthy or diseased fish of either sex. This suggests that infected individuals continued to feed normally at least during the incipient stages of this slow-developing disease. The lesions and necrotic areas were found to contain masses of minute (0.5-$0.7\mu \times 0.8$-1.1μ) gram-positive rods, typical of kidney disease. Data indicate that these cultured pink salmon had an inherent predisposition to the disease.

A brief investigation was made of lingcod (*Ophiodon elongatus*) mortalities in the Porlier Pass area. The actual cause of death was not determined, but it was discovered for the first time that lingcod are hosts for the widespread protozoan, Trichodina. These micro-organisms were seen feeding on the gill epithelium and it is suggested that they are directly or indirectly involved in the death of the host.

5. Ecological studies on upstream migration D.V. Ellis

Techniques for observing and recording salmon activities. These techniques have been further developed in 1960, to the point where it is now practicable to use cine-photography for three purposes: 1) underwater recording where note-writing by divers is impossible; 2) slow-motion recording of rapid activities such as jumping, attacking, etc., thus permitting detailed analysis of the sequence of muscular movements; and 3) time-lapse or standard-speed photography for the analysis of simultaneous movements of schooled migrants. A system of colour photography has been derived utilizing natural light and colour correction filters designed to produce maximum visual recognition from the film image, even though the resulting colours may have no visual significance to salmon.

As a result of attending an international meeting of underwater photographers, it has become obvious that our still photography, both black and white and colour, needs further development before full advantage can be taken of its potential as a recording technique in ecological and morphological studies. It is intended to spend time in 1961 improving our photographic techniques, particularly processing and printing, in order to obtain maximum detail on the prints and transparencies which serve as basic records for analysis.

Descriptive studies of salmon migration. These studies were concentrated for the third year from May to September on the Somass River system, Vancouver Island.

One general conclusion now shows clearly through the accumulated data. Salmon spawning migrations are not simply a matter of the fish swimming upriver and trying to pass obstructions as they come to them. Migrating adult salmon appear to actively select their routes and their times of migration, even when it would appear unnecessary for them to do so. They may migrate through only a fraction of the total water space available to them, and may spend only a fraction of the available time actually migrating. The remainder of the time is spent performing a number of activities with apparently no migratory function, e.g., waiting, circling back, wandering, finning, etc.

Observations, particularly in the Sproat River tributary, demonstrate a strong pathway selection along the deepest channel in low water velocities (up to 4 ft/sec), with little turbulence and with well-defined channels. They suggest the occurrence of rapid learning, which has been observed when salmon are misled by the deepest channel cue and subsequently reorient to the highest current velocity. They also show behavioural changes related to changes in water velocity, in that migrant adult sockeye and coho can sustain steady swimming in schools without resting at a swimming speed of less than 3 ft/sec, whereas resting periods interrupt steady swimming at swimming speeds greater than 3 ft/sec. At swimming speeds greater than 5 ft/sec, schooling breaks down and steady swimming is replaced by darting movements.

Observations, particularly at the Great Central Lake dam fishway on the Stamp River tributary, demonstrate 24-hour rhythms in numbers of fish migrating. The timing of peak numbers varies according to the species migrating (sockeye and coho), a monthly lunar cycle, numbers of fish travelling together (a crowding effect), and seasonal changes during the migratory period.

Salmon entry into rivers and creeks. These studies have been continued on the Somass system from May to September and on the Nanoose Bay creeks from September to November. Results obtained apparently conflict with a number of previous studies of the same subject, which are almost unanimous in describing a relationship between grouped salmon entry and increase in river discharge. Our studies suggest that the apparent conflict is not real; that there is in fact a previously unremarked, common, environmental situation "releasing" upriver movement by salmon accumulated offshore, but taking several days to completion due to the interference of a 24-hour activity rhythm.

The environmental situation common to the studies so far analysed is "weather change arising from approach of an atmospheric warm front". Furthermore, it appears that this environmental situation is perceivable by a number of different "sign" stimuli. In many cases, particularly in small rivers and creeks during rainy seasons, the sign stimulus is apparently increased current velocity in known habitats resulting from higher discharge following rain; but it may be something else under other conditions. For summer entries in the Somass River, a strongly suggested factor is cloud formation in a previously clear sky, perceived as a "configurational" stimulus.

There could well be selective pressure favouring both adaptation to "warm front weather change", which results in lower river temperatures during summer dry periods and increased discharge in rainy seasons (both favourable to migration), and perception of these weather changes by one or more of several potential sign stimuli, depending on local circumstances.

The observations of salmon migration made during the last three years suggest that many of the biological phenomena known to affect the migrations of such varied groups as birds, eels, oyster larvae, locusts, butterflies and dragon-flies, etc., can also be shown to affect salmon migrants when examined at the level of individual movements. These phenomena include at least the following: daily, lunar and seasonal cycles of either activity or behaviour or perhaps both, environmental effects of weather, topography (of the river bottom), dynamics of the environment (current velocity), social effects of crowding, rapid learning ability under some circumstances, and species differences.

6. Behaviour studies

C. Groot

Behaviour studies during the 1960-61 season have centered around two questions: a) How do the different species of the Pacific salmon behave in the different phases of their life cycles? b) What are the guiding cues used by the Pacific salmon during long-distance migrations? As far as the first problem is concerned, the accent has been on the reproductive phase, and in the second study, the accent has been on the importance of celestial phenomena as guiding cues during long-distance migration of sockeye smolts.

A. Studies on the reproductive phase of the Pacific salmon

The reproductive phase of the Pacific salmon as a whole probably consists of three or four phases, namely:

1. homing migration phase, which can be divided in a number of progressive and nonprogressive parts,

2. spawning phase, which consists of the courtship activities, the release of eggs and sperm, and the closing of the nest,

3. brooding phase, which only occurs in the female and during which she guards the redd, and

4. dying phase.

(1) Homing phase. Detailed observations have been made on the last part of the homing phase of stocks of coho and sockeye salmon that have a holding period in a lake prior to spawning. Fifty to one hundred adult salmon of each species were caught just before they entered either Great Central or Cultus Lake, and were kept at the Station in a concrete holding tank of 35' x 15' x 8' deep for two to three months until spawning time. Observations were made at regular times during 24-hour periods, every day, every three days or every week, depending on the development of the behaviour.

The data so far indicate that both sockeye and coho salmon go through an aggressive period in the holding tank of about a week to 10 days before settling down. During this period, sockeye salmon are most active during the late afternoon, at night and early morning. Different activities show daily peaks at different times during this active period. For example, the frequency of dashing and aggressive activities per unit time is higher during the afternoon and early evening and lowest around dawn; while fluttering and jumping peak during the night.

Coho salmon under these holding conditions show periods of high activity around dawn and dusk and sometimes during the night for activities like jumping and surface-nipping.

After the initial aggressive period both coho and sockeye adults settle down and are very quiet for some time. Then all kinds of activities increase again slowly over a period of 1 1/2 to 2 months. Especially those activities that are part of the spawning phase increase in frequency; males will show typical threat and aggressive behaviour and quivering and mouth-open postures, while females start showing low-intensity digging movements. When these activities have reached a certain level of frequency, males and females will move out of the aggregation or school and take up position in other parts of the tank. Territorial behaviour is often evident. The diurnal patterns of most activities change with the increase in frequency per unit time in such a way that the peak of activity is more during the daylight hours.

When the increase of the frequency of certain activities levels off, males and females introduced in an experimental tank with gravel on the bottom almost immediately show spawning behaviour.

(2) Spawning phase. The spawning behaviour of four species of Pacific salmon (chum, pink, coho, and sockeye salmon) has been studied under experimental conditions. Courtship procedures up to the moment of releasing reproductive products and covering the eggs have been recorded in detail. Movies of the spawning behaviour of all four species were obtained allowing for detailed analysis of different activities.

In general the spawning behaviour of all four species follows a rigid pattern in which a number of steps can be recognized. This is especially the case in the female; the male changes his behaviour in relation to the speed by which the female goes through these steps.

In short, the steps during a spawning sequence of a female are the following:

1. Searching. Swimming slowly over gravel beds, apparently looking for a place to build a nest.
2. Standing. Standing over gravel patch that has been chosen and defending it against other females. (Standing is not always seen.)
3. Nosing. Swimming slowly over gravel patch with head down, sometimes pushing nose into gravel, and starting to dig at different potential nest places.
4. Scraping. Swimming slowly in circles over shallow nest and scraping extended anal fin over gravel; digging is very intensive now.
5. Crouching. After circling, standing over nest and pushing extended anal fin down into deepest part of nest; digging getting less intensive.
6. Circling. Circling and concentrated digging at the deepest part of the nest, with the result of the development of a little pouch in the bottom of the pit; no more pushing down of anal fin in this phase.
7. Spawning. Digging almost stopped completely; a lot of circling with standing over nest; starting to push anal fin down again in deepest part of nest, which activity is finally accompanied with the opening of the mouth and vibrating of dorsal and anal fins; when the male joins in at this time and takes up the same position, then reproductive products are released.
8. Closing nest. Eggs are covered by female moving forward of nest and making short digging movements; movement forward is preceded by pushing anal fin down; this phase goes gradually over into phase 4 and the same pattern is followed until the next actual spawning; this happens 2 to 5 times until all the eggs are deposited by the female.

(3) Brooding phase. In the brooding phase the female moves back from the last nest and usually stands over the first nest. Digging movements are still seen once in a while extending over the whole redd. Both males and females of the same or other species of Pacific salmon are chased away in a very aggressive way.

(4) Dying phase. Few observations have been made so far on the dying phase. Under experimental conditions the brooding phase will last approximately a week to 10 days gradually going over into the dying phase which lasts about one to two days. In the latter the respiration rate increases and the fish start to lose balance.

Very little differences have been observed between the spawning behaviour of the four species studied. Differences are not so much in the form of the activities, but more in their intensity, duration and frequency. Greatest differences are found in the aggressive behaviour of the males. Two types of threat behaviour can be recognized. In one type (coho and chum salmon) the mouth is opened slightly and the black and white patterns of the inside of the mouth and the lips are displayed while the fish stand or swim parallel to each other (lateral display). Very little frontal display is seen in these two species. In the other type of threat behaviour (pink and sockeye salmon) the mouth is kept closed but the head and body are tilted upwards to display the black and white patterns on the lower jaw and belly during both lateral and frontal display.

These differences in aggressive behaviour, and some others that will not be discussed here, probably indicate a closer relationship between pink and sockeye, on one hand, and coho and chum salmon on the other hand. Furthermore, the threat behaviour of coho and chum salmon resemble that of the rainbow and some other trout very much. This may suggest that, if Dr. Neave's idea (1958) that _Oncorhynchus_ species have originated from a Salmo-ancestor is correct, the sockeye and pink salmon have changed most from this original pattern and the coho and chum least.

B. Studies on celestial orientation in sockeye smolts

Celestial phenomena have been found to play an important role in the orientation during migration of a number of animals. In 1959 some experiments were done to find out if sockeye smolts are able to use these phenomena in orientation in relation to compass directions. Since the results were very hopeful, a rather concentrated effort was made in 1960. The experiments of 1959 were partly repeated, and extended with improved equipment and better observation techniques in 1960. The tests were done with sockeye smolts caught during migration out of Great Central Lake, Babine Lake and Morrison Lake. The main experimental unit consisted of a circular, clear, plastic tank, masked around to permit vision of the sky only. The whole was placed on a rotatable cart with a hole in one side, which allowed for observations to be made lying on the bottom of the cart, face up, looking through the plastic tank from underneath.

(1) Experiments in standing fresh water with Great Central Lake sockeye smolts

Diurnal cycles were observed as follows:

(a) General swimming activity (position changes) shows a diurnal cycle with peaks around dusk and dawn. Here also the increases in activity seem to correlate with rapid decreases and increases in light intensity.

(b) Fluttering migration restlessness shows two peaks of increased activity, one around late dusk and one around late dawn, with the lowest value at midnight. There is a close relationship between the swimming and the fluttering activity.

(c) Food catching shows an increase in the late afternoon and early dusk and is at a low during the rest of the day.

(d) Dashing, which is probably an escape activity (overflow escape activity?) shows a rapid increase during the dusk period, decreasing during the night and dawn hours and staying relatively low during the daylight hours.

(e) Yawning shows the same trend as food catching.

(f) Surface nipping was not shown very much and had no apparent diurnal cycle.

(g) From the trends in the different activities of the 1959 and 1960 tests and evidences of diurnal migration patterns in nature, it was concluded that the highest increase in activity occurs in the late afternoon and around dusk. Best results could probably be expected during these periods when testing possibilities of celestial orientation. Therefore, all the following experiments were started at noon and terminatedeither after the late dusk or midnight period.

Directional preferences (pointing). Only the directional preferences for pointing have so far been analysed. For the following results the 1200-1500 hour (Pacific Standard Time) and early dusk observation periods are added together. The data are further divided into those obtained under cloud cover conditions of 0-5 or 0-6 and 6-10 or 7-10, respectively.

Tests I to IX done on the roof of the Biological Station at Nanaimo show a N to NE directional preference and tests X to XIII done near the field camp in Stamp Lagoon show a NE to E preference for cloud covers 0-5. The main axis of Great Central Lake lies from W to E but before reaching the outlets, Stamp River and Robertson Creek, the fish have to pass through lagoons, both lying in a northerly direction. The fish used for the tests I-XI were smolts that were taking the Stamp River exit and those used for tests XI-XIII were taking the Robertson Creek exit. So it appears that the directional preferences of the sockeye smolts tested correlate with the direction in which they have to swim to get out of Great Central Lake.

Tests done later in the season with fish that were at the tail end of the migration of sockeye smolts from Great Central Lake show directional preferences far more southwards, namely SE to S, with cloud covers of 0-6.

The directional preferences for the observations with cloud covers 6-10 or 7-10 show generally much more scattered patterns than the ones with less cloud covers.

(2) Experiments in standing salt water with Great Central Lake sockeye smolts

All these tests were done on the roof of the Biological Station from June 28 to July 20. The smolts used were from the same group as the fish used for tests I to IX but they were kept in salt water for one month prior to use in the tests. The following results on directional preferences are again based on observations in the 1200-1500 hour and the early dusk periods. Activity differences have not been analysed yet.

The tests in salt water show a southern directional preference with cloud covers from 0-5. Observations during more overcast periods still show a high southern preference together with a northeastern.

These results are very much the same as those obtained in 1959 in salt water (test X-XII, the only tests for which pointings were recorded in 1959). The southern directional preference correlates nicely with the direction the fish have to swim to get out of the next big body of water, namely Alberni Inlet.

When the fresh water and salt water directional preferences (with cloud cover 0-5) for Great Central Lake sockeye smolts are compared with each other in time, it is interesting to note that there is more or less a gradual change in preference from N to S, over a period of about three months, April 14 to July 20. Fish from the same group that were tested in fresh water in late April and early May, then showing a N directional preference, changed over in salt water in early July to a S preference. This correlates nicely with the change in orientation the sockeye smolts have to make to reach the sea starting from their fresh water nursery areas.

With some precautions it is concluded a) that the directional preferences of sockeye smolts under experimental conditions correlate with the compass directions in which the fish have to swim to get to sea, b) that these directions are found with help of celestial phenomena, c) that celestial phenomena alone are probably not enough to inform the fish about its geographical position (compare Great Central Lake tests and Nanaimo tests), d) that there is a change in preferred direction related to time and to change to salt water and e) that this orientation mechanism is an innate pattern.

(3) Experiments in standing fresh water with Babine Lake and Morrison Lake sockeye smolts

If the conclusions that the Great Central Lake sockeye smolts show inherited mechanisms for orientation which correlate with the compass direction of the geographical position of the big bodies of water through which the fish have to migrate is correct, then this probably applies to sockeye smolts of other lakes as well. Thus experiments in a big lake, with the compass direction of the main discharge axis pointing in an opposite or different direction from Great Central Lake, were planned. Babine Lake and adjacent waters fulfilled most of the requirements sought.

Tests were done at three different places in the northern part of the lake. The following results on directional preferences are again based on 1200-1500 hour (P.S.T.) and the early dusk observations.

Main directional preferences of the smolts from Nilkitkwa Lake were between NW and NE with cloud cover 0-5. Main directional preferences of the smolts caught in Morrison River just before they enter Morrison Arm were SW with cloud cover 0-6.

Thus the directional preferences of these sockeye smolts were correlated nicely with the compass direction of the main discharge axis of the bodies of water through which they have to swim to get out of the lake. The tests done with fish caught around Halifax Narrows did not show completely the expected W directional preference, but a SW to S preference, probably with a W tendency. Comparison of the separate observation periods show a main directional preference of S to SW for 1200 hours, SW to NW for 1500 hours, and W to N for the early dusk period. The number of observations is, however, too small for firm conclusions.

The directional preferences under cloud cover conditions between 6 or 7 and 10 for the Babine fence and Halifax Narrows tests are very much the same, being S to SE. The significance of this is not yet understood. It may be that overcast skies do not always interfere with orientation. The Morrison River tests show a more random directional preference.

The tests for each of the different situations for the Babine area are still few; more will be needed to be made next year to make sure that the 1960 findings are correct. There are definitely other factors than celestial phenomena playing a role in causing the fish to point or sit in a certain direction.

Some experiments were designed to obtain more information about these other factors, such as orientation to features of the tank, or a tendency to sit in the deepest part of the tank, to face the lightest part of the tank or to sit in the shaded portion. Although the data are not fully analysed yet, it appears that these factors play a role only with heavy overcast skies and cannot compete with celestial phenomena during clear skies.

The results for the midnight observations for 1960 do not show directional preferences which correlate with the late afternoon and dusk observations. Often there seems to be a tendency at night to face the lightest part of the sky.

In general it can be concluded that the Babine Lake tests support some of the ideas resulting from the Great Central Lake tests.

To summarize, these ideas can be stated as follows. Firstly, the smolts of sockeye salmon seem to have an inherited sense of direction that correlates with the compass direction of the big bodies of water these fish have to swim through during their seaward migration. Secondly, there is some sense of time or place that allows the fish to make a change in direction at the proper time. Thirdly, orientation during smolt migration is partly related to celestial phenomena.

P O L L U T I O N

M. Waldichuk

Pollution work during 1960-61 was confined mainly to analysis of existing survey data, preparation of data records, and chemical research on pollutants, particularly kraft mill effluent. An annual monitoring oceanographic survey was carried out during September in waters along the Lower Mainland of British Columbia, including the Fraser River estuary, Burrard Inlet, Howe Sound, and Malaspina Strait. A more detailed survey than in 1959 was carried out in Howe Sound, with particular reference to the waters adjacent to the pulp mills at Woodfibre and Port Mellon. For the first time, a detailed survey was made in Malaspina Strait, adjacent to the Powell River pulp mill.

Laboratory work was largely devoted to the fractionation of kraft mill effluent and its components and determination of the toxicity of the fractions.

Close co-operation was maintained during the year with the Area Director of Fisheries in consultation on problems of waste disposal from proposed new pulp mills, expansion of existing mills, and use of insecticides against forest defoliators and for spraying log booms in fresh and salt water against the ambrosia beetle.

A. Surveys

A survey with the "A.P. Knight" was conducted in the inshore waters along the Lower Mainland during the period September 6-16. This was the fourth annual survey for monitoring conditions in those waters which receive a considerable volume of domestic sewage and industrial wastes from the metropolitan areas of Vancouver. Although it was carried out earlier in the year than any of the previous surveys, at a time when one would expect the worst pollution associated with low runoff and high temperatures of late summer, this year's survey showed that relatively high dissolved oxygen concentrations were present in all areas. The cool summer and early onset of rains during 1960 probably prevented the severe oxygen depletion, which occurred during such years as 1958.

1. Fraser River estuary. Except at the western entrance to the Steveston Cannery Basin, where dissolved oxygen was at about 7.8 mg/ℓ in the bottom water, Fraser River water samples taken at all depths as far up-river as Port Mann were at nearly 100% saturation (10.5 mg/ℓ). pH values in the river were generally in the vicinity of 8.0. Although two stations gave pH values as high as 8.4, most of the samples were at a pH level less than 8.0 and somewhat lower than that found in 1959.

In the Strait of Georgia along the Fraser River estuary, the dissolved oxygen, pH and alkalinity regimes were about normal for the time of year the survey was made. There was nearly 100% dissolved oxygen saturation in the upper 10-metre layer and slightly more than 50% saturation near the bottom.

2. Burrard Inlet. The temperature, salinity, dissolved oxygen, pH and alkalinity distributions during the 1960 survey were generally similar to those observed in 1959 when the survey was carried out approximately a month later in the season. Water temperatures in the intermediate and deep water were somewhat lower in early September 1960 than they were in early October 1959, probably as

a result of the lower air temperatures preceding the more recent survey. Except in Port Moody bottom water, dissolved oxygen levels were relatively high during the 1960 survey at all stations, particularly in the surface layer at the upper end of Burrard Inlet, adjoining Indian Arm and Port Moody. At some stations in this region, supersaturation of dissolved oxygen to the extent of 190% was noted in the upper 2 metres. This supersaturation was probably due to a late-summer bloom of phytoplankton.

The near-bottom water in Port Moody was at a lower dissolved oxygen level (<3 mg/ℓ) than observed during any of the previous surveys. There was a tremendous vertical range in dissolved oxygen from 15.1 mg/ℓ at the surface to 3.0 mg/ℓ at 6 m, in the deeper parts of Port Moody. pH values showed a correspondingly large range from 8.5 at the surface to 7.5 at 6 m.

There was no evidence of large concentrations of phenol or oil in the water, from petroleum refinery wastes. Oil slicks, observed in great abundance during the 1959 survey, were absent during the 1960 observations.

Stations were occupied in the 1960 survey at the immediate approaches to the First Narrows from both the seaward and Vancouver Harbour sides. Their purpose was to provide data on the effect of tidal mixing in these narrows on the distribution of properties through Burrard Inlet. A fairly abrupt change in salinity, temperature and other variables occurred from the outer to the inner station, but some vertical stratification was evident at both stations, in spite of the turbulent mixing. It appears that water formed in the mixing area at the First Narrows contributes to the deep water in the Vancouver Harbour section of the inlet. The sill at the First Narrows prevents inflow of water at salinities greater than 29‰.

The Second Narrows forms another discontinuity in the distribution of variables through Burrard Inlet. There is nearly complete vertical homogeneity in salinity and other properties for about a mile of the inlet between Vancouver Harbour and Port Moody. Effects of mixing appear to be even greater at this constricted part of the inlet than at First Narrows.

Mixing in the two narrows of Burrard Inlet breaks the system up essentially into two vertical circulation cells. One cell lies between the Second Narrows and the upper part of Port Moody. The other spans the section through Vancouver Harbour between the two narrows. In this respect, circulation in Burrard Inlet is unlike that of the typical B. C. inlet (e.g. Alberni Inlet), where there is continuity of flow from the head to the mouth for surface water and *vice versa* for deep water. Brackish surface water leaving Port Moody mixes with saline deep water at the Second Narrows and returns in part to the deep zone of Port Moody. The same process repeats at the First Narrows, where surface Vancouver Harbour water mixes with saline, deep Strait of Georgia coastal water to form the mixture that enters the deep zone of the harbour.

3. Howe Sound. Following the preliminary survey of 1959, a more detailed survey was conducted in Howe Sound during 1960, especially in those areas adjacent to the two pulp mills at Woodfibre and Port Mellon. More interest is being focussed on this whole area from the point of view of industrial expansion and conservation of the fisheries.

The pocket of very low dissolved oxygen was noted again in the bottom water in the upper end of Howe Sound. A water sample taken at the first station behind the inner sill had a dissolved oxygen content of 0.8 mg/ℓ and a pH of 7.1 at 240 m, indicating relatively stagnant conditions. At the uppermost station occupied, a dissolved oxygen concentration of virtually zero was noted at a depth of 100 m. On outer stations, seaward of the inner sill, the dissolved oxygen was generally slightly higher than 5.0 mg/ℓ at 100 m.

A line of stations occupied along the west side of Howe Sound, past Port Mellon, gave a vertical dissolved oxygen distribution typical of the wide, well-ventilated portion of Howe Sound. At a depth of 200 m, dissolved oxygen was at about 4.6 mg/ℓ and pH at 7.6. There was no evidence of harmful effects arising out of effluent disposal from the kraft pulp mill at Port Mellon. (The pulp mill at Woodfibre is at present undergoing conversion from sulphite to kraft and was not in operation during the survey.)

4. Malaspina Strait. A survey was conducted in Malaspina Strait, at the approaches to the Powell River pulp mill, for the first time since early Strait of Georgia surveys broadly included the area. Distributions of various properties appeared to be normal with no noticeable effect from the pulp mill waste disposal. This was as expected, inasmuch as the shores along this part of the Strait of Georgia are well exposed and there is rapid replacement of surface waters and no stagnation of deep water.

Dissolved oxygen concentrations in the surface waters at all stations were at levels of at least 100% saturation (9.5 mg/ℓ) and, in some cases, considerably supersaturated (11.5 mg/ℓ). Deep waters at depths greater than 100 m usually exhibited dissolved oxygen values of 4 to 5 mg/ℓ or 40 to 50% of saturation.

B. Analysis of seasonal and long-term changes

1. Alberni Harbour. Interest in Alberni Harbour increased during 1960, with the announcement by the MacMillan, Bloedel and Powell River Co. that expansion would soon take place in newsprint production. While there were no obvious incidents to suggest a serious threat of pollution in Alberni Harbour during 1960, it was probably mainly the effect of a wet, cool summer that prevented conditions from becoming critical. A heavy deposition of fibres and other particulate materials continues in the upper end of the harbour adjacent to the pulp mill.

No formal surveys of Alberni Harbour were made during 1960, except for one surface sampling cruise in May to determine kraft mill effluent distribution. However, the weekly sampling program at a station in mid-harbour was continued during the summer with the co-operation from the pulp mill technical staff. Winter sampling was changed from weekly to monthly during 1960-61, because it was not anticipated that trouble would arise during the cold, wet months. The original program of sampling for dissolved oxygen and biochemical oxygen demand in the Somass River and at the Alberni Harbour station was expanded early in 1960 to include temperature, salinity, and kraft mill effluent concentrations at three depths (surface, 10 and 35 ft) at the latter station.

There is evidence that the deep water, which does not undergo frequent flushing, is becoming progressively lower in dissolved oxygen content. Moreover, this oxygen-poor layer appears to be thickening from the bottom up. This is apparent in the dissolved oxygen concentrations, as low as 3.0 mg/ℓ, noted at 10 ft depth. While the bottom (35 ft) water appears to be normally free of kraft mill effluent (KME) as evidenced in the nitrosolignin test, there is frequently a relatively high concentration of KME at 10 ft depth.

Although the station used for monitoring conditions in mid-Alberni Harbour is about 1 mile from the core of heavy pollution in the area, it does provide a reasonably good index of the changing environment of the harbour as a whole. However, there is increasing local pollution in the vicinity of the pulp mill outfall resulting from heavy deposition of suspended materials from the effluent stream and general deterioration of bottom materials. It is planned to study this area more intensively.

A preliminary analysis has been made of the year-to-year changes in Alberni Inlet, which have occurred since the pulp mill went into operation. There has been a marked decline in the amount of dissolved oxygen present in the lower half of the water column from the 1954 to the 1959 survey. During the first survey, the range was between 4 and 5 mg/ℓ in the bottom 10 ft, while in 1959 it was only 2 to 3 mg/ℓ. There was a corresponding drop in pH.

Data taken during pre-pulp mill days in 1939 and 1941 have been compared with recent data for an estimate of long-term changes. It is surprising that remarkably low dissolved oxygen concentrations (1.7 to 2.0 mg/ℓ) were found in the bottom water even during that early period. However, this oxygen-poor water appeared to be confined to a fairly thin bottom layer with rapidly increasing concentrations above it. A comparison of dissolved oxygen at 20 ft depth during 1941 with that in 1959 shows a drop from about 5 mg/ℓ to 3 mg/ℓ. pH levels near the bottom were generally in the normal range for sea water in 1941 at 7.9 to 8.1, compared to values of 7.6 to 7.7 in 1959. There has also been a comparable drop in pH at the surface, where direct and immediate effect of the pulp mill effluent takes place.

2. Osborn Bay-Stuart Channel. Water analysis for KME (kraft mill effluent) at various strategic points in the Crofton area, on approximately a monthly basis, has continued during 1960-61 in connection with oyster condition studies carried on by the Marine Invertebrates Investigation. There has been a slight increase in the KME concentration in waters adjacent to the pulp mill outfall during the last year. This trend may be associated with an increase in production of the pulp mill and/or a gradual accumulation of pulp mill wastes in the receiving waters.

There was a marked difference in KME concentrations observed during low and high tides in a May sampling operation. Concentrations were approximately 1 1/2 times as high during low tide as they were at high tide in the vicinity of oyster leases as well as in deeper water. This indicates that removal of the wastes by tidal flushing can introduce considerable variability into KME values, depending on the stage of tide when the water samples are collected.

C. Chemical research on pollutants

1. Kraft pulp mill effluent

A. E. Werner

Research on this pollutant entered a new phase consisting of separation of total kraft mill effluent and some of its components into chemically different fractions, followed by a preliminary evaluation of their toxicology. Various chemical and instrumental techniques have been used in an effort to identify the numerous compounds present. Bioassay tests on the fractions have been carried out using the fresh-water crustacean, Daphnia pulex, to arrive at a gross index of toxicity.

(a) "Unbleached" kraft mill effluent. Total effluent from a full-bleach kraft pulp mill consists of several main components, which originate from the digestors, recausticizing unit, bleach plant and general mill sewage. Inasmuch as the bleach plant effluent was found to be less toxic than the other mill wastes, the separation procedure was eventually applied to kraft mill effluent without the bleach fraction, referred to as unbleached KME.

Several consecutive steps were designed for removing whole groups of substances having similar physical and chemical properties. The problem of redispersing some of the poorly-miscible fractions in the water for bioassay was overcome by steam distilling them. After each step, the separated fractions and residue were tested for toxicity (Table I).

Volatile components were separated by carrier distillation and trapped by freezing. Solids were removed by filtration. Certain groups of non-polar compounds were removed from the filtrate by solvent extraction; others were removed by steam distillation with and without preliminary acidification. Cations and anions were pregressively removed by ion exchangers and recovered by elution. The remaining liquid was vacuum distilled to separate neutral, water-soluble substances. Table I shows the scheme of separation.

Preliminary results have shown varying degrees of toxicity of different fractions. It appears that a major toxic principle of unbleached KME can be separated by steam distillation. This toxic substance is unstable to heat and/or oxidation and is partly extractable with hexane. A trace of steam volatile, hexane-insoluble, toxic cation is probably also present.

(b) Kraft black liquor. The dark, viscous fluid, resulting from cooking of wood chips by the kraft (sulphate) process, is called "black liquor" in the pulp trade. It is normally evaporated and burned for recovery of its fuel value and chemicals. Small amounts escape to the sewer from the pulp washing and screening process. As an odour abatement measure, black liquor is now commonly passed through oxidation towers in order to destroy some of the malodoriferous, sulphur-containing compounds.

It has been found that toxicity of total KME stems largely from its black liquor content. Therefore, it was found expedient to use black liquor, where the toxins are more concentrated, for the fractionation and identification procedures, instead of the highly dilute effluent.

The toxicity of black liquor is known to (1) vary in different mill samples, (2) decline on storage, and (3) decline on aeration. These phenomena

Table I. Fractionation procedure for kraft mill effluent analysis, and toxicity of fractions.

Operation (Substances removed)	Fraction Removed		Fractions Remaining	
	Toxicity*	Fraction code	Toxicity*	Fraction code
			T	K.M.E.
Carrier distillation with nitrogen (non-acidic volatiles)	NT	BR1	T	B1
Filtration (Solids)	NT	FR2	T	F2
Solvent extraction (Solvent-soluble organic substances)	NT	ER3	Sl.T	E3
Anion exchange with strongly basic resin [Cl⁻] (Anions)	NT	SAR4	NT	SA4
Anion exchange with weakly basic resin [OH⁻] (Neutralization process removed added HCl)	NT	WAR5	NT	WA5
Vacuum distillation (Neutral non-volatiles)	NT	DVR6	NT	DV6
Cation exchange with strongly acid resin [H⁺] (Cations)	Sl.T	DCR4	NT	DC4
Steam distillation from alkaline medium (Neutral volatiles)	T	SDR4	T	SD4
Steam distillation from acidic medium (Acidic volatiles)	NT	SDR5	NT	SD5

* T = toxic
NT = non toxic

Sl.T = slightly toxic

[a] Circles indicate point of separation

are connected with the oxidation of sulphide (and polysulphide) ions in the oxidation towers of the pulp mill.

(i) Sampling device. In order to prevent the rapid decomposition on exposure to air of the toxic compounds present in black liquor, a special sampling device was designed and constructed. It consists basically of a unit permitting the liquor to be collected and dispensed under an atmosphere of nitrogen. Thus sampling under completely anaerobic conditions is possible.

(ii) Analytical methods

(A) Toxic reducing compounds. Development of a simple, chemical method for predicting the probable toxicity of black liquor samples was started. The proposed method consists of steam distilling the sample and oxidimetrically titrating the distillate. It was assumed that the amount of oxidant solution reduced is related to the concentration of toxic compounds present in the black liquor.

(B) Sulphur compounds. An analytical separation method for some of the inorganic sulphur compounds was evolved and tested. The flow diagram for this method is given in Table II.

When unoxidized black liquor is acidified, hydrogen sulphide evolves and sulphur may precipitate from any polysulphide or thiosulphate ions present. Thiosulphate was detected in unoxidized black liquor by precipitation with nickel ethylene diamine nitrate reagent. No evolution of sulphur dioxide has been observed, because this gas reacts at once with lignin to give lignin sulphonic acids. The presence of non-precipitating lignin fractions in oxidized black liquor would be explained by this reaction.

(iii) Progressive reductive acidification. When carbon dioxide is passed into oxidized black liquor, the smell of mercaptans is replaced by a phenolic odour, and after a few minutes, gelling occurs. There is no immediate precipitation of lignin. With similar treatment of unoxidized black liquor, much hydrogen sulphide is released, but complete removal is difficult. Precipitation of lignin is more rapid and heavier than with oxidized black liquor. Subsequent addition of 5% hydrochloric acid failed to release further hydrogen sulphide in either case. Extraction of the acidified mixture with benzene gave a bright yellow, organic extract, which did not contain sulphur. Oxidized black liquor, on acidification, did not yield enough hydrogen sulphide to blacken lead paper whether or not pretreated with carbon dioxide. Other weak acids (acetic, boric, benzoic) were investigated and proved less advantageous than carbonic acid for splitting thiosulphate ion.

Lignin sulphonate formation was prevented by addition of magnesium metal to the black liquor prior to acidification with carbon dioxide. Such treatment resulted in release of all the sulphide and thiosulphate sulphur as hydrogen sulphide from both the oxidized and unoxidized black liquor. The completeness of removal was proved by subsequent acidification with 5% hydrochloric acid, when neither sulphur nor sulphur dioxide separated. Excess of reducing agent and its reaction products was removed by filtration. The use of other metals (Fe, Al) for reduction was not successful. Reduction of some of the organic components is believed to be small, in the light of the chromatographic evidence given in a later section. The whole separation scheme is illustrated in Table III.

Table II. Separation scheme for inorganic sulphur compounds in black liquor.

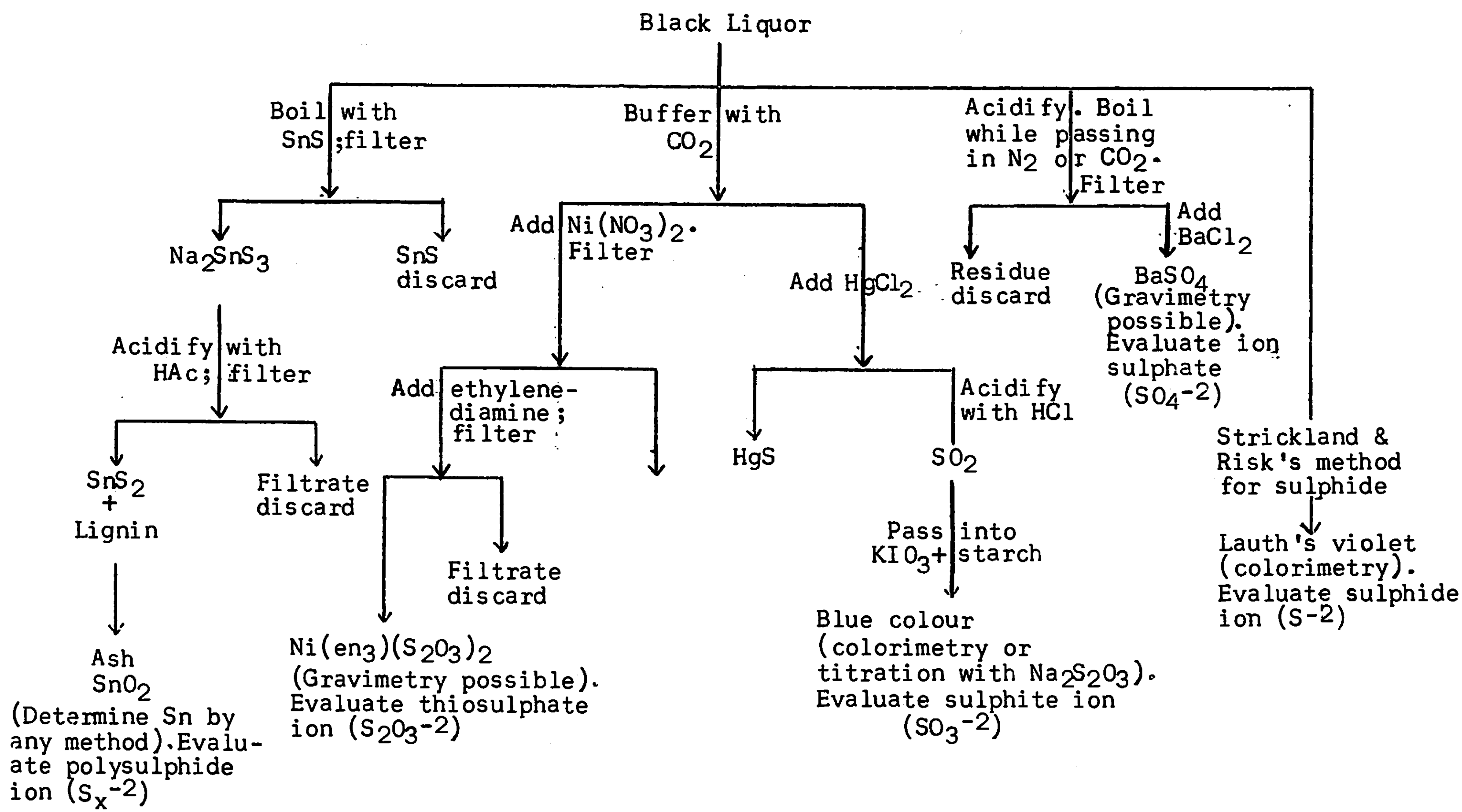
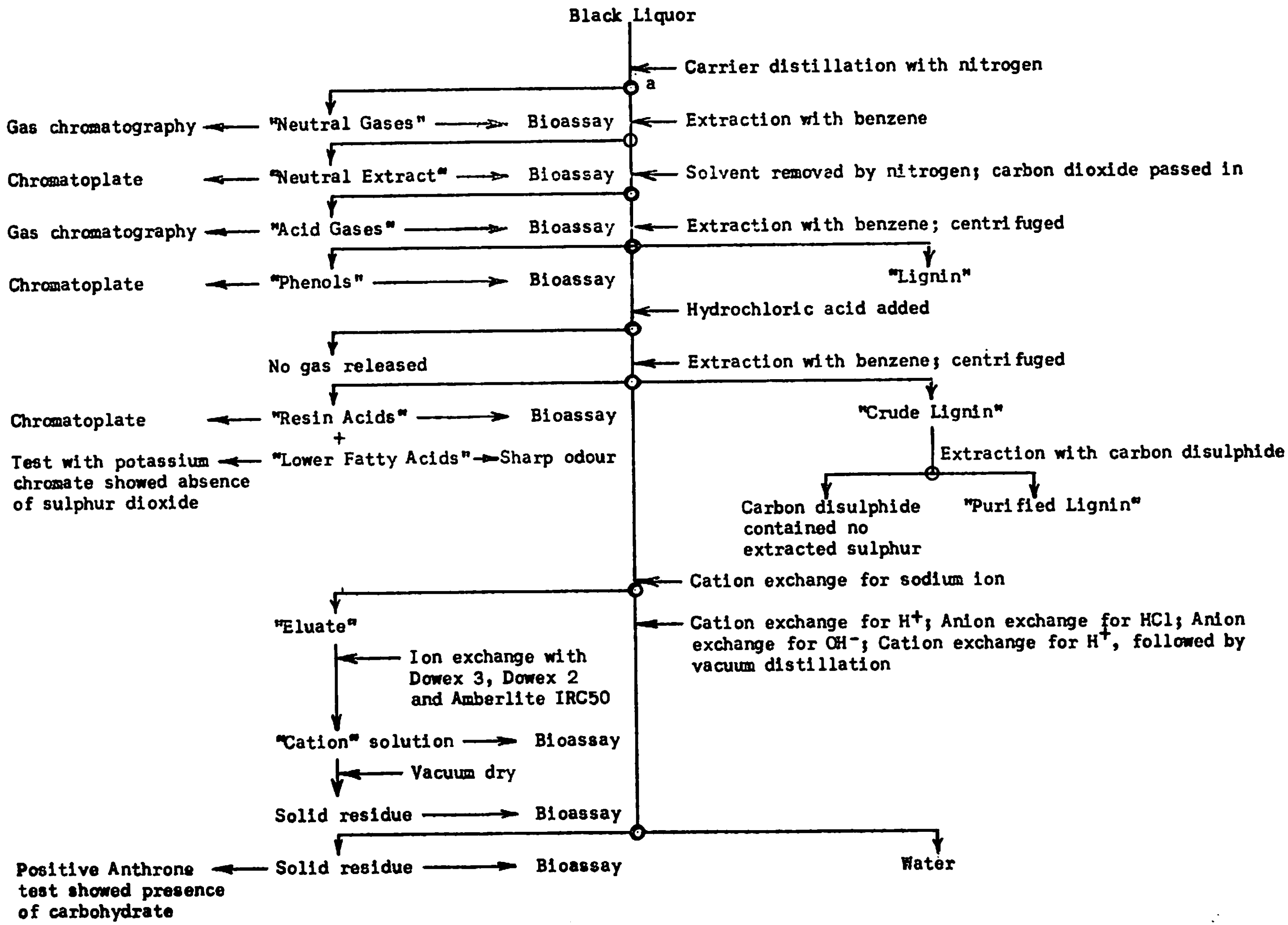


Table III. Fractionation of unoxidized black liquor



[a] Circles indicate points of separation.

(iv) Toxic fractions. Most of the fractions separated were mixtures of several components. Attention was directed mainly to those fractions with toxic properties. They can be classified according to the following:

(A) Gases. Direct carrier distillation of kraft mill effluent and black liquor with nitrogen and freezing of the distillate did not yield a toxic gas. However, upon acidification with hydrochloric, citric or carbonic acids, a toxic gas evolved (Table IV).

Table IV. Toxicity to *Daphnia* of gases evolved from black liquor.

Preparation	Exposure time	Percentage mortality
Alkaline black liquor	45 min	0%
" " "	48 hr	0
Acidic " "	<1 min	100

Only hydrogen sulphide and methyl mercaptan have been identified in it by gas chromatography (Fig. 1).

(B) Solvent extracts. Extraction with organic solvents (benzene, ether, hexane) of black liquor and kraft mill effluent yielded a series of extracts. Vacuum distillation was the first additional separation procedure applied to them. Apart from demonstrating the composite nature of these extracts, it was relatively inconclusive (Table V).

Table V. Micro vacuum distillation of ether extract of kraft mill effluent.

Temperature °C	Pressure mm Hg	Remarks	
		Distillate	Residue
100	0.20	1st Fraction: colourless	
140	"	2nd " : "	
200	"	3rd " : yellow	
220	"	4th " : "	
234	"		Boiling stops; no charring
218-222	0.10		Dark; partly soluble in aqueous alcoholic sodium hydroxide; partly soluble in acetone.
200-205	0.18	greenish yellow	

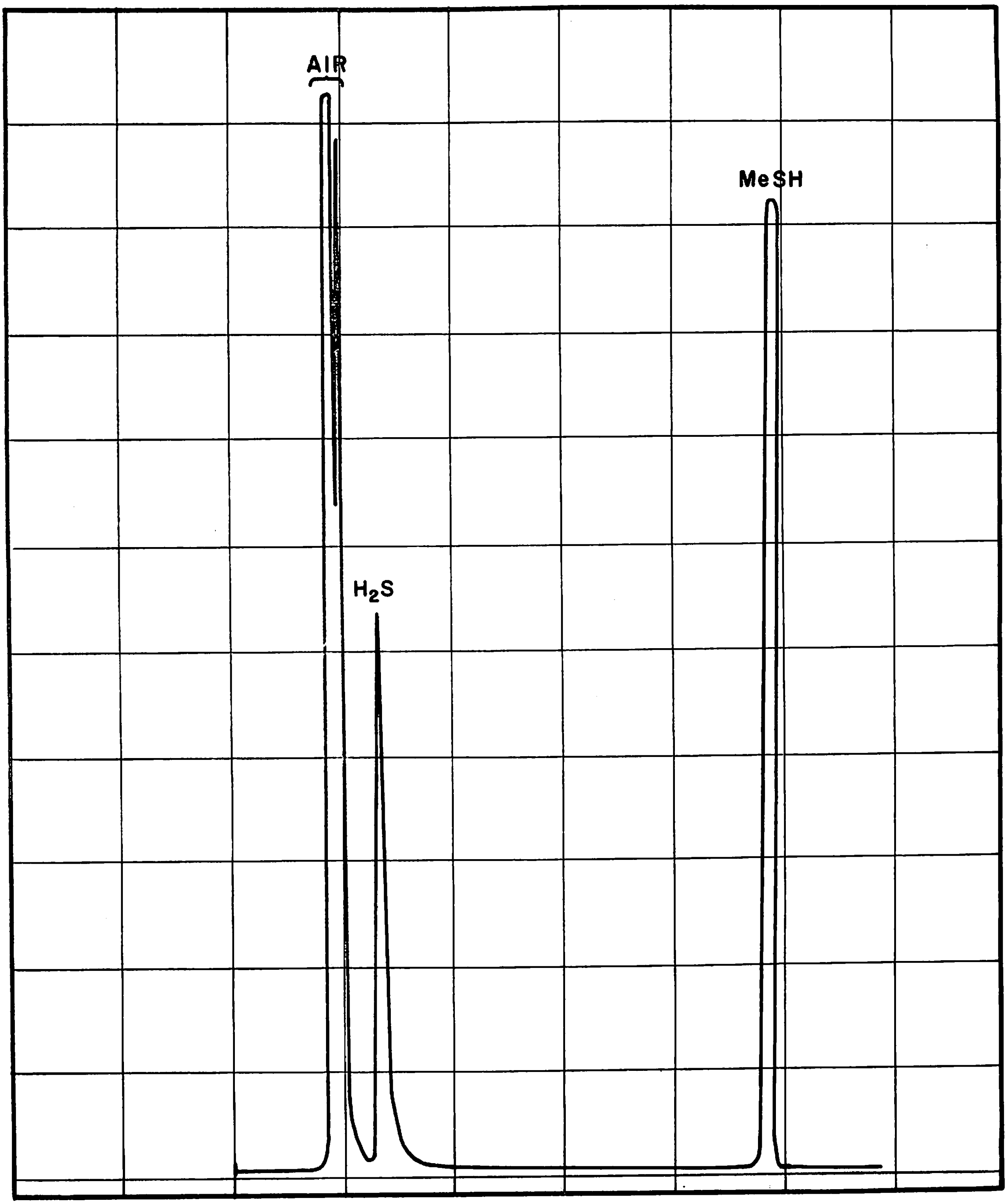


Figure 1. Gas chromatogram of vapour phase from acidified, unoxidized black liquor. (Column: 6 ft; Packing: silicone on fire brick; Carrier: helium; Temperature: 40°C)

Ultraviolet and infrared spectroscopy revealed the presence of aromatic ring systems and an absorption maximum indicative of neoabietic acid [Fig. 2(A) and 2(B)]. Spot tests were applied which shed some light on the functional groups present (Table VI). Column chromatography on silicic acid, with a series of solvents of increasing dielectric constant, split the mixture into several components [Fig. 2(C)]. Some of these components had an odour of dry wood, others of eugenol.

Information obtained by column chromatography was used in setting up chromatoplate experiments, which resulted in separation of at least 6 different compounds [Fig. 2(D)]. It was noted that, with the exception of one spot, all fractions of the non-reduced "neutrals" coincided with those of the "phenols" and "resin acids". This suggests that no reduction of the substances by the magnesium-carbon dioxide treatment had taken place.

(C) Cation. A slightly toxic, weakly basic substance was isolated from black liquor by ion exchange. In a concentration 490 times that present in black liquor, this substance killed 50% of the *Daphnia* in 1 hour. It is probable that this estimate is low as the toxicity declines rather rapidly (Table VII). Isolation was possible because the substance is lightly held by sulphonic-acid type cation exchangers, passing other exchangers freely (Table VIII).

The final solution of the purified toxin was concentrated by vacuum evaporation. During this process, some loss by thermal decomposition occurred as witnessed by the appearance of a terpene-like odour. It is believed that freeze drying would be more satisfactory for effecting concentration. When the α-pinene, present in black liquor from the pulped wood, is passed through oxidation towers of a mill, some pinol hydrate (i-l-p-menthene 6, 8 diol) is probably formed. This substance can be dehydrated to the ether pinol, which may contribute the terpene odour referred to above. Further investigation of the material will be pursued by gas chromatography.

(D) Steam distillates. Some toxic principles of black liquor were separated by steam distillation. Acidification of the remaining, non-toxic liquid failed to release any further toxic, steam-volatile substances. The toxic steam distillate gave a foam stable to alkali and anion-active dispersers. Acids or cation-active emulsifiers caused collapse of the foam. This suggests that the active ingredient itself is anion-active, which corresponds with the finding of the neoabietic acid peak in the infrared spectrum.

2. Phenol determination in sea water

M. Waldichuk

The 4-aminoantipyrine (4-AAP) test for phenols was evaluated for its applicability to phenol determination in sea water. A considerable colour suppression occurs in standards made up in sea water, which is presumably a salt effect. Standards in average coastal sea water (ca. 25‰ salinity) gave an absorbance on the spectrophotometer 25% lower on the average than in distilled water. A synthetic sea water at 30‰ salinity gave a slope for phenol standards similar to that for standards in natural sea water of the same salinity. This indicates that it is necessary to make up phenol standards in either artificial sea water or in phenol-free sea water in order that phenol determinations in sea water be valid.

Table VI. Spot tests on ether extracts of kraft mill effluent.

Test	Observation	Conclusion	Remarks
Bromine in CCl_4	rapid discoloration, no HCl	unsaturation	
Phosphomolyblic acid, NH_4OH	blue colour	reducing groups	
Trioxane in H_2SO_4	red	aromatic ring	
Friedel-Craft with $CHCl_3$	reddish-purple-brown	benzene, phenanthrene ring	
Storch-Morawski	reddish	resin acids	
Digitonin in EtOH	slight white precipitate	3 β-hydroxy sterol	
Ceric nitrate	no colour	no lower alcohols	
Ferric chloride in $CHCl_3$	no colour	no phenols	test not given by all phenols
Nitrous acid in H_2SO_4, alkali	dark brown	p-substituted phenol	
Millon's reagent	yellow	p-substituted phenol	
Cobaltinitrite, $CHCl_3$	brown	phenol with open ortho position	
Benzoyl peroxide fusion (a),(b)	(a) violet; (b) purple	methoxy group	(a) chromotropic acid; (b) Schiff's reagent
Rhodamine B in C_6H_6	pink	carboxyl group	
Hydroxamic acid (a)	dark violet	carboxyl group	peculiar sec. octanol odour
Resorcinol fusion; alkali	green fluorescence	o-or peri-dicarboxylic group	
Hydroxamic acid (b)	no colour	no anhydride	test later positive
Hydroxamic acid (c)	violet	ester groups	
Bisulphate fusion, then nitro-prusside + morpholine reagent	blue	glyceride	test on hexane extract
Sodium fusion, then nitro-prusside; Ag^+; Pb^{++}	brown; brown; yellow	sulphur	test inconclusive
Cuprous chloride	yellow	Thiol or Thion group	minute quantities only
Ammonium molybdate reagent	no colour	no Xanthate	
Formate fusion + Gardner's reagent	blue colour	sulphonic acid group	test negative on repetition

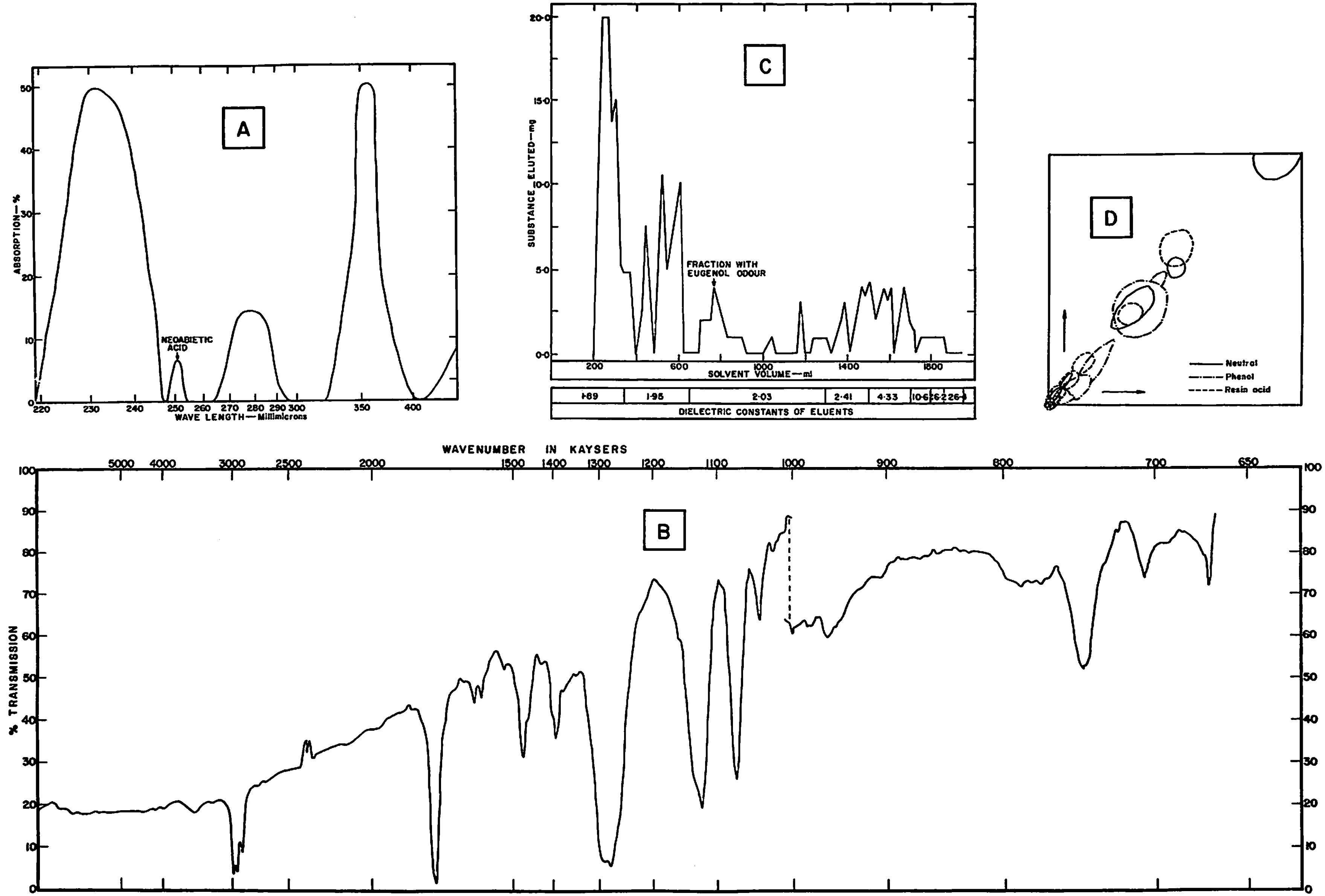


Figure 2. Some chemical characteristics of solvent extract fractions of black liquor.
(A) Ultraviolet spectrum
(B) Infrared spectrum
(C) Silicic acid column chromatogram
(D) Chromatoplate spots. (Silicic acid, 25% ether in hexane and Gardner's spray with 2-dimensional development)

Table VII. Decline of toxicity of cation to *Daphnia*.

Material	Age	Exposure time	Percentage mortality
Cation solution	Freshly prepared	4 min	100%
" "	6 days old	27	100
Control	Freshly prepared	4	0
"	6 days old	27	0

Table VIII. Effect of cation exchangers.

Material	Solution Preparation					Bioassay	
	Conc. %	Column	Condition	pH adjustment	Passes	Exposure time	% mortality
"Phenol-free" oxidized black liquor	100%	--	--	--	--	30 min; 12 hr	0;100
"	100	Dowex 50W	Na^+	--	--	" "	0;0
"	5	--	--	--	--	" "	0;100
"	5	Amberlite ICR50	Na^+	--	--	" "	0;100
Isolated toxin solution	Unknown[a]	Dowex 50W	H^+	7	1st	13 min[b]	100
"	"	"	H^+	7	2nd	6 min	100
"	"	Amberlite ICR50	H^+	7	1st	7 1/2 min	100
"	"	" "	H^+	7	2nd	7 1/2 min	100

a Concentration was the same in the last 4 cases, but unknown.

b Exposure times in the last 4 cases are given to 100% mortality.

The stability of phenol solutions and extracts was checked. It was found that aqueous phenol solutions are quite unstable and determinations should be carried out on them as soon as possible, within at most six hours. However, the chloroform extracts were quite stable and virtually no change in absorbance occurred during one or two days of standing under normal laboratory conditions. Over a period of 17 days' standing, there was an average absorbance reduction of 1% in a set of standards stored in the laboratory.

The simple nitroso test used for spent sulphite liquor determination has been found to be quite satisfactory for concentrations of phenol in the range of 100 parts per billion and upward. This appears to be by far the fastest and most routine test when intermediate or high concentrations of phenol are present and the great sensitivity of the 4-AAP test is not required.

The 4-AAP test for phenols was tried out on samples containing black liquor and total kraft mill effluent in sea water. Although there was a positive response, a slurry-like substance was formed during chloroform extraction which interfered seriously with filtration. The technique does not overcome the background interference problem, which exists with the nitroso method, in determination of kraft mill effluent in sea water.

D. Radioactivity

M. Waldichuk

Problems connected with radioactive pollution in the sea have been kept under review, although no active research has been conducted here in this field.

1. Radioactive waste disposal. Interest in the problem of sea disposal of low-level radioactive wastes has been maintained through literature surveys, participation in committee work, and attendance at a symposium. A number of reviews and theoretical evaluations on certain aspects of radioactive waste disposal have been completed. These are being released as circulars and manuscript reports. The report of the Pacific Coast Subcommittee on Sea Disposal of Low-Level Radioactive Wastes, on which the writer served, is being published by the U. S. National Academy of Sciences.

2. Radioactivity in marine fish and shellfish. Salmon and shellfish samples have been collected from various points near Nanaimo for radiological analysis. These, along with sockeye samples from the Bering Sea and Alaska, have been submitted for analysis at the low-level radiation laboratory of Atomic Energy of Canada Ltd., Chalk River. Preliminary results of these analyses are given in Table IX with a comparison of analyses on molluscan shellfish collected elsewhere and on fresh-water fish.

Only zinc-65 appears to be significant among the radioisotopes found in marine fish and shellfish. The early analyses for zinc-65 in canned Pacific salmon, which prompted investigation of radioactivity in fresh fish and shellfish from the Pacific coast, gave much higher values than found so far in uncanned samples. Zinc-65 in Pacific oysters seems to be related to the distance the oysters were located from the Columbia River, the B. C. samples having concentrations somewhat lower than those in Puget Sound and much lower than those collected in Willapa Bay, Washington. The maximum zinc-65 concentrations found in B. C. oysters are about 16,500 lower than the maximum permissible concentration when oysters are used fairly steadily in the human diet.

Table IX. Radiological analyses of fish and shellfish samples

Species	Origin	Date	Concentration of Radioisotopes[a]					
			Strontium-90		Cesium-137		Zinc-65	
			μμc/kg	μμc/kgCa	μμc/kg	μμc/kgK	μμc/kg	μμc/kg
Salmon, pink, canned	B. C.	(1959)?	--	--	--	13	200-500	--
Salmon, coho, canned	B. C.	(1959)?	1.5	0.5	--	2	420	--
Salmon, sockeye, fresh[b]	Alaska	Aug. 1959	--	--	75	18	60	--
Tuna	Japan	?	--	--	--	8	nil	--
Perch	Ottawa River, Ont.	1960	28	35	1,000	550	nil	--
Butter clams[b]	Departure Bay, B. C.	Jul. 1960	--	--	nil	nil	6	--
Razor clams[c]	Copalis Beach, Wash.	Jan. 1960	--	--	--	--	8,000[d]	14,000[e]
Pacific oysters[b]	Ladysmith, B. C.	Jul. 1960	--	--	nil	nil	360	--
Pacific oysters[b]	Denman Island, B. C.	Jul. 1960	--	--	nil	nil	130	--
Pacific oysters[c]	Willapa Harbour, Wash.	Jan. 1960	--	--	--	--	58,000	--
Pacific oysters[c]	Olympia, Wash.	Jan. 1960	--	--	--	--	500	--
Eastern oysters[c]	Chesapeake Bay, Md.	Jan. 1959	--	--	--	--	178	--

a Concentrations are given in micromicrocuries per kilogram (μμc/kg) in all cases, with additional data on micromicrocuries per kilogram of calcium for Sr^{90} (μμc/kgCa) and micromicrocuries per kilogram of potassium for Cs^{137} (μμc/kgK).

b Samples sent in from Nanaimo and analyzed at Chalk River.

c Data taken from literature.

d Analysis on muscle tissue.

e Analysis on soft tissue other than muscle.

MARINE COMMERCIAL FISHERIES - K.S. Ketchen
HERRING - F.H.C. Taylor

The object of herring research has been to provide the scientific basis for a management program designed to permit the greatest catch possible from all stocks under conditions which will promote maximum recruitment.

Results to date have indicated that at existing fishing intensities restrictions on catch are probably not necessary. No direct relationship has been found between the numbers of spawners and the strength of the resulting year-class in any population, with the possible exception of that of the upper central district. Year-class strength appears to be determined by natural factors, possibly during the larval stage, rather than by any effect of the fishery. The size of the catch depends in turn upon the strength of the dominant contributing year-classes. However, since in most populations the total mortality rate in recent years has been estimated to be at least 80%, it does not appear that further substantial increases in fishing effort can result without the spawning escapement being greatly reduced, possibly to dangerous levels.

Existing data for any population do not show at what spawning stock size a direct relationship to recruitment will result. Therefore, before a definite conclusion can be reached on the need for catch quotas in the herring fishery, and before recommendations on this subject can be made, a large-scale experiment, in which fishing intensity is allowed to increase and is manipulated so as to produce readily recognizable effects on spawning stock size, is required to determine at least in one population the relationship between size of spawning stock and resulting recruitment.

At the present time emphasis in research is placed on continuing programs designed to assess both the level of abundance in each population (from data on catch and spawn deposition) and the strengths of the contributing year-classes. A program to study the distribution and abundance of herring during the summer months off the west coast of Vancouver Island was continued a second year in 1960.

The herring investigation group is responsible for the preparation of material required in connection with the Canadian reports to the International North Pacific Fisheries Commission on the qualification of British Columbia herring stocks for abstention by Japan.

A comprehensive review of the investigation and management of the British Columbia herring fishery was prepared for presentation to the British Columbia Herring Management Committee between November 1959 and May 1960.

The data presented in this report are mainly for the 1959-60 herring fishing season (from May 1959 to March 1960) and on two offshore cruises in the summer of 1960.

A. Continuing Programs

1. The 1959-60 fishery

J. S. Rees

The 1959-60 herring season was seriously affected by industrial disputes. Only one company, the Prince Rupert Fishermens' Co-operative Association, operated normally. Price negotiations drastically limited the summer fishery and delayed the start of the winter fishery until October 6. In December, the companies announced that, because of the sharp decline in price on the world market for fish meal and oil, herring fishing would not be resumed after the Christmas closure unless a new agreement providing them some relief in costs was negotiated. No agreement was reached during the 1959-60 season.

Nearly the entire summer catch of 4,774 tons was taken by the Prince Rupert Fishermen's Co-operative Association from Area 5.

The total winter catch (Table I) amounted to 180,295 tons, only 8,000 tons less than the average catch for the past seven years but 28,000 tons below the 1958-59 winter catch. Of this total, 160,897 tons were caught before the Christmas closure and 19,398 tons after. The Prince Rupert Fishermens' Co-operative Association was responsible for the bulk of the post-Christmas catch, although one other company did operate for a brief period.

The large pre-Christmas catch was the result of good fishing in the middle and lower east coast and upper and lower west coast of Vancouver Island sub-districts. The middle east coast yielded 19,915 tons (twice the quota of 10,000 tons) and the lower east coast 55,083 tons (15,000 tons over the quota) in a fishery lasting from October 6 to November 9. Only 250 tons of a 3,000-ton quota extension for food purposes were taken. The catch in the lower west coast of Vancouver Island sub-district was 19,458 tons, about average, although less than half the second catch of the preceding season. The upper west coast catch was 42,046 tons - greater even than the previous record of 35,684 tons in 1958-59. Catch per unit of effort in these sub-districts was as high or higher than in the previous year (Table I).

Of the post-Christmas catch of 19,398 tons, 14,309 tons were taken in the northern sub-district, 2,584 tons in the Queen Charlotte Islands (Skidegate Inlet), 1,123 tons in the upper central and 648 tons in the lower central sub-districts. The total 1959-60 catch from the northern sub-district (23,504 tons) was about average; of this 4,446 tons were taken in the summer fishery, 4,749 tons in the pre-Christmas winter fishery and 14,309 tons after Christmas. The catch from the upper central sub-district, mostly taken before Christmas, was also about average for the last 7 years (Table I). The lower central was probably the only sub-district, with the exception of the Queen Charlotte Islands, not fully exploited in 1959-60 because of economic factors. The main fishery here usually develops after Christmas, relatively late in the season.

During the winter fishery of 1959-60, nearly all herring seiners were equipped with mercury vapour lights (usually four) for "pit-lamping". This is the first season in which virtually the entire fleet has been equipped with extra lights. In previous seasons this technique had been used by some boats on a more limited scale. Mercury vapour lamps were thought to attract herring better than normal incandescent lamps. The fishermen generally agreed that this method of fishing was successful in the lower east coast sub-district and to a

Table I. Catch and catch per unit of effort by sub-district for the 1959-60 summer and winter fisheries with comparative figures from the previous year.

Sub-district	Season	Catch tons 1959-60	Catch tons 1958-59	Average catch 1951-52 to 1959-60[1]	Catch per unit of effort[3] 1959-60	Catch per unit of effort[3] 1958-59
West coast Queen Charlotte Islands						
Area 1	summer[2]	-	5,793	-	-	50
Area 2AW	winter	-	-	-	-	-
Area 2BW	winter	-	-	-	-	-
Upper east coast Queen Charlotte Islands Area 2AE	winter	3,420	11,842	10,202	44	50
Lower east coast Queen Charlotte Islands Area 2BE	winter	-	7,527	20,678	-	113
Northern Areas 3-5	summer	4,446	1,208	24,695	-	14
	winter	19,058	10,587		59	29
Upper Central Area 6	summer	-	578	7,468	-	29
	winter	7,620	1,525		57	20
Lower Central Areas 7-10	summer	-	2,855	23,907	-	22
	winter	3,755	34,490		26	47
Upper east coast Vancouver Island Areas 11-12	summer	-	8,349	8,519	-	27
	winter	9,937	6,428		46	55
Middle east coast Vancouver Island Areas 13-16	summer	-	46	17,932	-	-
	winter	19,915	10,411		49	25
Lower east coast Vancouver Island Areas 17B-20	summer	328	3,232	44,919	-	17
	winter	55,083	46,478		51	51
Lower west coast Vancouver Island Areas 21-24	summer	-	-	18,515	-	-
	winter	19,458	41,649		51	38
Upper west coast Vancouver Island Areas 25-27	summer	-	-	14,252	-	-
	winter	42,046	35,684		159	108
Total	summer	4,774	22,061	-	-	-
	winter	180,292	206,621			
Grand Total		185,066	228,682	-	-	-

1/ Catches in 1952-53 omitted because of fishermen's strikes.
2/ Summer fishery - June 1 to August 16, except in the lower east coast where the opening date is May 1.
3/ Catch per unit of effort is in tons per seine-day.

lesser extent on the west coast of Vancouver Island. Elsewhere on the coast the method was not as successful.

2. Herring sampling during the 1959-60 season R. S. Isaacson

Samples obtained from the commercial herring catch provide information which is basic to a study of the fishery. The standard length, weight, sex and stage of maturity are recorded for each fish sampled and two scales are taken for age determination. Fifty fish are considered an adequate sample. Each sample is taken randomly from the hold of the boat just prior to unloading.

A total of 339 samples was obtained, including 22 during the summer fishery in the northern sub-district. Samples were obtained from each of the twelve populations of herring which supported the fishery. The sampling intensity was lower than in the previous season, fewer samples being taken in the lower east coast sub-district. Sampling in the middle east coast sub-district was limited as most of the catch was delivered to plants which did not have freezing and storage facilities available.

Age composition (Tables II and III). Fish of age IV from the 1956 year-class made an above-average contribution to the catches in the middle east coast, lower east coast and upper west coast sub-districts. This year-class had been a strong contributor in most sub-districts as III-year-old fish in the previous season. In the lower east coast and upper west coast sub-districts both the 1956 and the incoming 1957 year-class (age III) appeared strong and were mainly responsible for the above-average catches made in these sub-districts. In most of the other populations the 1957 year-class appeared to be below average strength, particularly in the northern sub-district. The major offshore population in this sub-district supported moderate-sized summer and winter fisheries both having mainly fish of age IV. The inshore fishery in this sub-district took place during the winter in the vicinity of Prince Rupert Harbour and produced a record catch for this locality of 13,885 tons. Over 70% of this catch was comprised of fish of age II from the 1958 year-class. This year-class also made above-average contributions to the catches in the upper central, major lower central, upper east coast, and lower west coast populations. It appears probable that the 1958 year-class will be of above-average strength.

Length and weight (Tables IV and V). Herring from all populations surrounding Vancouver Island and from the upper Queen Charlotte Islands population were generally of average size and weight at all ages. In the northern inshore, upper central, and lower central major populations both III- and IV-year-old fish were below average size. The II-year-old fish which were unusually abundant in the northern inshore population were all of average size and weight.

Sex ratio and maturity. Females outnumbered males in all populations although in most instances the margin was slight. Most of the fish caught were mature, the highest proportion occurring in the upper west coast sub-districts (97.1%) and the lowest in the northern inshore population (50.4%).

Table II. Age composition (in percent) of the herring catch from each sub-district or population during the 1959 summer and 1959-60 winter fishing seasons.

Sub-district or population	Season	In year of age I	II	III	IV	V	VI	VII	VIII	IX	X
Upper Queen Charlotte Islands (Area 2A east)	winter	-	15.84	35.81	42.19	3.12	1.44	0.67	0.72	0.21	-
Northern (offshore) (Areas 4, 5)	summer	-	-	0.86	65.02	19.78	7.17	5.32	1.48	0.37	-
	winter	-	5.35	4.15	54.06	18.23	10.64	5.58	1.75	0.23	-
(inshore) (Areas 3, 4, 5)	winter	-	70.45	7.54	15.77	4.06	1.05	0.86	0.11	0.16	-
Upper Central (Area 6) Major population	winter	0.05	74.32	12.97	9.00	2.72	0.53	0.36	0.05	-	-
Minor population	winter	0.42	50.57	16.33	22.76	6.86	1.41	0.50	0.78	0.36	-
Lower Central Major population (Area 7)	winter	-	25.56	25.19	39.85	7.89	1.13	0.19	0.19	-	-
Minor population (Areas 8, 9, 10)	winter	-	30.83	30.43	25.48	11.09	1.87	0.29	-	-	-
Upper East Coast (Areas 11, 12)	winter	-	29.42	18.73	28.48	13.66	6.76	1.75	0.77	0.25	0.17
Middle East Coast (Areas 13, 14)	winter	-	10.89	36.51	44.87	6.73	0.77	0.23	-	-	-
Lower East Coast (Areas 17A, B, 18, 19, 20)	winter	-	4.83	56.78	35.28	2.58	0.38	0.06	0.09	-	-
Lower West Coast (Areas 21, 23, 24)	winter	-	27.48	48.10	19.37	3.98	0.53	0.35	0.18	-	-
Upper West Coast (Areas 25, 26, 27)	winter	-	4.67	56.01	24.28	9.95	3.37	1.07	0.39	0.17	0.09

Table III. Numbers of herring (in millions) caught in each sub-district or population during the 1959 summer and 1959-60 winter fishing seasons.

Sub-district or population	Season	In year of age I	II	III	IV	V	VI	VII	VIII	IX	X	Total
Upper Queen Charlotte Islands (Area 2A east)	winter	-	6.55	14.82	<u>17.46</u>	1.29	0.60	0.28	0.30	0.09	-	41.39
Northern (offshore) (Areas 4, 5)	summer	-	-	0.30	<u>22.88</u>	6.96	2.52	1.87	0.52	0.13	-	35.18
	winter	-	1.65	1.28	<u>16.66</u>	5.62	3.28	1.72	0.54	0.07	-	30.82
(inshore) (Areas 3, 4, 5)	winter	-	<u>172.81</u>	18.52	38.68	9.96	2.58	2.10	0.27	0.39	-	245.31
Upper Central Major population (Area 6A,B)	winter	0.04	<u>57.94</u>	10.11	8.02	1.12	0.41	0.28	0.04	-	-	77.96
Minor population (Area 6C,D,E,F,G,H)	winter	0.38	<u>45.55</u>	14.71	20.50	6.18	1.27	0.45	0.70	0.32	-	90.06
Lower Central Major population (Area 7)	winter	-	6.18	6.09	<u>9.64</u>	1.91	0.27	0.05	0.05	-	-	24.19
Minor population (Areas 8, 9, 10)	winter	-	<u>8.59</u>	<u>8.48</u>	7.10	3.09	0.52	0.08	-	-	-	27.86
Upper East Coast (Areas 11, 12)	winter	-	<u>36.63</u>	23.32	<u>35.46</u>	17.02	8.41	2.18	0.96	0.31	0.21	124.50
Middle East Coast (Areas 13, 14)	winter	-	19.73	66.14	<u>81.30</u>	12.19	1.40	0.41	-	-	-	181.17
Lower East Coast (Areas 17A, B, 18, 19, 20)	winter	-	23.93	281.37	<u>174.85</u>	12.77	1.89	0.31	0.44	-	-	495.56
Lower West Coast (Areas 21, 23, 24)	winter	-	55.01	<u>96.27</u>	38.78	7.96	1.07	0.71	0.36	-	-	200.16
Upper West Coast (Areas 25, 26, 27)	winter	-	18.30	<u>219.50</u>	95.15	39.00	13.20	4.20	1.53	0.66	0.36	391.90

Table IV. Average length (in mm.) by sub-district or population of herring caught during the 1959 summer and 1959-60 winter fishing seasons.

Sub-district or population	Season	In year of age I	II	III	IV	V	VI	VII	VIII	IX	X	Mean
Upper Queen Charlotte Islands (Area 2A east)	winter	-	148.7	171.7	186.6	186.1	200.3	236.3	235.0	235.0	-	176.1
Northern (offshore) (Areas 4, 5)	summer	-	-	179.7	197.0	202.9	217.0	220.0	234.2	239.0	-	201.5
	winter	-	153.2	178.9	200.2	207.1	217.4	223.7	230.4	224.0	-	201.6
(inshore) (Areas 3, 4, 5)	winter	-	145.4	169.6	191.6	201.9	210.2	218.1	231.0	225.5	-	158.6
Upper Central Major population (Area 6A,B)	winter	115.0	150.7	167.0	181.1	192.9	207.2	221.7	198.0	-	-	156.9
Minor population (Areas 6C,D,E,F,G,H)	winter	110.4	147.7	161.6	168.4	180.9	183.5	192.7	186.6	194.3	-	158.5
Lower Central Major population (Area 7)	winter	-	146.3	165.1	179.8	194.7	199.0	-	-	-	-	169.0
Minor population (Areas 8, 9, 10)	winter	-	145.4	159.2	169.6	179.8	189.0	196.0	-	-	-	160.5
Upper East Coast (Areas 11, 12)	winter	-	145.0	169.5	178.7	183.1	185.7	189.1	199.9	177.7	184.5	168.9
Middle East Coast (Areas 13, 14)	winter	-	152.5	181.9	195.2	203.4	217.7	205.5	-	-	-	186.5
Lower East Coast (Areas 17A, B, 18, 19, 20)	winter	-	159.4	186.1	197.8	205.3	217.5	216.2	220.4	-	-	189.7
Lower West Coast (Areas 21, 23, 24)	winter	-	161.9	181.9	191.9	203.4	205.3	208.0	228.0	-	-	179.6
Upper West Coast (Areas 25, 26, 27)	winter	-	160.5	184.0	193.9	201.3	208.9	214.8	219.9	224.2	228.5	188.2

Table V. Average weight (in gms.) by sub-district or population of herring caught during the 1959 summer and 1959-60 winter fishing seasons.

Sub-district or population	Season	In year of age I	II	III	IV	V	VI	VII	VIII	IX	X	Mean
Upper Queen Charlotte Islands (Area 2A east)	winter	-	39.6	66.6	88.3	90.6	116.1	181.2	192.2	198.5	-	74.8
Northern (offshore) (Areas 4, 5)	summer	-	-	81.1	106.1	117.5	145.5	152.8	181.4	180.3	-	114.9
	winter	-	47.5	77.9	112.6	127.3	153.4	164.2	180.9	171.3	-	118.5
(inshore) (Areas 3, 4, 5)	winter	-	37.6	65.8	98.1	117.5	132.9	150.6	178.3	174.8	-	55.2
Upper Central Major population (Area 6A,B)	winter	16.0	46.8	68.0	87.1	106.7	137.7	170.7	114.0	-	-	55.2
Minor population (Areas 6C,D,E,F,G,H)	winter	15.0	43.0	58.5	66.0	83.4	88.6	94.0	87.3	98.3	-	55.5
Lower Central Major population (Area 7)	winter	-	41.7	64.8	85.0	108.2	113.7	147.0	124.0	-	-	71.0
Minor population (Areas 8, 9, 10)	winter	-	41.8	59.2	72.1	86.5	98.1	97.0	-	-	-	60.8
Upper East Coast (Areas 11, 12)	winter	-	39.5	71.0	86.5	96.2	97.9	98.0	119.7	86.7	94.0	72.9
Middle East Coast (Areas 13, 14)	winter	-	48.4	90.2	114.0	129.8	163.3	117.8	-	-	-	99.7
Lower East Coast (Areas 17A, B, 18, 19, 20)	winter	-	55.4	93.6	115.8	130.3	160.5	165.7	175.6	-	-	101.1
Lower West Coast (Areas 21, 23, 24)	winter	-	60.7	90.9	109.1	131.9	137.0	133.0	175.0	-	-	88.4
Upper West Coast (Areas 25, 26, 27)	winter	-	57.1	89.1	105.6	119.7	133.5	145.5	153.8	174.5	164.5	96.8

3. Extent of spawn deposition

D. N. Outram

One of the major phases of herring studies is the annual assessment of the extent and intensity of herring spawn deposition along the beaches each spring. Since the amount of spawn is related to the numbers of spawning fish this information, when combined with data on catch and age composition, provides estimates of the total number of fish present at the start of a season, of the proportion taken by the fishery and of the strengths of the various year-classes. The relationship between the amount of spawn deposited and the number of adult fish which will arise from it is important to herring management. Only if a direct relationship exists between number of spawners and number of recruits can it be considered that the population might be overfished.

Since Pacific herring deposit eggs principally on intertidal vegetation, it is possible to measure the amount of spawn deposited. From 1942 onwards coastwide spawn surveys have been carried out annually by officers of the Department of Fisheries. In some years independent and more detailed surveys have been carried out by Fisheries Research Board personnel along the east and west coasts of Vancouver Island. The same procedures were followed in 1960 as in previous years with respect to estimates of spawn deposition.

In 1960, 168.5 statutory miles of spawn were found in the coastal waters of British Columbia, an increase of 9% from the 1959 level but well below the 20-year (1937-56) average of 205 miles. It might be considered that, because of the absence of the regular post-Christmas fishery, the amounts of spawn deposited would have been much greater. However, an examination of the 1959-60 catch records indicates that over 160,000 tons had nevertheless been taken - a figure not far below the average for the last 10 years.

Except for the Queen Charlotte Islands and upper central sub-districts, spawn deposition increased in those sub-districts which had no fishery or only a limited fishery in 1959-60 and remained level or decreased in those which provided average or above-average fishing (Table VI). In the Queen Charlotte Islands, spawn deposition showed a decrease despite the absence of a fishery and in the upper central region it increased by 50% in spite of a catch at least average for recent years. In the lower central sub-district an increase of 262% occurred. Only a small fishery took place here in 1959-60. Spawning showed little change in the northern upper east coast of Vancouver Island and the lower west coast of Vancouver Island sub-districts from the 1959 level. The fisheries in these sub-districts in 1959-60 were about average for recent years.

Marked reductions took place in the upper east coast of the Queen Charlotte Islands (27%), the lower east coast of the Queen Charlotte Islands (54%), the west coast of the Queen Charlotte Islands (22%), the lower east coast of Vancouver Island (19%) and the upper west coast of Vancouver Island (25%) sub-districts. In the latter two the pre-Christmas catch was well above average.

Table VI. Statutory miles of herring spawn deposited in the coastal waters of British Columbia in 1960, adjusted to a standard intensity of medium by sub-district. For comparison, 1958 and 1959 results together with a 20-year (1937-56) average are also shown.

Sub-district or population centre	Statutory miles of herring spawn			
	20-year average 1937-56	1958	1959	1960
Upper east coast Queen Charlotte Is.	3.3	0.2	1.1	0.8
Lower east coast Queen Charlotte Is.	14.7	1.5	12.5	5.8
West coast Queen Charlotte Is.	--	0.4	12.0	9.3
Northern	17.4	12.2	21.6	22.6
Upper central	24.1	1.2	8.4	12.6
Lower central	34.9	20.0	9.0	32.6
Upper east coast Vancouver Is.	16.7	9.9	12.5	12.0
Middle east coast Vancouver Is.	26.4	11.9	31.4	34.7
Lower east coast Vancouver Is.	28.5(29.9)*	12.3(23.7)	25.2	20.4
Lower west coast Vancouver Is.	14.5	16.7	9.4	8.5
Upper west coast Vancouver Is.	12.5	11.5	6.9	5.2
Lower mainland (District 1)	--	5.1	4.7	4.0
Totals	192.9(205.0)	102.9(114.3)	154.7	168.5

*Figures in parentheses are estimates derived from combined results of both fishery officers and Biological Station surveys.

4. Status of the stocks in 1959-60

F.H.C. Taylor

On their winter pre-spawning migration herring concentrate into large schools on which the main fisheries depend. Since spawning occurs soon after the close of the fishery, the level of abundance in any population can be estimated reasonably well from data on catch and size of the spawning stock (Table VII).

In 1957-58, abundance in most populations was at a relatively low level. In all, below-average catches were followed by below-average spawnings. In 1958-59, abundance increased in nearly all populations. While the increases were only moderate in the north and on the Queen Charlotte Islands, sharp increases occurred in the south, particularly on the west coast of Vancouver Island. In 1959-60, abundance increased somewhat in the northern, upper and lower central populations, remained steady in the middle east coast and upper west coast populations, and decreased somewhat in the lower east coast and lower west coast. As a result herring were more abundant than usual in the middle east coast, upper west coast and probably also the upper east coast sub-districts, of about average abundance in the northern and lower central and somewhat less abundant then usual in the lower east coast and lower west coast.

In southern populations (south of Cape Caution) the level of abundance is determined principally by the number of III-year-old fish present; in northern populations the numbers of IV- and V-year-olds have a considerably greater influence. In 1958-59, the generally high level of abundance in most populations resulted from the presence of the very strong 1956 year-class, which contributed the III-year-olds. The 1957 year-class does not appear to be nearly as strong as the 1956 and is probably of no more than average strength in most populations. In the upper west coast population, however, this year-class appears to be strong for it was the dominant contributor to the large catch made there. In the northern and upper central populations, II-year-old fish (1958 year-class) dominated the catch and were responsible for the increase in abundance in these populations. This year-class also made an above-average contribution in the lower west coast population. The presence of unusually large numbers of II-year-old fish in these populations may indicate that this year-class (1958) may be of above-average strength.

B. Term Programs

1. The offshore distribution of herring

F.H.C. Taylor

The program to determine the offshore summer distribution of herring was continued in 1960. Two cruises were made, one from mid-May to mid-June, the other in August. Both were confined to the continental shelf off Barkley Sound on the west coast of Vancouver Island.

The same gear was used as in the previous year. It consisted of nylon gill-nets of 3/4", 1 1/4", 1 1/2", 1 3/4" and 2 1/4" mesh, stretched measured, set in panels of 5 nets, one of each mesh size. These nets were used either as drift nets, with 5 panels of 5 nets each set at various depths, or as sunken gill-nets with one panel of 5 nets anchored on the bottom. A No. 5 midwater trawl was used with 80" aluminum otter boards, and Mark V kite-otters as depressors.

Table VII. Spawn deposition and catch in 1957-58, 1958-59, 1959-60, together with average, by major populations.

Sub-district or population	Area	Spawn in miles at standard intensity				Catch in tons			
		20-year average 1937-56	1958	1959	1960	20-year average 1937-8 to 1956-7	1957-8	1958-9	1959-60
Upper Queen Charlotte Islands	1 + 2AE	3.3	0.2	1.1	0.8	9,530	274	17,635	3,420
	2AW	-	0.4	10.0	9.3	-	-	-	-
Lower Queen Charlotte Islands	2BE	14.7	1.5	12.5	5.8	13,430	12,288	7,527	-
	2BW	-	-	2.0	-	-	-	-	-
Northern	3-5	17.4	12.2	21.6	22.6	21,460	12,185	11,795	19,060
Upper Central	6	24.1	1.2	8.4	12.6	11,270	6,819	2,103	7,620
Lower Central	7-10	34.9	20.0	9.0	28.4	21,520	7,553	39,345	3,750
Upper East Coast	11-12	16.7	9.9	12.5	12.0	7,550	3,523	14,777	9,940
Middle East Coast	13-16	26.8	11.9	31.3	34.7	12,690	10,069	10,458	19,920
Lower East Coast	17A-19	29.9	23.7	25.2	20.4	40,310	17,311	49,711	55,080
Lower West Coast	23-24	16.6	16.7	-	8.5	16,050	12,923	41,649	19,460
Upper West Coast	25-27	19.8	11.5	6.9	5.2	11,440	48	35,684	42,050

The midwater trawl was used with an echo sounder transducer attached to the headline to provide precise information on the depth of the net.

During the first cruise 3 drift net sets, 2 sunken net sets and 2 midwater trawl hauls were made on La Perouse Bank, together with 5 sunken net sets within a mile of shore and 2 sunken net sets and 2 trawl hauls in Barkley Sound. One drift net set was made on Swiftsure Bank. On the second cruise 4 drift net sets, 6 sunken net sets and 2 midwater trawl hauls were made on or just outside La Perouse Bank, 5 sunken net sets within a mile of shore and 3 midwater trawl hauls in Barkley Sound. One sunken net set was made off Matilda Inlet in Clayoquot Sound. Further midwater trawl hauls were prevented on the first cruise by the loss of one of the depressors and on the second by the breakdown of the main winch.

From the experience gained on these cruises it would appear that a midwater trawl used with depressors and a headline transducer is a more efficient method of fishing summer herring than drift or sunken gill-nets. The latter require more time to set and haul, and fish and remove the catch.

In addition to these net sets extensive echo sounding was carried out over the coastal banks, and in Barkley and Clayoquot Sounds.

Herring on the first cruise were taken in two of the drift and sunken net sets and both midwater trawl hauls on La Perouse Bank, in 4 of the inshore sunken net sets and in the 2 trawl hauls in Barkley Sound. On the second cruise herring were found in 2 drift and sunken net sets on La Perouse Bank, in the 5 inshore sunken net sets and in one Barkley Sound trawl haul. Table VIII shows by type of net and mesh size the number, the percentage age composition and (in parentheses) the average length in millimeters of fish of each age caught on the coastal banks, inshore and in Barkley Sound on both cruises. The percentage age compositions were determined from length frequency distributions using an age-length key. This method explains why an age composition rather than a single age appears when only a single fish was caught. Selectivity curves for the gill-nets have not been obtained, hence the age composition of the populations fished cannot be estimated except in a very general way.

The most interesting feature was the predominance of II-year-old fish in nearly all catches. Fish of age III were not encountered in nearly the numbers expected, when it is considered that pre-recruit fish of this age should be nearly as numerous as II-year-olds. Three-year-olds were, however, more numerous in the midwater trawl hauls made near the outer edge of La Perouse Bank on the first trip and were generally somewhat more numerous on the second trip than on the first. Since metamorphosis is not completed until June no juveniles were encountered on the first cruise but some were taken on the second in August - both within and just outside Barkley Sound. These catches confirm earlier findings that juvenile herring migrate out of the sounds in early autumn. The tendency of herring at each age to be larger in August than in June is what would be expected, since summer is the period of rapid growth. Unfortunately the numbers of fish were too small to permit reliable estimates of the growth rate.

From the catches of herring and from echo sounding it would appear that herring are widely scattered over the coastal banks in small schools during the summer. No concentrations large enough to support a commercial purse seine or drift net fishery were encountered in 1960 or during the trips made the previous year.

Table VIII. The number, percentage age composition, and average length in millimeters (in parentheses) of fish caught on each cruise, shown by locality and method of capture.

Locality	Type of net	Mesh size	Number caught	Age composition and average length I	II	III	IV	V	VI
				1st Cruise - mid-May - mid-June, 1960					
La Perouse Bank	Gill	3/4	1		90.00 (142)	10.00 (142)			
	Gill	1 1/4	951		92.98 (136)	6.94 (142)	0.06 (202)	0.03 (202)	
	Gill	1 1/2	5		78.00 (157)	22.00 (183)			
	Gill	1 3/4	4		70.00 (142)	5.00 (145)	25.00 (212)		
	Trawl		55		27.45 (140)	58.55 (181)	12.91 (202)	1.09 (202)	
Inshore	Gill	1 1/4	97		94.33 (135)	5.67 (137)			
	Gill	1 1/2	2			100.00 (170)			
	Gill	1 3/4	26			86.92 (181)	10.77 (198)	2.31 (202)	
Barkley Sound	Trawl	3	3,667		91.38 (137)	8.55 (148)	0.05 (202)	0.01 (202)	
				2nd Cruise - August, 1960					
La Perouse Bank	Gill	1 1/4	1		80.00 (157)	20.00 (157)			
	Gill	1 1/2	6		90.00 (152)	10.00 (155)			
	Gill	1 3/4	10		4.00 (167)	51.00 (184)	44.00 (193)	1.00 (192)	
Inshore	Gill	3/4	11	100.00 (85)					

continued.....

Table VIII continued

Locality	Type of net	Mesh size	Number caught	Age composition and average length					
				I	II	III	IV	V	VI
	Gill	1 1/4	38		93.90 (139)	6.10 (142)			
	Gill	1 1/2	156		76.30 (156)	23.20 (161)	0.50 (167)		
	Gill	1 3/4	11		5.09 (163)	45.50 (167)	3.60 (167)		
Barkley Sound	Gill	1 1/4	181		86.80 (150)	13.20 (152)			
	Gill	1 1/2	1,327		85.00 (152)	14.90 (156)	0.10 (168)		
	Gill	1 3/4	124		6.40 (163)	61.10 (181)	30.00 (189)	2.50 (200)	
	Gill	2 1/4	21			9.50 (187)	29.00 (203)	44.80 (214)	16.70 (226)
	Trawl		378	32.80 (90)	55.80 (142)	10.70 (156)	1.10 (189)		
Matilda Inlet	Trawl		7		24.30 (167)	64.30 (174)	11.40 (173)		

2. <u>Echo sounder surveys of the density of herring schools in the winter of 1959-60</u> W. E. Barraclough

This program was undertaken to determine the feasibility of estimating the abundance of herring from regular echo-sounder surveys. An attempt was made to follow changes in abundance of herring in the lower east coast sub-district from November, 1959, to February, 1960. On each of 4 cruises of the vessel "A.P. Knight" during the above period similar courses were followed through all regions where herring were likely to be found.

Herring schools were recorded on a Kelvin-Hughes MS29-F echo sounder as dense cloud-like blotches, horizontal patch-like layers, plumes, daubs, flecks and perpendicular scratches. The lengths of all traces were measured in millimetres. Adjustments were made to the measured length to compensate for variations in echo amplitude greater or less than 5 fathoms. An estimate of density of herring was obtained by expressing the adjusted lengths of traces as millimetres of trace per mile run. Contours were drawn at the selected density levels shown in Table IX to show variations in density throughout the sub-district.

Table IX. Contour levels.

mm/mile	Description of trace
0-4	Isolated plumes, flecks, daubs, strokes
5-9	Scattered plumes
10-19	Small schools
20-39	Sizeable schools, to support a light fishery
40-69	Schools of a size to support a fishery
70-99	Heavy concentrations of schools
100+	Intense concentrations which "blacken" the paper

As an example of the type of results obtained, the contour maps for Captain Passage and the adjacent part of Trincomali Channel for the 4 cruises are shown in Figure 1. These 4 maps, as well as showing the complete range of densities, show readily the monthly changes that occurred in the distribution and concentration of herring schools. In spite of its high density level, because the distance traversed through Captain Passage is small (1.3 miles) this region probably contains a smaller body of herring than other more extensive regions with a lower calculated density. Nevertheless in Captain Passage the density remained consistently high throughout the four months, higher than any other area surveyed. It is interesting to note that the earliest known herring spawning on the British Columbia coast occurs nearly on the adjacent parts of Saltspring and Prevost Islands during the second or third week of February.

The actual number of miles sounded and the corresponding densities (mm/mile of herring) are given in Table X for specific localities within each of the three statistical areas. In November, 1959, relatively high densities were recorded from a number of localities on the outskirts of or leading into the main system of channels forming the sub-district. Such localities for instance

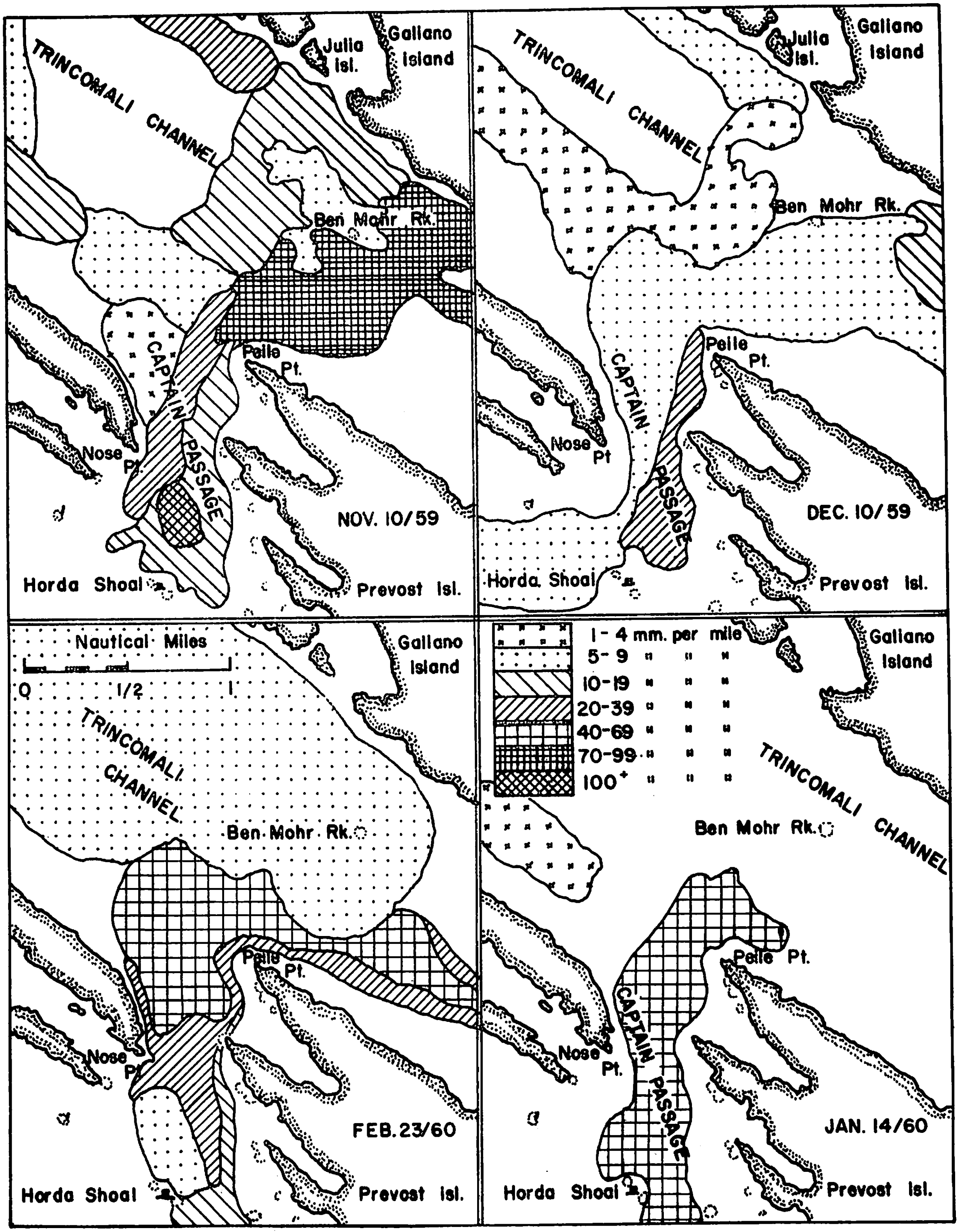


Fig. 1. Density of herring expressed as mm. per mile.

Table X. Miles sounded and density of herring in Areas 17, 18, and 19.

	November, 1959		December, 1959		January, 1960		February, 1960	
	Miles echo sounded	mm per mile	Miles echo sounded	mm per mile	Miles echo sounded	mm per mile	Miles echo sounded	mm per mile
Area 17								
Nanoose Bay to Nanaimo	14.0	13.6	11.0	0	11.0	0	14.3	2.9
De Courcy Island Area	7.6	0.9	7.7	0	7.7	0	7.6	2.1
Trincomali Channel - North	19.7	13.7	6.9	0.3	19.2	2.1	18.9	7.6
Trincomali Channel - Middle	18.6	20.2	18.3	2.8	19.4	0.4	17.0	8.1
Stuart Channel - North	20.3	20.7	18.6	1.1	18.9	1.9	18.0	2.5
Stuart Channel - South	15.2	3.6	8.3	0.3	15.3	0.2	7.5	2.5
Total miles echo sounded and average mm per mile	95.4	13.8	70.8	1.1	91.5	0.95	83.3	4.8
Area 18								
Sansum Narrows	11.0	28.7	no soundings		11.4	0.9	11.0	0.7
Satellite Channel	12.0	0.6	9.7	0	12.0	1.4	9.7	30.9
Swanson Channel	7.5	2.3	8.0	0	8.4	6.0	8.3	3.6
Ganges Area	6.3	4.3	1.4	4.6	6.6	3.0	7.0	3.5
Captain Pass	1.3	32.6	1.3	22.0	1.7	58.0	1.5	23.8
Active Pass Area - Trincomali Channel Sound	5.0	32.6	4.3	9.1	4.1	0	4.3	21.5
Total miles echo sounded and average mm per mile	43.1	13.3	24.7	3.0	44.2	4.4	41.8	11.7
Area 19								
Haro Strait	14.5	0.6	14.5	0	no soundings		no soundings	
Zero Rock to Discovery Island	17.4	0.6	17.4	0				
Trial Island to Race Rocks	16.4	1.6	16.4	0				
Race Rocks and William Head to Victoria	7.1	22.4	7.1	0				
Total miles echo sounded and average mm per mile	55.4	3.7	55.4	0				

are outside Nanoose Bay, the northern end of Trincomali Channel near Porlier Pass, the southern end of Trincomali Channel near Active Pass and the William Head region. In these areas the densities dropped significantly on later surveys. There was apparently a dispersal of herring from these areas to the more sheltered channels and bays near the spawning grounds. The contour maps suggest that herring schools enter the Strait of Georgia first and then become diverted through these "entrance" areas. The schools then tend to break up and spread out into more isolated schools for about two months prior to their merger again into larger schools on the spawning grounds.

In the localities surveyed in Area 17 there was an average decline in density of about two-thirds (from 13.8 mm to 4.8 mm/mile) from early November to late February. Only a slight decline in density (from 13.3 to 11.7 mm/mile) was found in Area 18. It is difficult from the results obtained to say whether the decline in Area 17 was the result of the fishery or of the less complete coverage following the break-up and dispersal of herring into smaller schools. The figures obtained, however, do provide a measure of herring density in many of the localities known to be occupied by herring during the winter season.

A clearer picture might result if an accurate assessment could be made of the relationship between density shown by the echo sounder and actual tons of herring. To determine this relationship, a concerted echo-sounding program would have to be carried out in conjunction with a commercial seiner during an actual fishery. If such an estimate were available it should be possible to estimate the size of the spawning population in tons and to relate this to the miles of spawn deposited.

3. <u>Determination of the number of salmon and salmon grilse in herring catches</u> W. E. Barraclough

During the 1960-61 season the majority of the herring purse seiners again used mercury-vapour lights to attract herring to the vessel. This system of fishing lead to complaints that large quantities of young salmon and other fish were also attracted by the lights and taken in the purse-seine catches.

After the fishery started in 1959-60 the Biological Station was asked to undertake a study of this problem, and to outline methods whereby the number of such salmon could be estimated. Such a method was developed at one of the reduction plants at Steveston and the results of the initial investigation were presented in the Station's report for 1959-60. Young salmon are easily removed from the conveyor system on the roof of Imperial Cannery by two observers stationed at two different check points. Herring are spread out thinly on these conveyors, well washed and any young salmon are readily seen. This year it was estimated that the two observers could check about 75 to 85% of the load with accuracy. A check was also made on each vessel unloading of the number, species and approximate size of salmon removed by the crew, by the unloaders or by plant personnel stationed along the conveyor to remove debris and dog-fish. The machine where large herring were graded out by thickness for kipper-ing also separated out young salmon and these were noted when the grader was operating.

Observations at this plant were made at three different periods during the winter fishery - November 22-25, December 8-9 and December 14-16, 1960.

The numbers of adult salmon and grilse counted in the catches during these periods from different areas are presented in Table XI. The tonnages of herring examined from the different areas, and whether or not lights were used are also shown.

The number of grilse per ton of herring was much higher in the catches when lights were used. This was particularly noticeable in Satellite Channel in November and December, and in Nanoose Bay and in Swanson Channel in December. The catch of grilse per ton of herring from Swanson Channel in December was relatively high in comparison to other areas whether lights were used or not. No salmon or grilse were found in herring catches from Barkley or Nootka Sounds even though lights were used there to attract herring.

Although catches made using mercury-vapour lights contained on the average about 3 times as many grilse and 2 1/2 times as many adult salmon as catches made without lights, the numbers caught in 1960-61 were not large. The large numbers of grilse reported the previous season were mainly taken earlier in October in a locality near Victoria not fished this season.

In February, 1961, a few landings from seiners that were fishing in the Upper Queen Charlotte Islands and northern districts were examined for grilse. None of these vessels used lights. No grilse were observed in 104 tons of herring caught in Skidegate Inlet (Area 2AE) on February 6 or in 246 tons caught in Hecate Strait (Area 5) on February 14, 1961.

4. A chemical method for separating herring eggs from substrate

D. N. Outram

Herring eggs are very adhesive when deposited, the outer membrane becoming firmly bonded to the vegetation used as a spawning substrate. Formerly, eggs could only be removed for enumeration by mechanically scraping them from the vegetation - a laborious, time-consuming procedure that was also damaging to the spawn. Reliable estimates of the number of eggs deposited per unit area of substrate were, consequently, difficult to obtain.

A method has recently been evolved for the separation of eggs from the vegetation chemically, by partial digestion of the outer membrane. The preserved spawn samples were treated with a normal solution of potassium hydroxide at 40°C for 20 to 40 minutes, depending on the type of vegetation. The time required was shortest for spawn-laden eel-grass (*Zostera* sp.), intermediate for sea-lettuce (*Ulva* sp.) and longest for rockweed (*Fucus* sp.). Too long immersion in potassium hydroxide results in the complete disintegration of the egg. The detached eggs, after washing, were separated from debris, in a high-density salt solution (5% zinc sulphate). The detached eggs were preserved in Bouin's solution to harden them, since the partially-digested, outer membranes were fairly readily ruptured.

The chemical separation of eggs from substrate will permit more reliable estimates of the intensity of deposition and therefore of the total amount of spawn deposited in each area.

Table XI. Observations made at Steveston of salmon and salmon grilse in herring purse seine catches, November and December, 1960.

Area	Time of set: Day	Time of set: Night	Time of set: No lights	Time of set: Lights	Tons	Adult salmon (More than 18" = 460 mm): Spring	Adult salmon: Coho	Adult salmon: Chum	Grilse (less than 18" = 460 mm): Spring and coho	Grilse: Spring	Grilse: Coho	Grilse per ton
November 22-25, 1960												
17A Nanoose Bay		×		×	328	4		1		5	2	1/47
17B Porlier Pass to Walker Rock		×	×		671	1	1	1		4		1/168
	×				60							-/60
18 Active Pass		×	×		323	2		1		2	24	1/12
Swanson Channel		×	×		80	1				2	3	1/16
Satellite Channel		×		×	258	2		7		63	15	1/3.3
December 8-9, 1960												
18 Active Pass		×		×	18	1		2		1	1	1/9
Swanson Channel		×	×		204	1				3	12	1/14
Satellite Channel		×	× (2 sets)	× (1 set)	43						8	1/5
23 Barkley Sound		×		×	246							-/246
December 14-16, 1960												
14 Deep Bay		×	×		17				0	0	0	-/17
17A Nanoose Bay		×		×	214	8			24	29	3	1/3.8
18 Swanson Channel		×	×		128	1			3	4	20	1/4.7
Swanson Channel		×		×	410				24	68	83	1/2.4
26 Nootka		×		×	149							-/149

5. <u>The application of aerial photography in estimating the distribution of intertidal vegetation used as spawning substrates by Pacific herring</u> D. N. Outram

Surveys in 1959 and 1960 have indicated that aerial photography of herring spawning grounds may aid materially in increasing the accuracy of the measurements used in evaluating spawn abundance. By plotting the distribution of intertidal vegetation from aerial photographs it was thought that a sounder analysis could be made of the extent of the spawnings which take place annually in these regions. More important, an estimate of the "patchiness" of the sea-weeds and sea-grasses on each spawning ground could possibly be derived. In southern British Columbia over 80% of the spawn is found on eel-grass (<u>Zostera</u> sp.), rockweed (<u>Fucus</u> sp.) and "japweed" (<u>Sargassum</u>).

<u>Survey methods</u>. At present, ground surveys of the extent of herring spawnings are carried out from a small boat. The length of a spawning area can be readily estimated but width measurements and adjustments for the "patchiness" of the vegetation are frequently difficult.

Four experimental flights were undertaken to answer the following questions: (1) Can shore-line vegetation exposed at low tides be differentiated from a rocky or sandy background? (2) Could differentiation between green and brown seaweeds be resolved better with colour film than with black and white? (3) Would a survey by helicopter prove superior to one from conventional-type aircraft? (4) What was the optimum flying height? Some compromise was required between the acquisition of large numbers of very low-level photographs with good detail and a smaller number taken at higher levels, each covering a considerable area but lacking ground detail.

In Table XII information on camera equipment and other aspects relevant to these experimental flights are given.

The degree of patchiness was determined by superimposing a transparent grid of 1/8" squares over each aerial photograph and noting the proportion of grid squares covering areas of intertidal vegetation.

<u>Results</u>. An analysis of vertical black and white photographs taken along the shore-line of one of the major spawning regions in Area 17A (from Departure Bay to Hammond Bay) yielded the following information. (1) Surveys from helicopter were preferable to surveys from conventional-type aircraft because of increased visibility, thus enabling the aircraft to be kept on course. (2) A survey carried out from an altitude of not more than 1,000 feet appears to be adequate. (3) On 300 and 2,050 yards of "japweed" at Departure Bay and Horsewell Bluff, respectively, very little adjustment for "patchiness" was required since this type of brown algae usually grows in a continuous belt. However, on 750 yards of rockweed at Hammond Bay only 40 to 50% of the rocky shore-line was actually covered. At Departure Bay it was found that only 50 to 60% of the sand flats were covered with eel-grass beds. (4) Some familiarity with the region under study proved to be necessary for interpreting the details on aerial photographs. (5) Although vegetation could be discerned from the background in most black and white photographs colour film exposed simultaneously with black and white was of considerable help in distinguishing between brown and green seaweeds.

Table XII. Camera equipment, type of aircraft and other information relevant to experimental flights over lower east coast of Vancouver Island herring spawning grounds in 1959 and 1960.

Date of flight	Spawning ground	Height of tide	Weather	Type of aircraft	Flying height	Automatic camera equipment: Type	Lens	Film	Speed	Setting	Filter	Photographic information: Type and size	Scale	Black and white or colour	Remarks
April 23, 1959	Boat Harbour	+ 1'	sunshine	Avro Anson	1,000'	F56	8 1/4"	Ektachrome	1/225	f6.3	none	vertical 7" x 7"	1" = 40 yds.	colour	Differentiation between types of seaweeds by colour.
April 23, 1959	False Narrows	+ 1'	sunshine	Avro Anson	1,000'	F56	8 1/4"	Ektachrome	1/225	f6.3	none	vertical 7" x 7"	1" = 40 yds.	colour	
March 16, 1960	Hammond Bay	+ 2'9"	overcast	Bell helicopter	500'	two F24's and one F56	7"	SXX	1/225	f5.6	none	vertical pairs 9" x 9"	1" = 14 yds.	black and white	Stereo-pairs in black and white taken simultaneously with colour of seaweed beds.
March 16, 1960	Horsewell Bluff	+ 2'9"	overcast	Bell helicopter	500'		8 1/4"	Ektachrome	1/225	f5.6	none	vertical 7" x 7"	1" = 14 yds.	colour	
July 7, 1960	Nanoose Bay to Departure Bay	+ 1'	sunshine	Beaver	1,200'	F56	8 1/4"	SXX	1/225	f16	none	vertical 7" x 7"	1" = 48 yds.	black and white	Black and white coverage of major spawning grounds in Areas 17A and 17B.
July 8, 1960	Ladysmith Harbour to Boat Harbour	+ 1'	sunshine	Beaver	1,200'	F56	8 1/4"	SXX	1/225	f16	none	vertical 7" x 7"	1" = 48 yds.	black and white	

Discussion. It would appear that the patchiness factor varies between spawning grounds depending on the dominant type of spawn-laden vegetation present. In the accompanying table the extent of the herring spawn depositions which took place along the Departure Bay-Hammond Bay shore-line in 1960 is given, together with applied adjustments for the patchiness of the vegetation.

Spawning ground	Type of vegetation	Length of spawning zone (in yards)	Patchiness factor (% covered with vegetation)	Length after adjustment for patchiness factor (in yards)
Horsewell Bluff	japweed	2,050	95%	1,948
Departure Bay	japweed	300	95%	285
Departure Bay	eel-grass	1,150	55%	632
Hammond Bay	rockweed	750	45%	338
Total		4,250		3,203

It would seem on the basis of the above data that the extent of spawn-laden vegetation could be over-estimated by as much as 50% on some spawning grounds. Aerial photographic surveys of those portions of the shore-line used by spawning herring may thus prove a useful supplement to regular ground surveys.

MARINE COMMERCIAL FISHERIES

GROUNDFISH

- K.S. Ketchen

Production of groundfish other than halibut from grounds along the British Columbia coast amounts to about 70 million pounds annually. This is roughly equivalent to the halibut production from the entire northeastern Pacific. The fishery is an international one, employing several types of gear and involving many species of demersal fish. The problems of investigation are of such complexity that they require a long-term, continuing program of study.

The groundfish program is designed to provide (1) a "watching brief" on changes in size of the numerous stocks contributing to the fishery, (2) an understanding of the biological and economic factors responsible for such changes and (3) definition of the requirements for management of the fishery on a maximum sustained yield basis.

Main projects. Background information required for study of the fishery and of fish population dynamics is derived from three continuing projects:

(1) Compilation and analysis of catch records. Accurate description of changes in stock size depends on the collection of reliable statistics of catch and fishing effort. Such statistics are obtained by a system of interviewing vessel skippers at the principal ports of landing (Vancouver and Prince Rupert). This procedure, supplemented by log-book records and Department of Fisheries sales slips, provides a complete picture of the Canadian catch by species from each statistical area and a representative sample of fishing effort exerted by various classes of vessel.

To complete the record of catch in international waters, co-operation is being maintained with the Pacific Marine Fisheries Commission.

(2) Age and growth studies. Routine sampling of the catches of important commercial species is conducted at the main ports of landing, for the purpose of obtaining data on changes in size and age composition. Such data provide valuable information on growth and mortality rates and on changes in recruitment and market requirements.

(3) Tagging. Tagging enables differentiation of stocks or populations of a particular species and hence is of great importance in the interpretation of catch statistics. Tagging also provides information on growth and mortality rates, and therefore is useful as a check on conclusions drawn from age determination.

Review of immediate interests. The main work of the investigation is being advanced on a rather broad front in order to cope with the ever-changing and unpredictable course of the fishery. However, there are subjects of particular concern or importance which require special mention. The following is a synopsis of recent developments and progress towards solution of immediate problems.

(1) International Trawl Fishery Committee. One of the problems confronting this recently formed Committee involves evaluation of the status of the brill (petrale sole) fishery and examination of the efficacy of existing

regulations. Off the Washington and British Columbia coasts, brill are much less abundant than in former years, but farther to the south there is little indication that a decline has occurred. Apparently there are several stocks to the south of the Washington coast, but the extent to which they overlap with the two main stocks off British Columbia and Washington has never been clearly defined. Accordingly, the Committee recommended that tagging be conducted on deep water (spawning?) concentrations of brill off southern Oregon and that the winter closure in that area be waived for at least one year to provide an assessment of dispersal from the tagging site. This work was undertaken by Oregon early in 1960 and the results will be a subject of discussion at future meetings of the Committee.

(2) Groundfish statistics. Because of the amount of detailed information that is required for effective study of the groundfish fishery, the burden of collecting and compiling statistics of catch must be borne by the staff of the investigation, rather than by the Department of Fisheries. This rather mechanical task has consumed a large amount of effort, which might otherwise have been directed along more scientific lines of interest. Fortunately, the problem of data processing has now been greatly simplified by the adoption of IBM methods. All catch and effort data for the years from 1954 onwards are now on punch cards. The backlog of detailed catch statistics from 1945 to the present has now been assembled and is appearing in a special statistical circular series. Publication of data records on fishing effort will follow in this series.

(3) Mesh regulation in the Strait of Georgia. By Order in Council (P.C. 1960-1056), regulation of mesh size in trawl nets will come into effect on January 1, 1962, in the Strait of Georgia. It will apply to the cod-end section of the net only and will require that the internal mesh measurement be at least 4 1/2 inches. This is about one inch larger than the size now generally in use. A Station Circular (No. 61) has been prepared, which explains the biological basis for the regulation. Further discussions with representatives of industry and the Department are planned for the near future to clarify the requirements and make a few amendments to the wording of the regulation.

(4) Research on rock sole, grey cod and brill. Currently, these are the species of greatest interest to the investigation, and special effort is being made to reach conclusions on the status of the fisheries. A report on part of the work on grey cod has been submitted for publication. A report on the rock-sole fishery of Hecate Strait is now in manuscript form and work is being resumed on the final stages of a report on the brill fishery. It is hoped that both will be completed in 1961.

Catch Statistics

In 1960, port observers stationed at Vancouver and Prince Rupert conducted 788 interviews with vessel skippers. Data on catch and fishing effort and related general information were collected on 616 trawler landings, 66 crab and shrimp landings, and 106 line and troll boat landings. This represents an 85.5% coverage (by weight) of all landings in the Province. As in the past, it has been impossible to cover the Sidney-Victoria area by interviews and a leak still exists in the coverage of day-boat operations out of Steveston.

The total landing of groundfish (other than halibut) in 1960 was about 31 million pounds (7% more than in 1959). Otter-trawlers accounted for 25.9 million pounds (84%), while the remainder was taken by hand-line and long-line gear.

Once again grey cod was the dominant species in the trawl catch, although the catch was lower in 1960 than in 1959 (7.0 as compared with 9.5 million pounds). To offset this decline, there was a sharp increase in the landing of flatfish (7.6 million pounds as compared with 5.0 million pounds in 1959) and also in the landings of minkfood (5.8 million pounds as against 3.9 million pounds). These were the major features of the 1960 fishery.

Table XIII illustrates the trend in trawl catches over the past 16 years.

Table XIII. Trends in British Columbia landings of trawl fish.
Thousands of pounds

Year	Lemon sole	Rock sole	Brill	Butter sole	Dover sole	Rex sole	Fldr.	Grey cod	Ling cod	Rock-fish	Dog-fish liver	Mink food
1945	2,174	414	810	1,451	515	91	246	1,604	1,390	1,312	856	212
1946	2,209	1,085	2,398	1,540	1,008	159	633	2,862	1,453	569	519	27
1947	950	2,786	1,765	252	417	65	187	941	535	88	402	41
1948	2,045	2,135	7,722	651	157	119	128	920	993	84	586	43
1949	1,688	1,678	3,291	29	171	161	184	1,682	1,625	134	576	63
5-yr. mean	1,813	1,619	5,197	784	453	119	276	1,602	1,199	437	588	77
1950	5,276	2,148	2,046	11	694	235	326	2,467	1,735	234	122	41
1951	2,162	3,548	1,592	1,824	972	234	450	6,719	1,875	434	203	398
1952	2,496	5,998	1,827	3,716	941	180	493	4,885	1,118	588	230	1,426
1953	2,341	1,923	1,049	375	464	89	134	3,454	816	588	252	2,295
1954	1,508	2,590	941	216	402	22	277	5,700	984	866	325	3,114
5-yr. mean	2,757	3,241	1,491	1,228	695	152	336	4,445	1,306	542	226	1,455
1955	1,593	3,661	654	470	497	130	282	4,622	1,634	340	276	7,129
1956	2,007	4,175	620	693	375	52	254	5,154	2,446	527	67	10,568
1957	1,080	4,200	1,059	1,292	448	40	195	8,505	2,173	475	146	3,982
1958	1,320	4,592	923	500	272	30	135	10,057	2,131	939	197	3,031
1959	1,664	1,904	841	212	180	9	106	9,187	2,469	1,164	294	4,178
5-yr. mean	1,533	3,706	819	633	354	52	194	7,505	2,171	689	196	5,778
1960	2,142	4,049	998	102	219	12	197	6,812	2,501	980	277	5,827

A. <u>Tabulation of 1960 trawl landings in British Columbia</u>

J. A. Thomson
and A. N. Yates

For the first time, catch statistics were coded directly for analysis by IBM punch cards. Statistics of effort obtained by port observers in Vancouver and Prince Rupert were also recorded. The continued close co-operation of the Department of Fisheries supplemented the records of the port observers and in addition provided coverage of landings on Vancouver Island and at Steveston. Full coverage of catch and effort was provided for 87.9% of the food-fish catch and 77.6% of the minkfood catch. There are no effort statistics for the remainder.

The summary of monthly trawl landings for British Columbia in 1959 is presented according to four major divisions: (1) Hecate Strait, (2) Queen Charlotte Sound, (3) west coast of Vancouver Island (including the Washington coast), and (4) the Straits of Georgia and Juan de Fuca. Weights are given in thousands of pounds.

Table XIV. Groundfish catches in Hecate Strait in 1960.
(P.M.F.C. Areas 5C and 5D)

Month	Lemon sole	Rock sole	Brill	Butter sole	Dover sole	Rex sole	Fldr.	Grey cod	Ling cod	Rock-fish	Mink food
Jan	88	-x-	4	--	--	--	--	512	4	--	16
Feb	192	4	2	38	--	--	3	538	2	16	88
Mar	236	13	2	56	1	--	14	549	3	2	644
Apr	98	-x-	-x-	5	--	--	9	197	1	1	514
May	232	131	5	--	--	-x-	13	253	10	--	26
Jun	113	666	69	--	1	1	-x-	196	35	1	195
Jul	229	693	40	--	16	2	4	305	20	1	175
Aug	152	235	16	--	17	3	13	462	122	--	150
Sep	38	102	3	--	11	3	1	400	16	-x-	191
Oct	87	409	24	3	1	--	1	179	21	-x-	102
Nov	130	2	71	--	--	--	--	91	26	--	332
Dec	72	--	19	--	--	--	-x-	75	5	--	142
Total	1,667	2,255	255	102	47	9	58	3,757	265	22	2,575

-x- = less than 500 pounds

Groundfish catches in Hecate Strait were 3,394,000 pounds higher than in 1959. This brought the total landings close to the 1958 level. Most of the increase was in landings of flatfish, especially rock sole which jumped to over two million pounds after last year's low of 714,000 pounds. Of all the flat-fishes only butter sole declined, the total landings reaching only half that of 1959. A rise of over a million pounds in minkfood landings balanced an equivalent decline in grey-cod landings.

Table XV. Groundfish catches in Queen Charlotte Sound in 1960.
(P.M.F.C. Areas 5A and 5B)

Month	Lemon sole	Rock sole	Brill	Dover sole	Grey cod	Ling cod	Black cod	Rock fish	Ocean perch	Mink food
Jan	--	--	--	--	--	--	--	--	--	--
Feb	10	1	--	--	12	-x-	--	--	--	--
Mar	2	27	-x-	--	6	2	--	1	--	7
Apr	10	102	3	--	55	5	--	4	--	69
May	13	410	34	28	192	62	1	26	351	183
Jun	2	309	67	2	123	100	-x-	17	32	167
Jul	-x-	325	62	5	247	194	-x-	11	56	5
Aug	-x-	90	25	3	102	148	-x-	1	26	72
Sep	12	247	46	3	98	118	3	7	108	129
Oct	4	61	12	15	32	45	7	9	213	388
Nov	4	--	2	--	--	-x-	--	--	--	159
Dec	--	--	--	--	--	--	--	--	--	--
Total	58	1,572	251	56	867	675	12	76	786	1,179

-x- = less than 500 pounds

Total landings from Queen Charlotte Sound showed an increase of 540,000 pounds over 1959. Grey-cod landings, low all over the coast, dropped by 37% (505,000 lbs) and rockfish declined from 496,000 to 76,000 pounds. To offset the latter there was an increase of 276,000 pounds or 54% in landings of ocean perch. As in Hecate Strait increased landings of flatfish and minkfood accounted for the general rise in total landings.

Table XVI. Groundfish catches off west coast of Vancouver Island in 1960.
(P.M.F.C. Areas 3B, 3C and 3D)

Month	Lemon sole	Rock sole	Brill	Dover sole	Fldr.	Grey cod	Ling cod	Black cod	Rock-fish	Skate	Dogfish liver	Mink food
Jan	1	12	2	-	16	4	2	-	3	-x-	1	4
Feb	1	12	-	-	2	3	1	-	3	-x-	-x-	25
Mar	3	2	-x-	-x-	13	8	3	-	1	1	-x-	13
Apr	12	12	2	-	14	59	3	-	-x-	3	-	10
May	1	12	14	1	6	61	38	-	1	2	-	63
Jun	1	26	30	2	7	192	209	-	-x-	4	-	11
Jul	2	10	38	1	-	60	309	5	1	-x-	-x-	87
Aug	2	5	101	-x-	-x-	41	219	21	-x-	2	-	29
Sep	1	6	157	-x-	1	84	236	30	-x-	1	-	74
Oct	1	3	97	1	-x-	17	79	20	8	2	4	22
Nov	7	3	15	-	2	28	24	24	2	2	6	210
Dec	7	2	-	-	2	1	-x-	-x-	1	1	-x-	84
Total	39	105	456	5	63	558	1,123	100	21	19	11	632

-x- = less than 500 pounds

In spite of 211,000 pounds caught by Canadian trawlers off the coast of Washington and included in Table XVI, landings from this area showed a slight decline from 1959. A drop in grey-cod landings from 886,000 to 558,000 pounds (37%) was balanced by rises in landings of rock sole (48,000 lbs), lingcod (310,000 lbs) and minkfood (114,000 lbs).

Table XVII. Groundfish catches in the Strait of Georgia in 1960. (P.M.F.C. Area 4A)

Month	Lemon sole	Rock sole	Brill	Fldr.	Grey cod	Ling-cod	Rock fish	Skate	Dogfish liver	Crab	Mink food
Jan	44	20	--	6	238	-x-	9	12	5	4	130
Feb	72	24	-x-	23	328	-x-	10	9	15	5	109
Mar	32	19	-x-	11	407	16	5	9	4	6	146
Apr	29	7	1	7	67	8	2	5	-x-	4	86
May	38	10	3	4	103	32	3	7	-x-	9	262
Jun	12	6	2	--	58	24	1	3	1	2	197
Jul	8	3	7	--	16	18	--	1	--	-x-	3
Aug	12	1	4	--	11	9	-x-	1	--	--	35
Sep	13	--	4	--	21	12	4	3	--	1	121
Oct	14	5	9	1	98	236	18	2	14	-x-	129
Nov	46	14	4	11	160	83	13	11	14	26	114
Dec	58	8	-x-	13	122	-x-	11	7	6	27	109
Total	378	117	35	76	1,629	438	76	70	59	85	1,441

-x- = less than 500 pounds

Food-fish landings from the Strait of Georgia dropped by 1,664,000 pounds, a decline of 33% from 1959. Minkfood landings also declined by 19% or 348,000 pounds. Decreases in landings of grey cod and lingcod (553,000 lbs and 246,000 lbs respectively) were too large to be offset by minor increases in lemon sole, rock sole and flounder.

The grounds lying off Victoria Harbour were not nearly as productive as they had been last year.

B. Co-ordination of catch statistics for the Pacific coast

J. A. Thomson

Since 1956 the Pacific Marine Fisheries Commission has compiled catch records of otter-trawl landings by month, by major species, and by areas adjacent to the Pacific coast of North America. The Fisheries Research Board has provided statistics of the British Columbia trawl fishery arranged according to the same statistical areas. Figure 2 illustrates the areas of particular interest to Canada. This figure also shows the mean annual catch for each area (1956-59) and the proportion taken by Canadian vessels. From this figure it is apparent that only in Hecate Strait does Canada take the lion's share of the catch in international waters.

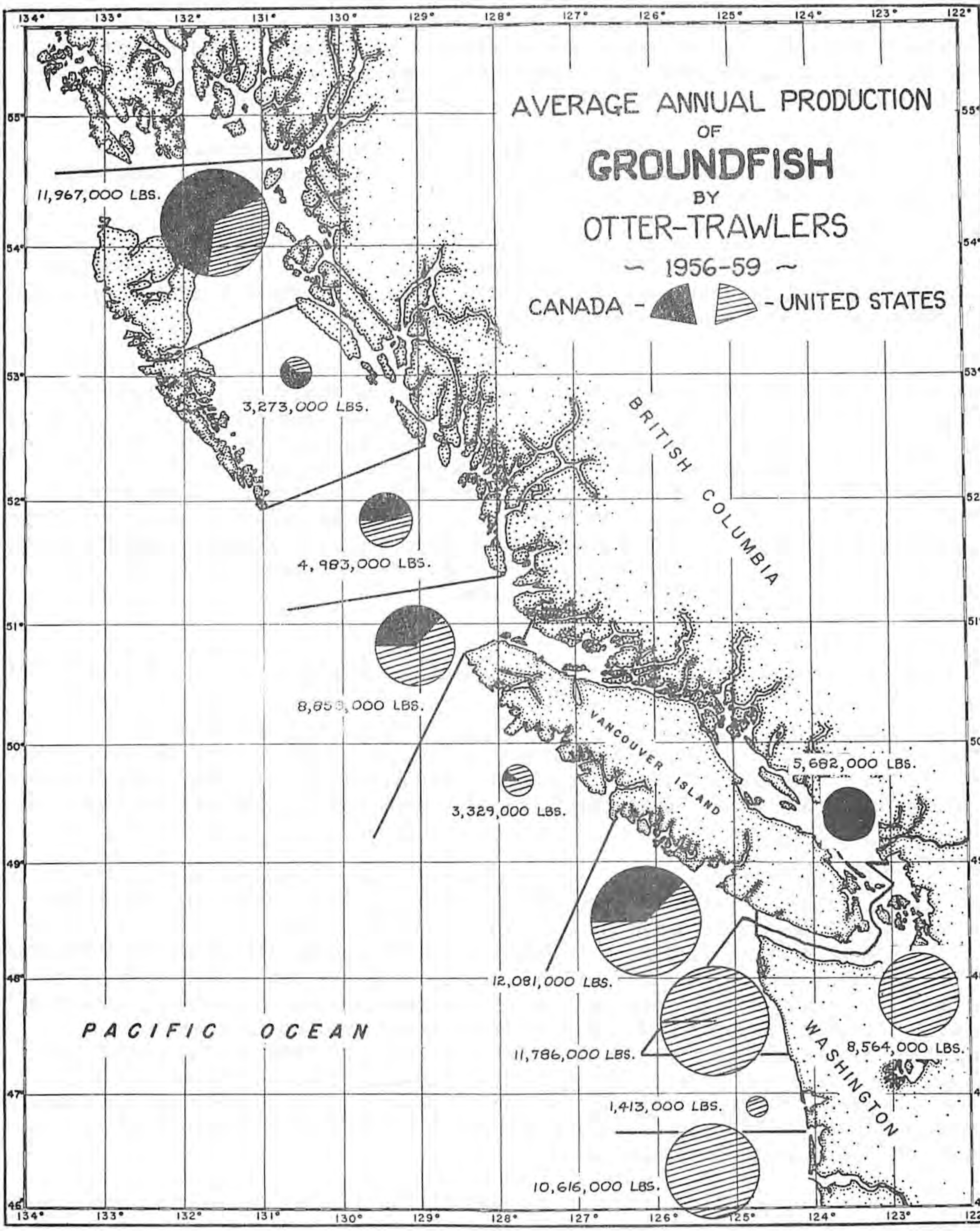

AVERAGE ANNUAL PRODUCTION
OF
GROUNDFISH
BY
OTTER-TRAWLERS
~ 1956-59 ~
CANADA -
- UNITED STATES
11,967,000 LBS.
3,273,000 LBS.
4,983,000 LBS.
8,853,000 LBS.
3,329,000 LBS.
5,682,000 LBS.
12,081,000 LBS.
11,786,000 LBS.
8,564,000 LBS.
1,413,000 LBS.
10,616,000 LBS.
BRITISH COLUMBIA
VANCOUVER ISLAND
WASHINGTON
PACIFIC OCEAN
134°
133°
132°
131°
130°
129°
128°
127°
126°
125°
124°
123°
122°
55°
54°
53°
52°
51°
50°
49°
48°
47°
46°

Fig. 2.

In 1959 the total otter-trawl production from Area 3 (Willapa Bay, Washington to Cape Scott, Vancouver Island) was 27.8 million pounds, about one million pounds less than the 4-year mean. This was an increase of 4.3 million pounds over 1958. The increase was mainly due to a rise in landings of grey (true) cod, lingcod and blackcod (sablefish). Production from territorial waters, 17.1 million, was a million pounds higher than in 1958.

Area 5 which runs from Cape Scott to Dixon Entrance produced 29.6 million pounds, the highest on record. Over half this production came from northern Hecate Strait alone (Area 5D).

Table XVIII summarizes the United States and Canadian catch by species in the various sub-areas adjacent to the Canadian coast. In 1959, Canadian vessels took the greater percentage of the catch in northern Hecate Strait and on the Goose Island ground (Areas 5D and 5B).

The difference in northern Hecate Strait was very small. Landings of food fish alone showed a greater share going to the American fleet but the inclusion of minkfood into the total production swung the division the other way. Much of the Canadian minkfood catch in northern Hecate Strait comes from inshore or territorial waters. This narrow difference reflects the increased interest taken by Washington State trawlers in Hecate Strait. Increasing interest on the part of Canadian trawlers in the Goose Island fishery explains the rising production of this ground. In 1956 Canadian trawlers took 29% of the total catch from that area; in 1957, 32%; in 1958, 56%; and in 1959 the Canadian catch was 2,727,000 pounds or 64%.

C. <u>The controlled trawl fishery of the Strait of Georgia</u> C. R. Forrester

(1) <u>General</u>. The total catch of food fish from the "experimental" fishing areas in the Strait of Georgia declined to 739,000 pounds in the 1959-60 season. This catch is the second lowest which has been recorded from the experimental areas. Table XIX shows total catch, total effort and average catch/effort for the years since 1952-53.

The drop in total catch of approximately 100,000 pounds may be attributed mainly to a reduced catch of grey cod from Nanoose Bay. There the catch was about 360,000 pounds in 1959 but dropped to 285,000 pounds in 1960. The catch of incidental species from Nanoose Bay was 15,000 pounds less than in 1959 and there was a reduction of almost 10,000 pounds from the lemon sole fishery of Union Bay. Average catch per hour on all grounds during the 1959-60 season was slightly higher than the mean, but in the Nanoose grey-cod fishery alone it declined from a record high of 709 pounds per hour in 1959 to 376 pounds per hour in 1960. Nevertheless, catch of grey cod was close to the mean for the past 10 years. Sharp variations in year-to-year fishing success are of common occurrence at Nanoose Bay and are presumed to be largely the result of variations in year-class strength.

Catch according to individual areas in the 1959-60 season is shown in Table XX.

Table XVIII. Otter trawl landings by Canadian and United States vessels operating in waters adjacent to the British Columbia coast in 1959. United States data provided by the Pacific Marine Fisheries Commission.

Fishing areas:	Cape Elizabeth to Cape Flattery		Vancouver Island Lower west coast		Vancouver Island Upper west coast		Strait of Georgia	Puget Sound	Cape Scott		Goose Island		Lower Hecate Strait		Upper Hecate Strait	
P.M.F.C. area:	3B		3C		3D		4A	4B	5A		5B		5C		5D	
Country:	Can.	U.S.A.	Can.	U.S.A.	Can.	U.S.A.	Can.	U.S.A.	Can.	U.S.A.	Can.	U.S.A.	Can.	U.S.A.	Can.	U.S.A.
Sable fish	1	729	111	144	—	21	9	—	4	31	-x-	—	-x-	—	2	3
True (grey) cod	—	3,031	862	646	25	481	2,175	1,693	717	621	655	106	600	1,126	4,153	5,304
Lingcod	—	581	797	3,024	15	127	684	80	150	292	692	252	42	30	90	94
Ocean perch	—	1,103	—	680	—	348	—	—	380	3,135	130	539	—	4	—	—
Other rockfish	—	2,962	29	745	—	817	85	80	169	1,037	326	252	5	—	39	82
Petrale (brill) sole	—	371	408	1,695	13	485	39	-x-	44	200	85	33	76	59	175	166
English (lemon) sole	—	3,193	15	25	-x-	10	336	1,652	21	54	27	16	65	20	1,201	766
Rock sole	—	-x-	50	85	8	2	88	59	366	110	679	81	349	149	365	43
Dover sole	—	1,074	9	623	—	173	149	22	—	112	4	93	-x-	-x-	18	187
Rex sole	—	13	2	—	—	—	3	—	—	—	—	—	—	—	5	—
Starry flounder	—	128	23	—	—	—	65	199	—	12	1	—	—	—	16	470
Other flatfish	—	-x-	8	—	—	—	4	—	—	—	—	—	—	—	212	—
Dogfish	—	4	381	—	10	—	1,320	1,381	1	—	—	—	—	9	253	—
Misc. species	—	73	10	—	3	—	75	5,012	10	—	12	—	-x-	—	41	2
Sub-total	1	13,262	2,405	7,667	74	2,464	5,032	10,178	1,862	5,604	2,611	1,372	1,137	1,397	6,570	7,117
Animal food	—	660	516	795	3	—	1,779	131	443	—	116	17	9	—	1,312	15
Total	1	13,922	2,921	8,462	77	2,464	6,811	10,309	2,305	5,604	2,727	1,389	1,146	1,397	7,882	7,132

x = less than 500 lbs.

Table XIX. Catch and effort in experimental areas in the Strait of Georgia.

Winter season	Total catch of food fish	Total effort	Average catch per hour
	(pounds)	(hours)	(pounds)
1952-53	859,650	2,303	370
1953-54	1,091,600	3,014	340
1954-55	848,900	3,013	280
1955-56	570,900	2,254	250
1956-57	768,600	2,377	320
1957-58	913,400	2,816	324
1958-59	849,032	1,485	572
1959-60	739,000	1,949	379
Mean	830,100	2,401	355

Table XX. Otter-trawl landings from experimental areas in the Strait of Georgia, October 1959 to March 1960.

	Cape Lazo	Union Bay	Yellow Rock	Qualicum Parksville	Nanoose Bay	Total
Hours of fishing	611	68	293	220	757	1949
Lemon sole	56,760	24,379	15,440	8,693	1,433	106,705
Rock sole	6,166	--	17,213	4,941	981	29,301
Flounder	233	370	7,055	156	--	7,814
Grey cod	100,086	5,913	113,200	58,525	284,857	562,581
Lingcod	415	484	1,049	7,969	509	10,426
Rockfish	5,984	--	99	529	2,010	8,622
Other fish	2,862	2,188	2,329	5,058	1,092	13,529
Dogfish	7,447	1,167	13,502	96,531	19,724	138,371
Mink food	1,767	--	395	445	6,575	9,182
Total food fish	172,506	33,334	156,385	85,871	290,882	738,978

(2) Union Bay fishery. The lemon-sole fishery in Union Bay has posed some difficult problems from the standpoint of management. Despite rather severe restrictions on fishing effort, apparent stock size (as indicated by catch/effort) continued to decline after initial (1951 and 1952) fishing on the stock which had accumulated through five years of total closure (Table XXI).

By 1957, catch per hour had fallen to 178 pounds (about one-quarter of that in 1951) and it appeared that removals of more than 50,000 pounds per

Table XXI. Statistics of the lemon sole fishery at Union Bay.

Year of catch	Catch (pounds)	Effort (hours)	Catch per hour (pounds)
1951	154,700	201	769
1952	239,000	402	594
1953	44,400	99	449
1954	100,900	391	258
1955	72,800	326	223
1956	64,200	295	217
1957	51,900	292	178
1958	32,300	102	317
1959	24,400	68	355
1960	48,500	141	344

year were greater than the annual replacement. Accordingly, in order to build up the stock, a quota of 30,000 pounds was imposed in 1958 and 1959. It was relaxed in 1960 to test the indications from catch/effort that stock size was again increasing. It is too early to say whether the quotas were responsible for the increased catch/effort in 1959 and 1960, or whether it was the result of increased recruitment of young fish. Previous studies have shown that recruitment varies substantially. Apparently recruitment was responsible for the rapid build-up of stocks between 1946 and 1951 (year-classes of 1944 and 1945 were exceptionally strong). Thereafter, the year-classes were relatively weak, and this factor plus the removals by fishing drove the stock down to its low level in 1957. Recent improvement may be due mainly to the re-appearance of strong year-classes, but this will not be known until the age composition data have been analysed.

D. Trends in catch per unit of effort

Statistics of catch per unit of effort provide the basis for measurement of year-to-year changes in stock size and variations in recruitment. Their use in the study of an otter-trawl fishery, however, is fraught with numerous complexities. Among these are the effects of fishing for more than one species of fish at one time, which necessitates careful sorting of fishing effort directed to particular species. The efficiency of capture may vary from year to year because of variations in availability rather than because of variations in true abundance, or it may follow a trend because of a progressive change in the efficiency of the fisherman and his gear. Some of these factors can be measured in a quantitative way, but others cannot. In the results presented in the sections which follow efforts have been made to eliminate some of the more obvious factors which tend to distort the true relationship between catch/effort and abundance. In several cases the methods are still under critical review, so the results may be subject to further revision.

1. Brill catch per unit of effort K. S. Ketchen

Two major and more or less independent stocks of brill have been identified in waters adjacent to British Columbia - the so-called southern stock and northern stock. These are considered separately in the sections which follow.

(a) The southern stock. Between 1948 and 1956 this stock underwent a noticeable decline in abundance, at least in part as a result of a sharp decline in recruitment. Between 1956 and 1959 the trend in abundance was reversed, apparently as a result of improved recruitment, for average age of fish in the catch began to decline. As shown in Table XXII, the recovery of the stock seems to have been arrested - since catch per unit of effort in 1960 (based on the May-August fishery by single gear trawlers of 10 to 49 gross tons) was down from that in 1959. However, it was still well above the average for the past six or seven years. As in all studies of catch/effort, short-term changes are difficult to evaluate. The decrease in 1960 may indicate a true decrease in abundance, but it could be a reflection of decreased availability. Or, it is possible that availability was abnormally high in 1959 and that the upward trend in abundance is still continuing.

Table XXII. Catch per effort of brill in the southern area.

Year	Average catch per hour (lbs)	Year	Average catch per hour (lbs)
1945	41	1953	175
1946	73	1954	108
1947	113	1955	73
1948	242	1956	34
1949	232	1957	87
1950	220	1958	96
1951	108	1959	140
1952	182	1960	121

Average age of fish in the 1960 catch was up slightly from that in 1959, which would support the view that there has been a small decrease in recuritment.

(b) The northern stock. Assessment of the condition of the northern stock presents more difficult problems than the southern stock because it occupies four widely separated summer feeding grounds in Queen Charlotte Sound and Hecate Strait. The methods of combining the data for these grounds into a single picture were outlined in the summary reports for 1958-59 (p. 147). However, it has since proved advisable to weight catch/effort for each ground by the total United States-Canadian catch rather than by total effort. This changes the absolute values of catch/effort but does not alter the general trends. These revised data are shown in Table XXIII with preliminary estimates for 1960.

There is a general parallel of catch/effort trends between the northern and southern stocks: a rising trend with a peak in 1948, a decline thereafter to a low point in 1956. While catch/effort on the northern grounds was higher

Table XXIII. Catch per effort of brill in the northern area.

Year	Average catch per hour (lbs)	Year	Average catch per hour (lbs)
1945	357	1953	256
1946	393	1954	73
1947	540	1955	98
1948	902	1956	59
1949	651	1957	165
1950	390	1958	105
1951	522	1959	141
1952	273	1960	117

after 1956, evidence of a trend is not as clear as on the southern grounds. Still, the similarities are remarkable when considered in the light of the different histories of exploitation (about 5 years separated the discovery and exploitation of virgin stocks in the two areas). Trends in average size and age have followed closely those observed on the southern grounds, which suggest that variations in recruitment have been an important factor in the trends in abundance. Recovery of the stock to former levels of abundance would seem to depend on a change in the environmental conditions which are suppressing the supply of recruits.

2. <u>Lemon sole catch per unit of effort in Hecate Strait</u> K. S. Ketchen

The principal British Columbia fishing ground for lemon sole is in northern Hecate Strait. Estimates of annual catch per unit of effort are based on the performance of double-gear trawlers of 25 to 49 gross tons during the months of March to June, inclusive. For the past 10 years, fishing effort and catch have followed a slow downward trend, presumably because of the increasing costs of operation. Abundance, as shown in Table XXIV, shows little or no sign of trend since 1948. Average catch per hour in 1960 was somewhat below the

Table XXIV. Catch per effort of lemon sole in northern Hecate Strait.

Year	Average catch per hour (lbs)	Year	Average catch per hour (lbs)
1945	1,367	1953	745
1946	988	1954	563
1947	1,093	1955	677
1948	632	1956	868
1949	553	1957	534
1950	932	1958	633
1951	639	1959	632
1952	731	1960	581

1948-60 mean of 670 pounds. Given sufficient incentive, production of lemon sole from northern Hecate Strait probably could be increased by 50% and sustained without much effect on the present level of stock and without lowering the minimum market size. Results of population-model studies suggest that yield-per-recruit could be increased by reducing the minimum market size to 12 inches from the present 13 inches.

3. Rock sole catch per unit of effort in Hecate Strait — J.A. Thomson and C.R. Forrester

The usual practice of equating catch per unit of effort to a standard gear or class of trawler does not yield adequate results when applied to the rock-sole fishery in northern Hecate Strait, for the following reasons: Firstly, there is no single gear class which has continued in the fishery for the period under study (1945-1959). During this time there has been a complete changeover from single to double gear, but their relative efficiencies have varied so much from year to year that it is impossible to calculate a reliable conversion factor for expression of catch/effort in terms of one particular type of gear. Secondly, difference in experience, or local knowledge of individual fishermen seems to play a larger role on the grounds in question than elsewhere on the coast. This means that there is no clear-cut division between the efficiencies of various tonnage classes of trawlers.

For these reasons catch per unit of effort for the rock sole in northern Hecate Strait has been derived in the following manner: During the fishing season (May to October) the catch/day has been calculated for each individual trawler. The raw data were subjected to a 50% qualification level so that only those trips, where rock sole made up more than half the total landing, were considered. This eliminated the problem of incidental catch. In computing an annual average, individual values of catch/day were then weighted to the total rock sole catch of each trawler. This gave more weight to those trawlers which fished throughout the season and at the same time retained data from trawlers making only one or two trips to the grounds. The results of this analysis are given in Table XXV.

Table XXV. Average catch per effort of rock sole in northern Hecate Strait, not corrected for changes in gear efficiency.

Year	Pounds per day	Year	Pounds per day	Year	Pounds per day
1945	6,308	1950	8,961	1955	13,832
1946	6,112	1951	13,317	1956	10,891
1947	9,494	1952	13,743	1957	9,560
1948	8,749	1953	9,722	1958	14,716
1949	8,528	1954	17,647	1959	14,307

Superimposed on the year-to-year fluctuations in catch/day there is an upward trend over the period in question. This trend is shown by the slope of a least-squares line fitted to the data whose formula is Catch/Day = 6882 + 522 (year) where the year is expressed as $(x - 1944)$.

It has been shown elsewhere (Ketchen and Thomson, MS Rept. 663, 1958) that a "double-gear" trawler is generally more efficient than a "single-gear" one. During the period under study, the rock-sole fleet has changed from exclusively single gear to exclusively double gear. If this changeover is plotted by year in terms of percent of the fleet using double gear, the resulting line falls closely on the above trend line for catch/day. For this reason, the upward trend in catch/day is believed to illustrate a rising efficiency rather than an over-all upward trend in size of the rock-sole population. Therefore the trend line has been swung to a horizontal position and year-to-year deviations above and below the line have been used as measures of abundance or availability of rock sole. Estimates of average catch/day, independent of change in gear efficiency, are given in Table XXVI.

Table XXVI. Average catch per effort of rock sole in northern Hecate Strait, corrected for changes in gear efficiency.

Year	Lbs/day	Year	Lbs/day	Year	Lbs/day
1945	6,308	1950	6,351	1955	8,612
1946	5,690	1951	10,185	1956	5,149
1947	8,450	1952	10,089	1957	3,296
1948	7,183	1953	5,546	1958	7,930
1949	6,440	1954	12,999	1959	6,999

4. Grey-cod catch per unit of effort

K. S. Ketchen

Apparent abundance of grey cod on various offshore fishing grounds fluctuates sharply from year to year. While variations in availability may be partly responsible for this phenomenon, the main reason may be changes in recruitment. Very few ages are represented in the catches (perhaps no more than two or three), and thus one would expect changes in recruitment to be reflected in catch per unit of effort.

Annual average catch per effort for three major fishing areas is shown in Table XXVII. The figures are based on the performance of double-gear vessels (25-49-GT) in Hecate Strait and Queen Charlotte Sound and on single-gear vessels (same tonnage class) off the lower west coast of Vancouver Island.

Catch/effort in 1960 was lower in all three areas than in 1959, and this accounted for the sharp drop in total production. The correlation between catch and catch/effort has been quite close during the past four years (a period of strong market demand). Highest production was achieved in 1958 in northern Hecate Strait and in 1957 in Queen Charlotte Sound and off the west coast. Production was lowest in 1960 in Queen Charlotte Sound and off the west coast of Vancouver Island. However, in Hecate Strait, lowest production was in 1957 when catch/effort was about 100 pounds per hour more than it was in 1960.

The span of years for which reliable data are available is too short to permit any conclusions to be drawn about the status of the stocks. Presumably the fishery can be sustained at its present high and variable level, barring

Table XXVII. Catch per effort of grey cod.

Year	Average catch per hour (lbs)			Year	Average catch per hour (lbs)		
	N. Hecate Strait	Q. C. Sound	West coast		N. Hecate Strait	Q. C. Sound	West coast
1951	1,960	--	435	1956	585	(380)	480
1952	1,000	--	640	1957	885	1,140	900
1953	690	--	685	1958	1,560	930	440
1954	940	--	805	1959	1,105	760	855
1955	765	--	640	1960	775	660	325

the unlikely possibility that it does not reduce the annual supply of spawners to a point where it affects recruitment. Yield-per-recruit models suggest that, in view of the high natural mortality rate, maximum yield will be achieved by heavy fishing, beginning at age II. In northern British Columbia waters, at least, market limitations are such that fishermen tend to avoid or discard fish of age II and younger.

Age and Growth Studies

Routine sampling of commercial landings of groundfish was continued in 1960 at the ports of Prince Rupert and Vancouver. Otolith samples (for age composition and growth) were obtained from approximately 25,117 fish - mostly brill, lemon sole, rock sole and butter sole. Length measurements only were obtained on 32,866 fish which consisted mainly of grey cod, blackcod, ocean perch and lingcod.

Results of analyses of these and earlier collections are discussed in the sections which follow.

A. Age composition of brill from the lower west coast of Vancouver Island

C. R. Forrester

Age determinations from otoliths taken during the 1960 brill fishery on grounds off the lower west coast of Vancouver Island have been summarized in Table XXVIII. Approximately 2,200 female and 1,000 male fish were sampled during the season.

The 1953 and 1954 year-classes among male fish and the 1952 and 1953 year-classes among females were the dominant contributors to the 1960 fishery, as was the case in 1959. These year-classes appeared to have been stronger than the preceding six or seven year-classes and have been responsible for the recent upward trend in catch/effort. However, year-classes subsequent to those of 1953 and 1954 appear to be weaker than average. Average age in the 1960 catch increased slightly and catch/effort declined, suggesting that the recent increase in stock size has been arrested, at least temporarily. Prospects for an early return to former stock levels are now rather uncertain.

Table XXVIII. Age composition of brill off the lower west coast of Vancouver Island.

Age	% frequency Male	Female	Age	% frequency Male	Female	Age	% frequency Male	Female
IV	1.0	0.2	X	3.1	7.8	XVI	0.3	0.7
V	12.7	8.0	XI	2.0	4.1	XVII	--	1.4
VI	24.8	12.5	XII	2.4	2.1	XVIII	--	0.4
VII	31.3	25.8	XIII	2.4	0.5	XIX	--	0.2
VIII	14.6	20.9	XIV	0.9	1.4	XX	--	0.2
IX	4.5	12.3	XV	--	1.4	XXI	--	0.1

B. Age composition of the lemon sole in northern Hecate Strait

C. R. Forrester

Otolith samples of approximately 1,150 fish have been examined from the catch of lemon sole taken in 1960. Age determinations from these samples are summarized in Table XXIX.

Table XXIX. Age composition of lemon sole in northern Hecate Strait.

	Age (percent frequency)												Number sampled
	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	
Female	2.1	20.2	27.9	20.7	13.2	7.6	4.7	1.8	0.9	0.6	0.1	0.2	894
Male	0.4	12.7	27.8	17.8	15.5	13.9	8.1	1.9	1.9	--	--	--	259

Average length and age of female fish in 1960 are almost identical to those observed in 1959. The 1955 year-class which appeared fairly strongly as IV-year-old fish in 1958 became the dominant year-class in 1960. In both males and females the incoming 1956 year-class (IV-year-old fish) appears slightly stronger than average. There have been no major changes in the pattern of recruitment to this fishery in recent years.

C. Age and growth studies on rock sole in northern Hecate Strait

1. Age composition of rock sole

C. R. Forrester

Age determinations from approximately 1,150 otolith samples of rock sole collected during the 1960 fishery are summarized in Table XXX.

Table XXX. Age composition of rock sole in northern Hecate Strait.

	Age (Percent Frequency)										Number sampled
	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	
Female	1.0	33.8	51.7	9.4	2.3	0.9	0.3	0.2	0.3	0.1	936
Male	7.0	57.6	28.4	6.1	0.9	--	--	--	--	--	229

The Hecate Strait rock-sole fishery continues to be dominated by fish of young age and small size. V- and VI-year-old fish constitute just over 85% of the fish in the commercial catch. The average length of both male and female fish was about the same as in 1959 but there was some increase in average age (5.9 years in 1960 vs. 5.6 years in 1959). This may be a consequence of reduced growth rate through overcrowding. As mentioned elsewhere in these reports and in last year's report, catch/effort on the northern Hecate Strait grounds has been much above average in the last three years, apparently as a result of exceptional recruitment. In the year-classes now entering the fishery, the fish are of below-average size.

2. Estimation of rock sole year-class strength C. R. Forrester

Estimates of the variation in size of rock sole year-classes have been obtained from information on age composition and catch per unit of effort. Several possible indices of abundance have been examined by summing the numbers of fish per unit of effort (for a given year-class) over various age ranges: III to VI, IV to VII, V to VIII, etc. All give approximately the same results. For present purposes we shall consider estimates based on the age range IV to VII. These are shown in Table XXXI.

Table XXXI. Estimates of year-class strength in northern Hecate Strait rock sole. Index: Numbers of fish per unit of effort, from age IV to VII inclusive.

Year class	Numbers of fish (000's)	Year class		Numbers of fish (000's)
1939	21.1	1947		89.5
1940	13.7	1948		79.6
1941	15.5	1949		73.2
1942	52.4	1950		37.7
1943	84.3	1951		16.7
1944	44.9	1952		17.5
1945	27.8	1953		68.5
1946	47.3	(1954	incomplete	55.4)

The table shows that some year-classes have been as much as 6.5 times larger than others (e.g. 1940 year-class: 13,700 fish per unit effort vs. 1947 year-class: 89,500 fish per unit effort). It is suspected that the 1954 and 1955 year-classes may be even stronger than any of those which have been observed so far. However, data for these years are not yet complete.

The important bearing of recruitment on the year-to-year variations in fishing success can be demonstrated by a close correlation between catch/effort for all age groups combined and catch/effort of age groups IV and V combined (the latter cannot be treated individually because age of peak recruitment in numbers is not always either at age IV or V). A correlation between total catch/effort and catch/effort of ages greater than V is not apparent and this would indicate that year-to-year variations in fishing success are not merely the result of variations in availability of the stock to the fishery.

3. Mortality rates in the rock sole stock of northern Hecate Strait

C. R. Forrester

(a) Total mortality rate

Catch per unit of effort data have been used to obtain survival rates, s, of year-classes 1939 to 1951 (an average of survival rate, s, from ages VI to VII and age VII to VIII). These rates, with corresponding rates of instantaneous total mortality, i, are shown in Table XXXII.

Table XXXII. Survival rates (s) and instantaneous total mortality rates (i) in rock sole year-classes.

Year class	s	i	Year class	s	i
1939	.759	.28	1946	.654	.43
1940	.736	.31	1947	.655	.42
1941	.746	.29	1948	.410	.89
1942	.582	.54	1949	.421	.86
1943	.629	.46	1950	.531	.63
1944	.487	.72	1951	.561	.58
1945	.510	.67	Average	.591	.54

Trends in i (upward for year-classes 1939-45 and downward for year-classes 1948-51) are in general conformity with the history of exploitation and to some extent with information on the actual removals (by year-class) through fishing. However in detailed examination, the relationship between i and removals is rather poor. For two year-classes (1946 and 1947), i was relatively low, even though removals were high. Furthermore, while i has declined for recent year-classes in line with declining removals, their absolute magnitudes are much higher than would be expected from the relationship between i and removals for earlier year-classes (1939-45).

Further study is underway to find a satisfactory explanation of these discrepancies. The data, as they stand now, probably indicate lower and upper limits of i, the former being close to the rate for unfished stocks (i.e. close to the natural mortality rate - see below). For periods when fishing has been relatively heavy, i is probably somewhere between 0.6 and 0.8.

(b) Natural mortality rate

Several methods have been used in estimating instantaneous natural mortality (q):

(i) Mortality rate of lightly exploited year-classes. Examination of mortality rates by the method described above, showed that i for year-classes 1939 to 1941 was between 0.28 and 0.31 (see Table XXXII, above). These estimates refer to a period when the Hecate Strait fishery was in its infancy, and so may be regarded as approximations of q, the instantaneous natural mortality rate.

(ii) Age composition of catch in early years. Analysis of catch curves for the years of 1946 and 1947 (when the fishery was only just developing) yields i values of 0.42 and 0.37 respectively. Age groups were used which theoretically should not have shown, by that time, the effects of fishing and hence i would be roughly the same as q. However, the values estimated are slightly higher than those derived in the preceding section, probably because the method embodies the untenable assumption of stable recruitment.

(iii) Results of tagging. Analysis of tag returns by a method which is appropriate for taggings conducted in two consecutive years (1947 and 1948) yield an estimate of instantaneous natural mortality, q = 0.32. This is remarkably close to the estimates based on survival of year-classes (above).

(c) Fishing mortality rate

From results of the two tagging projects mentioned above, estimates of 0.26 and 0.25 were obtained for the instantaneous fishing mortality, p, in 1947 and 1948 respectively. Assuming that p is proportional to fishing effort (information on which is known for each year) it was found that the average for the years 1945 to 1959 inclusive was p = 0.19. Adding this to the best estimate of q = .33 (a mean of various estimates) we get an average estimate of i = 0.52. This is fairly close to the estimate given above in the section on total mortality rate (i = 0.54).

Thus, while further refinements are necessary, it appears that the estimated components of total mortality rate are approximately correct.

4. Back-calculation of rock sole growth from otolith measurements — J.A. Thomson and C.R. Forrester

Commercial samples from the Butterworth-Warrior Rocks ground were examined to determine a relationship between otolith size and fish length. This work is a prelude to determining size at ages that are not represented in the commercial sample. Otolith size, and later annulus size, was expressed as a radius measured perpendicular to the long axis. The commercial samples were augmented by samples obtained by special small-mesh trawls. The data were then plotted and a linear relationship on a semi-log plot was calculated between fish length and otolith radius. The formulae are:

Female - Radius (0.1 mm) = 21.796 $\log_{10}$ fish length (cm) - 12.943
fish length range 9-48 cm

Male - Radius (0.1 mm) = 19.108 $\log_{10}$ fish length (cm) - 9.864
fish length range 8-35 cm

From this, calculations of absolute fish length will be made and compared with observed data.

5. Length-weight relationship in rock sole

C. R. Forrester and J. A. Thomson

Data for determining length-weight relationships of rock sole from the Butterworth-Warrior Rocks ground are rather scanty. However, examination of samples taken from other areas reveal little difference within the size range taken commercially. The following length-weight formulae are based on a commercial sample taken in 1956.

A log-log curve was fitted to the data by least squares.

Female - Log_{10} weight (lb) = 3.2148 $\log_{10}$ length (mm) - 8.0779

Male - Log_{10} weight (lb) = 2.8995 $\log_{10}$ length (mm) - 7.2953

The females tend to be heavier than the males for any given length.

The above relationships were simplified into cubic equations which yielded adequate results for the present. The new equations are:

Female - Weight (gm) = 0.01352 length $(\text{cm})^3$

Male - Weight (gm) = 0.01273 length $(\text{cm})^3$

The calculated values diverge only slightly from the observed, at the lower end of the commercial sample (30 cm). Data from fish below commercial limits are needed for further refinement.

Tagging Studies

A. A review of results of recent tagging projects

1. Recoveries in 1960 from previous taggings

J. A. Thomson

(a) Rock sole. The rock sole fishery in northern Hecate Strait recovered 24 of the 1,300 rock sole tagged in July, 1959, along the Butterworth-Warrior Edge. In addition, 5 tags from the 1958 tagging in the same area were also recovered. There was no evidence of migration to other grounds away from the tagging area.

(b) Grey cod. Out of 1,233 grey cod tagged at Porlier Pass in March, 1959, 119 were recovered by April 1, 1960. A further 31 were recovered between April, 1960, and March 1, 1961. Recoveries, therefore, amounted to 9.6% the first year and 2.5% the second year. There is some indication that the dart-type tag is lasting better than the standard spaghetti tag since 20 out of the 31 recoveries were darts.

In March, 1959, a further 650 grey cod were tagged in Nanoose Bay. First year recoveries (to April 1) amounted to 96 tags or 14.8%. There were 12 recoveries in the second year (to March 1) or 1.2%. As above, the dart tags recovered outnumbered the spaghetti tags 8 to 4.

2. Flatfish and lingcod tagging in 1960 J. A. Thomson

(a) Lemon sole. In April, 282 lemon sole were caught and tagged off Victoria, between William and Albert Heads. Standard Peterson disc tags were used. To date (March 1, 1961) there have been 42 recoveries (15%). The recoveries illustrate an offshore migration on the part of some of the population. Out of 39 recoveries, 19 were on or near the tagging ground, 16 showed a westward movement towards the Umatilla Reef grounds, three were from the vicinity of the Columbia River Lightship. Eastward movement was shown by 4 tag recoveries, 2 from Satellite Channel and 2 from Orcas Island. Three tags were returned with unspecified location of capture.

(b) Rock sole. From June 23 to July 4, 1,509 rock sole were tagged just north of Lanz Island on the Cape Scott grounds. To date (March 1, 1961) 114 have been recovered (13%). Five recoveries were reported from the Goose Island grounds some 30 miles northward, the remainder were recaptured on the Cape Scott bank.

(c) Brill. 731 brill were tagged with Petersen discs on the Cape Scott grounds during the same period. There have been 35 recoveries to date. The recoveries show a wider dispersion than the rock sole. Two tags were returned from Bonilla Island in Hecate Strait, one from Esteban and one from the Esteban Deep ground off the west coast of Vancouver Island. A fifth tag was reported from Quillayute off the Washington coast. The remaining 30 recoveries were made in the tagging area.

(d) Lingcod. Plastic dart tags were used to tag 187 lingcod caught during October on the grounds near Victoria. There have been 22 recoveries to date (March 1), all from the vicinity of the tagging area.

3. Grey-cod tagging in 1960 J. A. Thomson

(a) Hecate Strait. In February, 1960, using the Station vessel "A. P. Knight", 1,228 grey cod were tagged on the grounds lying 8 miles southwest of White Rock Buoy in Hecate Strait. This was a comparative tagging, 610 grey cod being tagged with dart-type tags and 618 with the standard spaghetti type modified by the insertion of 15-lb test nylon in the Temflex tubing for strength and resistance to abrasion. To date (March 1, 1961), 263 tags or 21% have been recovered. Recoveries of dart tags numbered 127 or 20.8% compared with 22.3% or 136 for the spaghetti type. The difference is not significant.

The following breakdown of tag recoveries by month points out some aspects of grey cod migration in Hecate Strait. The grey cod on the White Rock ground in winter are spawning. The fishery on this ground coincides with the spawning concentration and thus is rarely pursued past the end of March. During the 1960 fishing season some 176 tags were recovered. Even before the end of March 1 there was evidence of a northward movement since about one-third of the recaptures were made at the northern end of the ground some 10 miles from the tagging area. Further evidence was afforded by the recapture of 3 tags in March from the "Two Peaks Ground" (between Butterworth Rocks and Rose Spit buoy) some 50 miles from the tagging site.

During the summer, some conflicting evidence of a southward movement from White Rocks was shown by the recovery of 4 tags on the "Horseshoe" ground (about 40 miles south of the tagging area). During this period (April to September), however, 16 tags were recovered on the "Two Peaks Ground".

In October, tags were again reported from the tagging area, and as the fishery intensified the number of tags recovered increased until a total of 45 had been found by March 1, 1961.

To summarize, 263 tags were recovered: 20 were recovered from grounds to the north of the tagging area and 4 from grounds to the south. The fishery during the tagging season recovered 177 and 45 had been recovered by March 1 in the following season. Seventeen recoveries came from unknown areas.

Tagging of grey cod was repeated on the White Rock ground from January 29 to February 17, 1961. Again, this was a comparative tagging, 520 grey cod being tagged with dart-type tags and 524 with the reinforced spaghetti type. To date (March 1), 28 tags have been recovered. The recoveries show the same northward drift to the top end of the ground as was shown last year. One tag was reported from Butterworth Rock, some 38 miles north of the tagging area.

(b) Victoria ground. The sudden interest in the grounds off Victoria during the fall of 1959 and the recovery of several Nanoose-tagged grey cod there made further study of this area highly desirable. Two trips were made to the area, one in April and the second in October, 1960. During the April trip, 82 spaghetti- and 148 dart-type tags were put on grey cod. The spaghetti tags were reinforced with a core of 15-lb test monofilament nylon. To date (March 1, 1961) there have been 36 recoveries (15%), 22 of them dart tags. Recoveries during the summer showed a slight westward migration to Port San Juan and Camanah Point. However, the bulk of the recoveries were made during the fall fishing season on the tagging ground. During the October trip a further 17 spaghetti (reinforced) and 314 dart tags were used (total 331). There has been one recovery to date (March 1, 1961).

4. Migration of grey cod in the Strait of Georgia

J. A. Thomson

During the past year recoveries from grey-cod taggings in the Strait of Georgia have been summarized in an attempt to find some pattern of migration or connection between stocks. While the final picture is not yet clear, some interesting points have already come to light.

1) There is a definite mixing between Porlier Pass grey cod and Nanoose grey cod. Fish tagged at Porlier Pass have been recovered from the same locations and at the same time as Nanoose tagged fish. Furthermore fish tagged at Porlier Pass one spring have been recaptured at Nanoose the following spring. The great majority of Porlier Pass grey cod, however, are recaptured very close to the tagging area, within the Gulf Islands. It is interesting to note that Nanoose-tagged grey cod have never been recaptured within the islands north of Active Pass. This mixing of the Porlier Pass stock with the Nanoose stock may be explained by the presence of younger fish in the Porlier Pass population. Furthermore, although Nanoose Bay is the northern limit for Porlier Pass tags, some Nanoose tagged grey cod have been recovered well north of the tagging area. At the present time it seems as though Porlier Pass grey cod are of two types, the younger fish which may mix with Nanoose fish, and older fish which seem to be more sedentary, remaining for the most part within the Gulf islands area. Nanoose grey cod also seem to fall into two groups, the larger forming the general population that moves through the lower Strait of Georgia and a smaller segment that moves northward from the tagging area.

2) There is some evidence of an exchange between gulf grey cod and populations off the west coast of Vancouver Island. Recoveries from both Porlier Pass and Nanoose Bay taggings have been made from waters off the entrance to Barkley Sound, Swiftsure Bank and the grounds off Umatilla Reef on the outer Washington coast.

3) In general, fish tagged at Nanoose Bay show a wider dispersion than those tagged at Porlier Pass. By measuring the distance travelled, and dividing it by the number of tags recovered from a certain area, a rough measure of dispersion has been obtained. For Nanoose Bay taggings the figure is 56 miles based on 245 recoveries. For Porlier Pass the same calculations yield a figure of 13 miles for 293 recoveries.

This study is based on some 1,900 grey cod tagged at Nanoose Bay and some 2,300 at Porlier Pass. Further investigation is planned.

Special Studies

Basis for trawl mesh regulation in the Strait of Georgia — K. S. Ketchen

On several grounds in the Strait of Georgia, production of lemon sole is much less than formerly. Coincident with the decline, there has been an increase in the production of minkfood from these grounds. While fisheries regulations specify a minimum size limit on lemon sole, to prevent the use of undersized individuals as minkfood, enforcement of the regulation has been very difficult. It appears, therefore, that an increase in mesh size would be a more effective method of enabling escapement of undersized (juvenile) fish. The expected benefits from such a measure have been set forth in Station Circular No. 61 (1961) and are presented here in summary form.

Lemon soles become liable to capture at age III (26.0 cm) but are not completely vulnerable to existing commercial gear until age III-1/2 (28.4 cm). They do not become acceptable to the foodfish market until they reach age IV (30.0 cm), but could be used (and are, to some extent) as minkfood.

A number of population models were constructed to determine what the yield per recruit would be if it were possible to utilize all fish taken by various sizes of mesh. With a net of 3-inch mesh (i.e. a size less than that now used commercially) the age of first capture would be III years; with a net of 3 1/2-inch mesh (prevailing mesh size) the age of first capture is at III-1/2 years, and with a net of 4 1/2-inch mesh (that now proposed for the Strait of Georgia) the age of first capture would be IV years.

Using these ages and a still later age of entry, yields were computed on the basis of 1,000 pounds of fish reaching III years of age. In the models it was assumed that the instantaneous rate of fishing mortality is 0.40 and the instantaneous rate of natural mortality increases from 0.20 to 0.26 between age III and VI and thereafter remains constant at 0.26. These are the best available estimates of actual conditions.

The results are shown in Table XXXIII, in terms of yield both in pounds and in dollars. In the latter case it was presumed that all fish less than 12 inches (30.5 cm) could be sold as minkfood (at 3¢ per pound) and all fish over that size could be sold as food fish (at 7¢ per pound).

Table XXXIII. Yield in pounds and dollars from 1,000 pounds of lemon sole reaching age III.

First capture		III	III-1/2	IV	IV-1/2
	minimum age (years)	III	III-1/2	IV	IV-1/2
	minimum length (cm)	26.1	28.2	30.0	31.6
	Yield in pounds	1154	1169	1164	1134
	Yield in dollars	66	73	81	79

These results suggest that, by raising the age of first capture from III-1/2 years to IV years (i.e. by increasing the mesh size from 3 1/2 inches to 4 1/2 inches) there would be a negligible change in the weight of fish caught, but there would be a fair increase in the value of the catch.

Assuming that our estimates of natural mortality rate are reliable, it appears that there would be an advantage to allowing lemon soles to escape capture until age IV; or in other words, to prevent their use as minkfood before they reach that age.

MARINE COMMERCIAL FISHERIES
CRAB AND SHRIMP - T.H. Butler

The crab fishery of the Queen Charlotte Islands has been under investigation since 1947 to discover and explain fluctuations and assess the need for regulation.

Review of data pertaining to the fishery was continued in 1960. Field work was concerned with testing a relationship between success of fishing and water temperature (which had become apparent on examination of past records) and determining the efficacy of a closure for soft-shelled crabs.

Apart from a project to test trawls and mesh sizes in 1959, shrimp research has been confined since 1953 to exploratory fishing. The ground in Barkley Sound, discovered by this Station in 1954, yielded 437,000 pounds during 1960, about 26% of the total production of the province. Late in 1960 a program of sampling on commercial shrimp grounds near the Strait of Georgia was started to determine seasonal differences in distribution, abundance, growth and reproduction. This project will continue throughout most of 1961.

Occurrences of king crab on the British Columbia coast have been summarized, and in July, 1960, a search was made for them in a coastal inlet. Many requests from fishermen and others for information on shrimp fishing areas and gear were attended to during the year. Considerable time was spent on a program of laboratory and field instruction for Mr. Bu Kwan Chung, FAO Fellow from Korea, who was at the Station from May 1 to August 31, 1960.

Crab

A. 1960 Queen Charlotte Islands crab fishery

In 1960 the total crab catch from the British Columbia coast was 5,067,700 pounds, the highest on record. Of the total, 3,513,679 (69.3%) were from the Queen Charlotte Islands. The catch in the northern region was higher than in 1959 (3,211,883 pounds), due mainly to the increased catch from McIntyre Bay. Another group, the Prince Rupert Fishermen's Co-operative Association, entered the crab fishery with one boat, and it is expected that its fleet will increase in 1961.

(1) Naden Harbour. The total catch in this area in 1960 was 53,540 pounds, a sharp drop from the 1959 total of 99,826 pounds. The spring fishery during April yielded 16,642 pounds at an average rate of 445 crabs per "man-day". During October 36,899 pounds were caught, an average catch of 156 crabs per day. This was the lowest rate of fishing in several years, in line with the prediction made last year based on the relationship between water temperature and relative abundance.

(2) McIntyre Bay. The total catch in 1960 was 665,685 pounds, and showed a considerable increase over the 1959 catch of 340,689 pounds. While abundance may have been higher in 1960, it is believed that the increased catch was the result mainly of greater fishing effort. Five boats from Masset began to fish

early in March and enjoyed good catches. By the end of April the traps of four boats had been moved to Hecate Strait. One vessel persisted in fishing throughout May and June and its catches accounted for most of the increased 1960 landings before the closure date of July 10.

After the season was re-opened on September 20 five Masset boats, by fishing throughout October and into November, took the greater share of the crab catch. For the first time in several years boats based at Prince Rupert and Port Edward fished this area; between September 26 and December 2, three boats caught 98,980 pounds.

(3) Hecate Strait. During the 1960 season, from April 8 to November 3, the total catch was 2,794,454 pounds. Six boats from Port Edward and Prince Rupert accounted for 1,539,165 pounds. Catch statistics have yet to be analysed, but it appears that effort and abundance of crabs were much the same as in 1959. A new development in 1960 was the southward extension of fishing grounds in Hecate Strait. Several boats found a fairly productive area as far south as Skidegate Inlet.

B. Experimental fishing, 1960

(1) McIntyre Bay. The regulation which prohibits crab fishing in McIntyre Bay between Rose Spit and Wiah Point from July 10 to September 20 has been in effect since 1958. Its purpose is to protect soft-shelled crabs. In 1959 the industry, though generally satisfied with the closure, requested that the position of the western boundary be changed. The claim was that crabs moulted earlier in the western sector, on Venture Bank off Masset Inlet, and were hard while crabs were soft-shelled on the ground between Tow Hill and Rose Spit. Limited experimental trap fishing by the "Investigator No. 1" in 1956 and 1959 seemed to confirm this opinion.

Between July 23 and August 5, 1960, 253 traps were hauled by the "Investigator No. 1". Following are the 1960 results compared with those obtained in earlier years.

Crab catch	1960		1956		1959	
	Venture Bank	Tow Hill to Rose Pt.	Venture Bank	Tow Hill to Rose Pt.	Venture Bank	Tow Hill to Rose Pt.
Total legal males	1281	2492	37	24	26	49
No. soft-shelled	314	1151	10	15	8	43
% soft-shelled	24.5	46.2	27.0	62.5	30.7	85.7

The results show fairly conclusively that during July and early August there are fewer soft-shelled crabs around Venture Bank than in the sector east of Tow Hill. A recommendation has been made to the Department of Fisheries that the boundary be shifted from Wiah Point to Skonun Point.

(2) Naden Harbour. The purpose of sampling here was to confirm predictions of year-class strength. Using the relationship of the success of fall fishing with April surface water temperature four years earlier, it was predicted that the 1960 fishery would be below average, the 1961 about average and the 1962 good.

On July 24 and 25, 30 trap sets were made and yielded an average catch of 9.5 crabs per trap. Comparable summer fishing in 1956 gave a catch of 7.9 crabs, and later in the fall fishery the average daily catch per man was 166 crabs. Thus, it was expected that the rate of fishing in the 1960 fishery would be about the same or slightly better than in 1956; as it turned out it was 156 crabs per day.

Nine tows with a small-meshed trawl yielded 1,236 male and female crabs mostly under legal size. This size distribution has been compared with sampling done in earlier years. The abundance of three-year-olds (averaging about 155 mm) seems lower than average. A similar picture was observed in 1955, and a year later, as four-year-olds, the crabs supported a relatively poor fishery. Thus, it is likely that rate of fishing in 1961 will not differ appreciably from that predicted, using the relationship based on water temperature. Two-year-old crabs between 85 and about 135 mm were abundant as predicted. In comparison, they were definitely more abundant than in 1954 and 1956, and as abundant or somewhat more than in 1955. The strong group present in 1955 produced a successful fishery two years later when the average daily catch was 420 crabs. The finding of an abundant group of two-year-old crabs in 1960 seems to confirm the prediction that a successful fishery will occur in 1962. Further sampling is planned during the summer of 1961.

Shrimp

More attention has been given to a program of exploration for new shrimp fishing grounds. The life histories of Pacific commercial shrimps are quite well known for one or two species, and somewhat sketchily known for the others. It is believed that the efficiency of shrimp fishing gear can be increased. A start has been made with trawls in an attempt to reduce incidental fish catches and to facilitate escapement of small shrimps, and further research is planned for the future. Fishermen have voiced the need for an improved prawn trap. Following is a summary of life history studies and trap testing carried out recently.

A. Life history studies. The first phase of the project was carried out from November 7 to December 2 with the "Investigator No. 1". Eighty-four trawl tows and 23 trap sets were made in 5 local areas near the Strait of Georgia between depths of 5 and 139 fathoms. A 40-foot "Gulf of Mexico" trawl of 1 1/2-inch mesh, with a 1/2-inch liner in the cod-end, was used. Some 6,400 shrimps belonging to six species were measured. The measurement taken with a vernier caliper was the carapace length from the orbit of the eye to the dorsal posterior margin of the carapace. Bottom temperatures and water samples were taken after most trawl tows and some trap sets.

The "smooth-pink" shrimp (*Pandalus jordani*) occurs along the east coast of Vancouver Island. A total of 1,091 specimens were measured from all tows.

Two distinct groups of males found in this sample (one between 9.0 and 13.6 mm, and the other between 14.2 and 18.8 mm in carapace length) were hatched in 1960 and 1959, respectively. Females ranged from 16.2 to 25.5 mm, and probably most individuals had reached the third year. Fourteen (2.1%) of the 659 females were ovigerous.

In all areas side-stripe shrimps (Pandalopsis dispar) occurred at about 50 fathoms and deeper, and 987 were measured. The sample from Vancouver Island (Fig. 3A) had two groups of males. One, between 10.0 and 14.8 mm, was hatched early in 1960 and the other, between 17.6 and 24.0 mm, probably belongs mostly to the 1959 year-class. Both age groups of males in samples from English Bay, Indian Arm and Howe Sound were on the average about one millimeter larger than the above. The size range of females was from 23.0 to 38 mm and over 80% were ovigerous.

A sample of 1,120 "pink" shrimps (Pandalus borealis) from English Bay (Fig. 3B) revealed two groups of males; the 1960 year-class ranged from 9.5 to 13.5 mm and those a year older from 14.3 to 19.2 mm. Females had carapace lengths of 14.5 to 25.2 mm. Probably most females were three years old but certainly smaller ones were in the second year, having reached the female phase directly. Likewise, large males appear to be spending a second year in that phase. The size distribution of males was much the same in Indian Arm and Howe Sound but females were considerably larger, reaching 28.8 mm in the latter area. In English Bay counts of whole pink shrimps per pound (a measure of average size) increased from 63 at 20 fathoms to 140 at 40 fathoms and then decreased to 90 at 70 fathoms. In other words a preponderance of large shrimps is indicated in shallow and deep tows, and fewer from 35 to 45 fathoms.

Samples of two other species were collected in shallow water in Burrard Inlet. Male "coon-stripe" shrimps (Pandalus danae) ranged from 9.8 to 21.0 mm but there was no clear separation into age groups. The same was true for females having carapace lengths from 13.3 to 25.8 mm. It appears that this shrimp has a long breeding season, and fishermen have stated in the past that ovigerous females may be found throughout the year. The sample of "humpback" shrimps (Pandalus hypsinotus) showed two separate groups of males: one, between 11.2 and 16.8 mm, which presumably hatched in 1960 and the other group, between 20.8 and 24.6 mm, probably a year older. Females ranged from 14.9 to 30.9 mm, and 21.4% were ovigerous.

From trawl and trap catches some 1,600 prawns (Pandalus platyceros) were sexed and measured. Some overlap of age groups was apparent but a conspicuous group of males, presumably hatched in 1960, ranged from 13.2 to about 22.0 mm. The other group was peaked at about 27.4 mm, and the largest male found was 38.6 mm. Carapace lengths of females were from 33.2 to 44.2 mm, and these seem to belong mainly to a single age group. Prawns caught on trawling ground were predominantly small males, and although these individuals were found at all depths they were most abundant shallower than 30 fathoms.

The second phase of the project extended from January 16 to 31, 1961. Fifty-three trawl tows and 10 trap sets were made in 3 local areas (Indian Arm and Howe Sound omitted) between depths of 10 and 114 fathoms. Some 5,000 shrimps belonging to five species were measured.

In all species considered growth, at least of males, occurred between November and January. Because practically all females are ovigerous they did

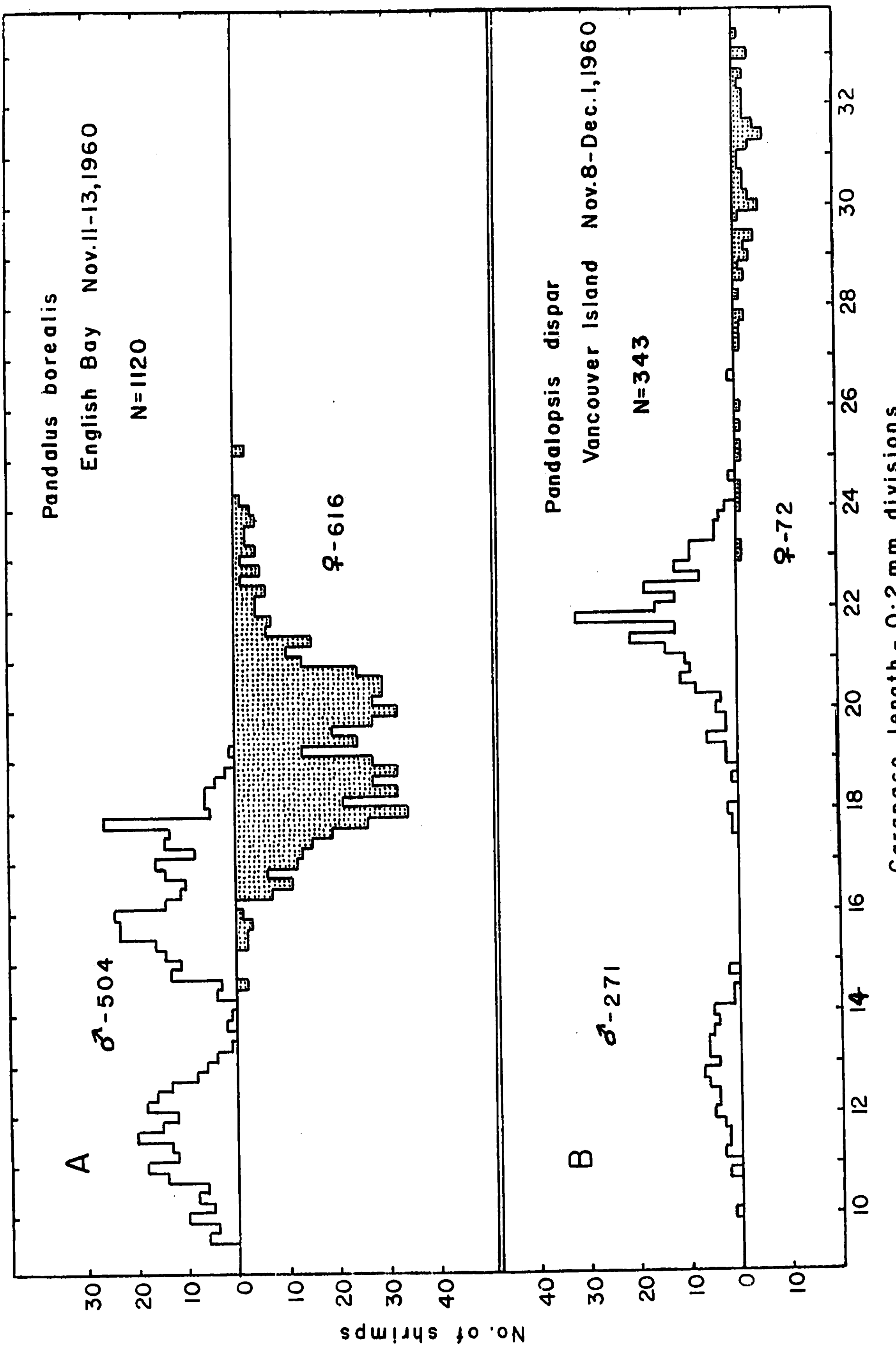

A
Pandalus borealis
English Bay Nov.11-13,1960
N=1120
♂-504
♀-616
B
Pandalopsis dispar
Vancouver Island Nov.8-Dec.1,1960
N=343
♂-271
♀-72
No. of shrimps
30
20
10
0
10
20
30
40
40
30
20
10
0
10
10
12
14
16
18
20
22
24
26
28
30
32
Carapace length - 0·2 mm divisions

Fig. 3.

not moult. Average increases of carapace lengths of males were from 1 to 3 mm, and the corresponding increases in total length were roughly between 5 and 12 mm. First-year male humpback and side-stripe shrimps showed the greatest increases. Rate of growth for each species did not vary with area.

Counts of whole pink shrimps per pound in English Bay showed much the same pattern as in November, increasing from 73 at 20 fathoms to 133 at 45 fathoms and then decreasing to 117 at 80 fathoms. Counts of side-stripe shrimps in the same area decreased from 58 at 30 fathoms to 30 at 70 fathoms, showing that larger individuals are found in deeper water.

B. Experimental trap fishing. Prawn fishing with traps was confined to two local areas near Nanaimo. Samples from catches were sexed and measured. During the first phase of the project in November, 1960, attention was given to animals apparently characteristic of good prawn grounds. Four decapod crustaceans were identified: "bristly crab" (Acantholithodes hispidus), spider crab (Chorilia longipes), "box crab" (Lopholithodes hispidus), "sponge shrimp" (Pandalus stenolepis). The numbers of another decapod varied inversely with the numbers of prawns. Two gastropod molluscs appeared in traps: Argobuccinum oregonensis and Cidarina cidaris. Sizeable pieces of five sponges were brought up, clinging to traps and lines: Rhabdocalyptus dawsoni, Staurocalyptus dowlingii, Aphrocallistes vastus, Geodia mesotriaena, Halichondria disparilis (identified by Dr. D. B. Quayle).

Prospecting for new prawn grounds is now a time-consuming, "hit and miss" procedure for both commercial fishermen and research agencies. It is our intention to select one or more of the above animals which may be collected easily by dredge or grab to indicate productive ground where hydrographic conditions of depth, topography and substratum are suitable.

Late in January, 1961, preliminary tests to improve prawn traps were carried out. A number of fishermen have claimed that traps covered with metal or wood catch more prawns than traps covered with screen or netting. Our standard prawn traps are 24" × 12" × 12", covered with 1 1/2-inch cotton netting, and have a tunnel or sloping entrance at each end. The two types of traps tested had the same dimensions as above but were modified as follows:

(1) Sides were covered with galvanized iron and tunnels with 1 1/2-inch netting.

(2) Sides and tunnels were covered with sheet metal.

Experimental traps were alternated in lines with standard traps. In six of nine sets, catches of metal traps with netting tunnels were higher (ave. 1.4 lb) than average catches of wholly web traps (.9 lb). In only two sets did catches of all-metal traps equal or surpass average catches of standard traps. Also, all-metal traps were difficult to lift because water was retained and drained slowly after breaking the water surface.

It is believed that prawns enter traps with metal sides more readily because they are attracted to the entrances by the odour of bait diffusing through the netting ends. The opinion of fishermen is that prawns seek shelter in traps covered with impervious materials, but generally poor catches in the all-metal traps seems to refute this view. Further tests are planned during 1961. When an efficient design is found, attention will be given to the use of inexpensive, durable materials in trap construction.

King Crab

The king crab (Paralithodes camtschatica), one of the largest of crustaceans, supports commercial fisheries at several places in the North Pacific Ocean. It occurs from Korea northward along the Asian coast to Siberia and the Bering Sea, and then southward into Alaskan and British Columbian waters. Since about 1930 there have been 8 verified records from the British Columbia coast. These are summarized in Table XXXIV.

The specimens from Prince Rupert Harbour were described as a new species (Paralithodes rostrofalcatus) by Dr. D.C.G. MacKay, but subsequent examination has shown them to be juvenile Paralithodes camtschatica. The Boundary Bay specimen was undoubtedly a survivor of a load of Alaskan-caught crabs which had been dumped (as dead or dying) in Bellingham Bay. The large male caught off Ucluelet appears to be a valid occurrence.

In addition to the ovigerous female caught in Kitkatla Inlet in February, 1960, numerous cast-off shells were observed along the shore-line. On July 30, 1960, several trawl tows and a tangle net set were made by the "Investigator No. 1", but yielded no king crab. The king crab is a cold-water species which breeds near Japan and Siberia in shallow water during winter or early spring. It is suggested that these crabs inhabit shallow bays and inlets like Kitkatla Inlet, Captain Cove and Baker Inlet during the winter, presumably for spawning, and migrate with the approach of higher summer temperatures to adjoining deep-water bodies like Ogden and Grenville Channels. Probably king crabs exist in other more southerly coastal inlets where depth and water conditions are suitable.

It is, however, unlikely that king crabs occur anywhere on the British Columbia coast in commercial quantities. Because it has a relatively long life (found to mature off Japan at 9-10 years) the king crab may be a useful indicator species for long-term trends in sea-water temperatures.

The American trawler "Dakota", fishing early in May, 1959, at 150-200 fathoms in southern Hecate Strait, caught a number of specimens of another type of king crab, Lithodes aequispina. This is the first known occurrence in Canadian waters and apparently the first time the species has been taken south of the Bering Sea where it was found at depths from 184 to 406 fathoms.

A paper summarizing all records of the two species is being prepared for publication in collaboration with Mrs. G. C. Carl (Dr. J.F.L. Hart) of Victoria.

Table XXXIV. Records of king crab, Paralithodes camtschatica, from British Columbia.

Date	Locality	Depth	Sex	Carapace width	Carapace length	Collector	Remarks
1930	West coast of Queen Charlotte Islands		♀	163 mm	152 mm	P. H. Johnson (Prince Rupert)	Now in Provincial Museum, Victoria
Early 1940's	Captain Cove (Ogden Channel)	13 fathoms	-	(3 ft. between tips of legs)		Lighthouse tender "Bernie"	Newspaper report
Oct., 1930	Prince Rupert Harbour (5 specimens)	15	-	♂-87 ♀-96	108 84	--	Described as P. rostrofalcatus
Fall, 1956	Boundary Bay	--	-	(about 18" between tips of legs)		By commercial trawler	Died in Vancouver Aquarium, Dec. 1956
Feb. 2, 1960	Kitkatla Inlet	24-28	♀	153	140	"A.P. Knight"	ovigerous
Nov. 28, 1960	Baker Inlet (Grenville Channel)	20-25	♀	--	--	Shrimp boat "Strafen"	soft
Feb. 13, 1961	Kitkatla Inlet	one- 15-23 f. four- 40 ft.	1-♀ 4-♂			"A.P. Knight"	One taken in trawl, others by skin diver

MARINE INVERTEBRATES - D.B. Quayle

The occupation with routine and priority investigations such as the deepwater clam survey left little time for the continuing study of marine invertebrate distribution and life history. In cooperation with the groundfish investigation, one collecting trip was made to the Hecate Straits area in 1960. The main purpose of the operation was to tag grey cod but it presented an opportunity to examine the trawl as a collecting device. The fishing grounds in this instance were not particularly rich in invertebrate fauna and the main organisms were echinoderms, typical of the form of bottom being fished. Comparative drags on other types of bottom indicate that the trawl, though selective, does collect representative marine invertebrates. The presence of an observer aboard trawlers, if only occasionally, would provide an inexpensive means of determining distribution and long-period changes in the composition of invertebrate fauna which may be related to possible changes in hydrographic conditions.

Pacific Oyster Breeding

For most of the summer of 1960, weather conditions were suitable for the development and maintenance of water temperatures adequate for successful oyster breeding, particularly in Pendrell Sound.

In Ladysmith Harbour, westerly winds associated with fine weather caused sufficient vertical mixing to prevent maintenance of suitable water temperatures for long enough periods. Consequently, there was little breeding activity and only very light non-commercial setting occurred. No cultch was exposed.

In Pendrell Sound, the first spawning of magnitude occurred on July 10 when the surface water temperature was 68°F. A spatfall was forecast for the last week of July. Although larval numbers were not large, this spatfall reached a maximum of 100 spat per shell.

On July 29, with the surface water temperature about 74°F, an excellent spawning occurred and a heavy spatfall was forecast for mid-August. The first spatting occurred on August 17 and shells removed on that date held an average of 30 spat per shell, with the main set yet to come. However, starting on August 19, average daily water temperatures fell from 67°F to 66°, 64°, 63°, and 62°F on succeeding days. As a consequence of this rather drastic and rapid temperature change, the set was not nearly as heavy as it would have been with normal temperature conditions. The average, however, amounted to 33 spat per shell, an adequate commercial set.

About 35,000 shell strings, imported from Japan, were exposed for the August set and a considerable proportion sold to United States growers.

Seed importation to the Pacific northwest from Japan has been declining in recent years and in 1961 the total is not expected to exceed 25,000 cases. Price increases, resulting in a more realistic view of the seed problem by growers, is partly responsible, and local seed supplies are being carefully examined. Pendrell Sound remains the most consistent seed-producing area on the Pacific coast and undoubtedly greater use will be made of its potential in the future.

Shellfish Toxicity

There have been no significant changes in the shellfish toxicity situation in the last year, beyond a slow decline in levels in the Cape Mudge area.

On October 28, 1960, the southerly boundary of the area of northern Georgia Strait which had been closed to the taking of clams since February 25, 1959, was moved northward about 50 miles to a line between Gartley Point near Comox to Hurtado Point near Lund on the mainland. Further, the taking of clams other than butter clams (Saxidomus) is permitted in the closed area.

The Cape Mudge sampling point continues to show some toxicity but the mean trend is downward. The mean toxicity value for 1959 was 232 micrograms and in 1960 the mean was 126 micrograms. The January 16, 1961, value was 65 micrograms.

In July, 1960, tests were made on a series of 6 replicate samples from Cape Mudge and these gave a mean of 161 micrograms of toxin with a range between 93 and 237 micrograms. The siphons of this group had a toxicity of 406 micrograms and the bodies alone 73 micrograms. At the same time, Cape Mudge clams were transplanted to Departure Bay where the toxicity value of local clams remains at about 40 micrograms. The toxicity of 4 samples of transplanted clams between September and December registered consecutive readings of 146, 184, 74 and 79 micrograms. The slow decline of toxicity in the Cape Mudge area may possibly be attributed to low metabolic rates due to consistent low temperature levels (this is a region of great turbulence) and to age (for the sampling area is not a commercial digging area). The clams are very old and growth has virtually ceased. The clams transplanted to Departure Bay, however, lost toxicity no more rapidly than the Cape Mudge clams.

Oysters and Pulp Mill Pollution at Crofton

Field study of the pollution problem at Crofton has been continued with sole emphasis on condition of oysters and its relation to kraft mill effluent (KME) as measured by the Pearl-Benson test.

1959 randomized block experiment. This experiment was described in the summary reports for 1959-60 and it was completed in early 1960.

In Table I is listed the mean condition factor of oysters at the three experimental stations (A, B and C) as shown in Figure 1. The April values are lower than those for October. Providing no undue stress had occurred in the intervening period it would be expected that the April level would be greater than, or at least equal to, the October level as at Station C. Since this is not so, it is conceivable that the cumulative stress of the KME has become apparent. However, with the amount and type of data, this is only conjecture.

New tray experiment, 1960. The continued low level of condition of the Barnes oysters relative to those on beds much closer to the outfall (see Table II) has given rise to some concern. No cause is immediately evident although this bed is subject to considerable wave action. Mainly because of the possibility that a tray experiment might give a lead on this problem and partly because of an unsuspected distribution of KME relative to the 1959 tray

Table I. Mean condition factor of 6 trays of Pacific oysters at each of 3 stations.

Date		Crofton - Experiment I A	B	C	Mean
1959					
April	1	77.0	77.0	77.0	77.0
May	6	85.5	99.5	89.0	91.2
June	8	101.5	120.5	107.8	109.9
July	9	110.8	117.4	92.6	106.9
August	6	128.4	124.0	102.3	118.2
September	6	77.6	128.1	97.7	101.1
October	30	100.0	130.7	93.0	110.2
1960					
April	15	*80.1	110.5	92.0	94.0

*small numbers because tray platform destroyed.

Table II. Monthly condition factor of Pacific oysters from commercial beds.

Date		Limberis	Biscoe	Barnes	*Station B	Thetis Island	Ladysmith
1959							
January	20	41	60	40	-	49	-
February	16	39	64	59	-	-	80
March	28	55	67	61	-	111	87
April	28	84	121	77	-	121	127
June	17	90	107	87	-	-	107
July	20	72	104	102	-	130	-
August	10	59	103	76	-	-	98
September	14	60	114	61	-	132	76
October	30	57	104	61	-	106	77
December	15	48	90	60	99	85	68
1960							
January	12	63	91	50	81	-	-
February	19	58	95	70	74	-	-
March	10	62	90	50	85	-	-
April	15	79	108	77	87	-	86
May	14	95	88	78	-	92	97
June	16	88	105	102	-	-	-
July	20	106	119	117	123	-	84

continued...

Table II continued

Date		Limberis	Biscoe	Barnes	*Station B	Thetis Island	Ladysmith
August	19	61	133	105	82	96	88
October	5	63	111	114	97	86	-
November	8	56	92	98	-	-	-
December	6	57	89	97	-	69	97
1961							
January	7	52	91	69	-	109	96

*old wild oysters - 300 yards from outfall near Station B

experiment, a new series of trays was set up in May, 1960, utilizing the original outfall station, but changing the others to Barnes' and Biscoe's beds (shown in Figure 1).

Exactly the same experimental design as used in the previous experiment was followed. Briefly it is a randomized block design with 6 replicates (trays) at each station. The distances from the outfall represent the three treatments. Oysters from one source (in this case Barnes' beds) are placed in 3' x 3' rubberized galvanized wire trays held off the bottom at about the two-foot tide level. Each tray holds 150 oysters. At intervals, samples of 20 oysters are taken and the condition factor determined by comparing the weight of the dried meat and the internal volume of the shell.

The results of this second experiment to date are shown in Table III. The data are insufficient as yet for comment.

Table III. Mean condition factor (6 trays) at each of three stations. The values in brackets indicate the condition factor of adjacent oysters grown on the bottom.

Date		Outfall (A)	Biscoe	Barnes
1960				
May	12	78	78 (88)	78 (78)
July	22	119	117 (119)	130 (117)
October	29	83	106 (111)	127 (114)
December	6	75	101 (89)	125 (96)

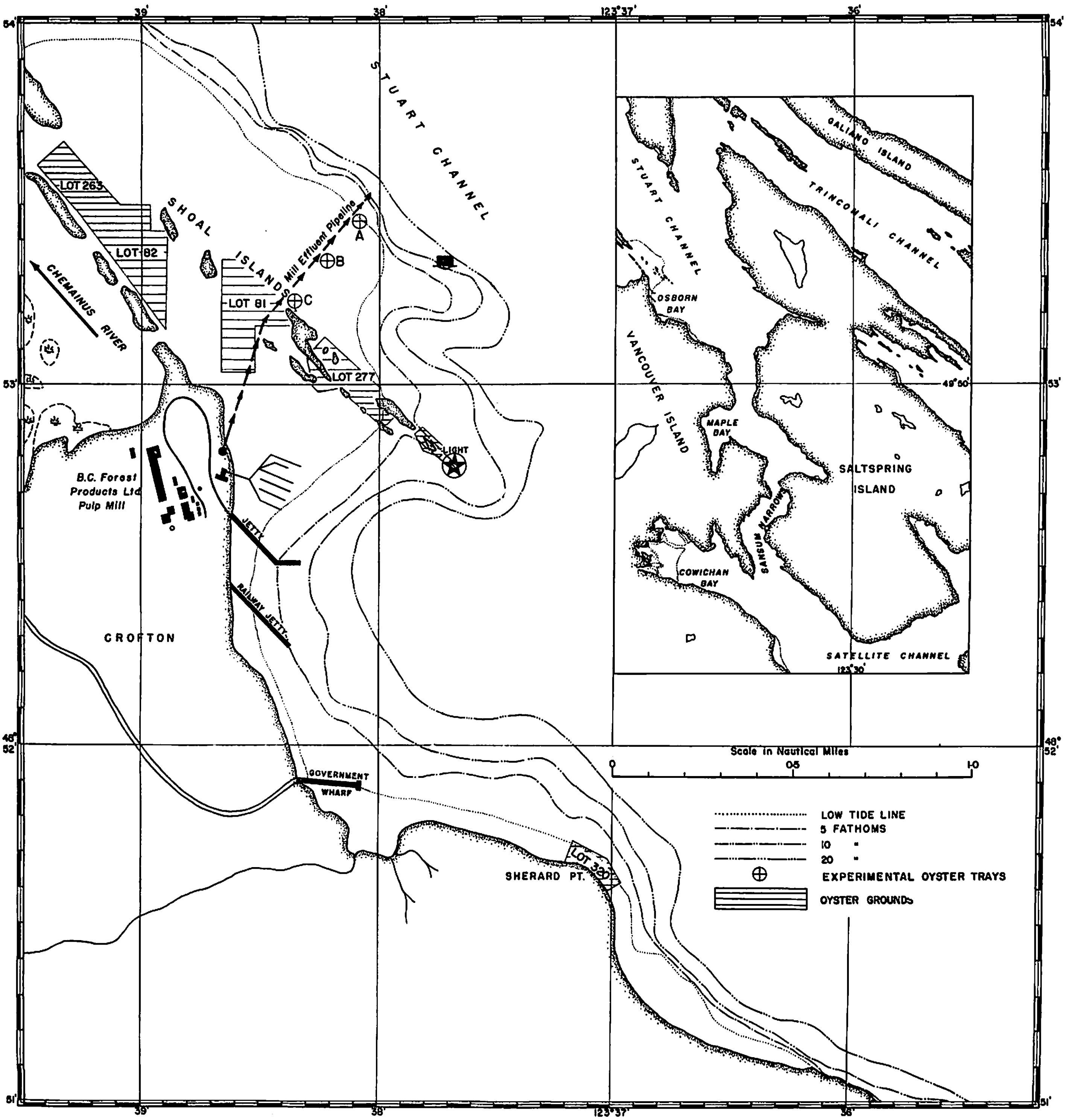


Fig. 1. Chart of Osborn Bay and contiguous waters showing locations of commercial oyster grounds and experimental oyster trays in relation to the pulp-mill effluent outfall. "A" indicates outfall tray location, "Lot 277" the Biscoe bed tray location and "Lot 320" the Barnes bed tray location.

<u>Relationship between kraft mill effluent (KME) and the condition of Pacific oysters at Crofton, British Columbia</u>. In planning the tray experiment it was assumed there would be a significant diminution (not necessarily linear) in the concentration of KME with distance from the outfall. The data in Table IV (a 24-hour series of KME readings at the outfall and at the tray stations) indicate the above assumption may not necessarily be true, for the variation in values between the trays is very slight. This is further supported by the data shown in Table V from samples at these stations taken throughout the year. Consequently, if the sampling results represent continuing conditions, the first tray experiment simply becomes an area-fertility test under the stress of a relatively constant level of KME. The conclusion then is that a fertility gradient exists over the study area with the possibility of a long-term (one year) cumulative effect of KME at the existing levels.

The new tray experiment is primarily concerned with differential fertility although a slight KME gradient appears to exist, and may complicate interpretation of the data.

Table IV. KME concentrations (PPM) at outfall and oyster stations, Crofton, British Columbia, July 11, 12, 1959. 24-hour series at 3-hour intervals. (Dr. Waldichuk's data)

Time at outfall*	1832	2056	2144	0035	0306	0545	0811	1030	1143	1407
Outfall	130.1	95.3	81.0	62.0	37.0	104.3	94.8	108.7	78.2	96.8
Tray A	7.9	5.1	10.8	9.6	9.3	16.7	10.0	7.3	12.1	9.7
Tray B	8.5	6.6	10.0	-	10.4	12.3	8.1	7.7	54.2	10.0
Tray C	10.0	12.1	9.2	10.7	12.3	15.1	11.6	7.7	16.7	11.4
Tide	Flood	Flood	Ebb	Ebb	Ebb	Flood	Flood	Ebb	Ebb	Ebb

*The 4 samples were taken within approximately 15 minutes after the time at outfall

Table V. KME concentrations in ppm in the Crofton area from field samples. (Dr. Waldichuk's data)

Date		Outfall	A	B	C	Biscoe	Barnes	Biological Station
<u>1959</u>								
January	20	35.7	7.0	5.8	7.0	5.1	5.1	5.1
February	16	45.9	-	6.3	-	4.0	5.8	16.2
May	12	90.8	8.1	9.7	-	7.7	-	9.5
June	8	63.8	15.1	10.5	9.1	7.2	4.0	9.5
August	18	120.0	7.1	10.4	-	5.0	-	6.3
October	30	79.7	10.7	13.4	13.4	13.6	7.9	5.0
December	10	79.0	22.7	10.1	9.9	12.8	10.3	6.8

continued......

Table V continued

Date		Outfall	A	B	C	Biscoe	Barnes	Biological Station
<u>1960</u>								
February	18	239.0	16.5	19.5	25.0	19.5	17.5	7.7
March	9	108.1	12.8	6.2	9.0	7.7	5.1	6.0
April	15	139.0	12.9	14.5	15.6	10.1	6.9	-
May	11*	-	11.4	11.4	10.3	11.7	11.3	-
May	12*	161.0	9.0	18.4	22.2	16.6	15.5	-
June	14	135.2	19.5	20.4	23.5	16.8	15.8	-
July	20	32.5	11.7	14.0	16.9	12.4	11.4	-
October	22	137.9	38.5	15.9	16.3	7.7	8.8	13.4

* May 11 - high tide
May 12 - low tide

<u>Commercial oysters</u>. In Table II is listed the monthly condition factor of Pacific oysters from commercial beds at Ladysmith and Crofton. Samples from Ladysmith are obtained from the shucking tables which account for the irregular sampling. The Crofton samples are taken directly from the beds.

The Limberis oysters continue at a low condition factor level except for the normal spring increase. Since April, 1959, the Biscoe oysters have held at a reasonable level. The Barnes oysters again experienced a drop to a low level during the winter of 1959-60 but were holding reasonably well during the autumn of 1960. Station B represents a group of very old bottom oysters located not far from the tray at Station B about 300 yards from the outfall. These have been under the stress of the KME from the outset and form an interesting basis for comparison. During the winter period, when the commercial oysters were at a particularly low ebb, those at Station B were as high in condition as those oysters more distant from the outfall, or higher.

Both the Ladysmith and Thetis Island oysters show about the same order of fluctuation as the Crofton oysters although not reaching the desperately low level of the Limberis and Barnes oysters.

<u>Deepwater Clam and Scallop Survey</u>

On the basis of representations made by the fishing industry in 1959, funds were allotted by the Industrial Development Service of the Department of Fisheries for a deepwater clam and scallop survey. This was to be carried out in 1960 mainly in the Hecate Straits area. Here there is an extensive flat with an area of 1,600 square miles varying between 5 and 20 fathoms in depth with chart designations indicating a bottom consistency of sand, shell or gravel. The presence of shells of <u>Spisula alaskana</u> (bar or surf clam), <u>Clinocardium nuttalli</u> (cockle), <u>Saxidomus giganteus</u> (butter clam), <u>Prototheca staminea</u> (little neck), and <u>Schizothaerus nuttalli</u> (horse clam) on beaches in the area indicated a deepwater source of these species because no suitable habitat occurred intertidally.

Through the cooperation of the Biological Station, St. Andrews, a deepwater hydraulic clam dredge, a Fall River rocker clam dredge and a Georges Bank type scallop dredge were obtained. The "Western Crusader", an 82-foot seiner-dragger, was chartered for a period of 68 days.

The apparent suitable areas in Georgia Strait were first examined, primarily to try out the gear and acquaint the crew with it. Small, non-commercial catches of scallops (Pecten caurinus) were made particularly among the Gulf Islands. No suitable clam ground was found. In this phase 49 drags were made.

In a second phase, 61 drags were made in the Hecate Straits area between July 3 and 10. The vessel was then required for salmon fishing and operations were suspended until a final period lasting from August 22 to October 4 during which 349 drags were made.

The results so far indicate that the prospect for a commercial fishery for deepwater molluscs in British Columbia is not encouraging. No concentration of any species in commercial quantities was located. The limitations of the hydraulic gear were determined and its method of operation provided stimulus for ideas on modifications for particular species. The bottom topography of the Hecate Straits flat is now better known and the distribution of the larger invertebrate fauna has been determined.

In summary:

1. The survey discovered no commercial quantities of deepwater clams.

2. A smaller area that may repay more detailed study was delineated.

3. The hydraulic principle was shown to have application in the harvesting of razor clams.

4. There is no evidence of sufficient quantities of scallops to warrant a commercial fishery.

Oyster Disease

Mass mortalities of Pacific oysters in British Columbia waters have been relatively rare during the thirty years of culture of this species in the province.

On a few occasions, mortalities of proportions that attracted attention have occurred in Boundary Bay. There were no apparent symptoms and the mortalities appeared to coincide with periods of higher than normal air and water temperatures.

In 1956, a disease superficially resembling that known as "maladie du pied" occurred in Pender Harbour, but little mortality resulted.

In 1960, however, there occurred at Henry Bay in Baynes Sound near Comox a mortality associated with deep pustules on the surface of the body or mantle or by pus-filled sinuses.

The mortality started in early April of 1960 when the surface water temperature was about 8°C. By mid-April the mortality was about 10%, and 33% of the living oysters had the characteristic pustules.

The peak of the disease occurred about mid-May. On May 28 mortalities of the 1-foot, 2.5-foot and 4-foot tide levels were 40%, 28% and 12%, respectively. The percentage of live oysters with pustules remained at about 33%. By mid-June gapers were difficult to find and the proportions of live oysters with pustules had dropped to about 16%. Soon after, healing of the pustules became evident along with covering of the blemishes on the shell adjacent to the lesions by layers of nacre.

On August 18, on the assumption the disease had run its course, a final assessment of the total mortality to that date was made by means of 70 square yard samples containing about 3,000 oysters or bones, The results indicated a mortality of 17% at the 4-foot tide level, 30% at the 2.5-foot level and 53% at the 1-foot level with a mean of 34%.

Distribution surveys indicated very little spread beyond the locus of infection at Henry Bay. There was occurrence diminishing with distance for about 3 miles south along the Denman Island shore from Henry Bay. No sign of the disease or mortality occurred in the Fanny Bay area or at Comox from where the Henry Bay oysters had been transplanted.

The oysters involved in the disease at Henry Bay were from Japanese seed originally planted at Comox and later transplanted to Henry Bay about a year or so before the outbreak. They were between 5 and 7 years old, quite large (50 to 60 oysters per gallon) and in excellent condition. The course of the disease was so rapid that dead oysters showed no decrease in condition. On the same bed and, in some instances, attached to older oysters were seed of the 1958 year-class. These showed no sign of the disease nor any mortality.

Transplanting presumably disease-free oysters from other areas to Henry Bay was done. Some mortality occurred but no meats were obtained from the dead oysters so it is not known whether or not death was due to the disease.

Laboratory transmission studies were carried out, testing both by "feeding" and "proximity". In the "feeding" tests a fine slurry of diseased oyster tissue was fed to oysters from a presumably disease-free area. In the "proximity" test Henry Bay oysters were maintained in the same tank with oysters from a presumably disease-free area. Within a month a mortality of 18% occurred in the "feeding" experiment, 14% in the "proximity" experiment along with 50% of the Henry Bay oysters. In the two control tanks the mortality was 3%. The indications are that the disease may be quite readily transmitted.

A bacteriological examination of the diseased oysters showed no one specific organism that may have been the cause of the disease. There was no sign of _Hexamita_, one of the better known causes of disease in oysters, particularly under low temperature conditions. Thioglycollate cultures to check for the possible occurrence of the fungus _Dermocystidium_ were negative. Detailed histological studies have yet to be made.

Discussion. One feature of this mortality that stands out is the fact that only the older ages were affected, although they were in very excellent condition. The onset of death was so rapid that as a general rule there was no sign of emaciation and the newly dead oyster meats were as plump as the living ones. Another striking feature is the localized nature of the outbreak. Henry Bay is quite open to Baynes Sound and in no way has a confined circulation pattern. No exceptional oceanographic features are apparent. The mortality started under conditions of fairly low water temperatures, about 8°C, and declined as the water temperatures rose to between 15° and 18°C at the surface near the shore. Most oyster diseases other than Hexamita are generally associated with high temperature regimes.

No special quarantines were considered because Henry Bay waters are part of the general circulation pattern of Baynes Sound which in turn is not isolated from the circulation pattern in Georgia Strait.

The fact that the mortality varied with tidal height is also puzzling. At the time of year when the mortality began, there was no significant thermocline over the short tidal range (3 feet) over which the oysters were spread. The only difference of note between the high and low oysters was one of size, those at the lowest level being slightly larger due to differential growth.

The laboratory infection experiment, which was not completely conclusive but which may become so on further histological study, does indicate the disease may be readily transmitted.

MARINE MAMMALS - G.C. Pike

Three groups of marine mammals - whales, fur seals, and sea lions - are currently being studied because of their intrinsic commercial or potential value, or because of their effect on other marine resources.

Whales and fur seals are regulated by international commissions, which attempt to promote maximum sustainable productivity with due regard to their relation to other marine resources. An essential part of the work is directed towards fulfillment of commitments to these international commissions. Studies of all three groups are coordinated in a unified marine mammal program because of similarities in research methods and techniques.

A biological study of fur seals was started in the fall of 1957 in accordance with provisions of the Interim Convention on Conservation of North Pacific Fur Seals. Under the terms of this convention, Canada agrees to take from 500 to 750 fur seals, pelagically, for research purposes, each year for a period of six years. The objective of this four-nation cooperative fur seal research program is to obtain essential knowledge on the size and population dynamics, the migration routes, and the extent to which food habits affect commercial fisheries.

Large commercial species of whales have been studied in accordance with requirements of the International Whaling Convention since 1948, when a whaling station at Coal Harbour began operations. Annual collections of routine data are designed to provide knowledge on age, growth, reproduction, feeding habits, migration, and racial identity. Seasonal and annual changes in the catch composition are followed in order to assess the effects of whaling on the stocks.

The ultimate goal of the sea-lion study is to assess the damage done to commercially valuable fish and gear, and to suggest methods for control. This requires a knowledge of life history features of the species which relate to mortality, reproduction, dispersion, and feeding. Preliminary work requires a knowledge of abundance and distribution, and of the nature, extent, and location of damage to fish and gear.

Information on all marine mammals in local waters is obtained through the distribution of special log-books for recording observations. Important contributions to this project include the weathership located at Station Papa; Swiftsure; Umatilla, and Columbia River lightships; research vessels; several strategically-located lighthouses, and Department of Fisheries patrol vessels.

1. Fur seals

Pelagic fur seal research was continued during its third year in 1960 in accordance with the terms of the Interim Convention on Conservation of North Pacific Fur Seals. A single vessel, the "Pacific Ocean", was chartered during the months of March, April and May to hunt seals. Seals were hunted during the first two weeks of March in Hecate Strait where a large concentration of adult females had been observed in February. Seals were hunted off the Washington coast as far south as the Columbia River during late March and in April and off the coast of British Columbia, mostly in the Barkley Sound region, in late April and in May.

Most seals were seen and taken within 40 miles of shore. A total of 512 seals were taken from 963 seen. Females comprised 84 per cent of the catch. Young seals, 1 to 4 years of age and mostly female, comprised 51 per cent of the catch; females 5 to 10 years of age comprised 28 per cent; and females more than 10 years of age comprised 11 per cent. The relative proportions of seals 1 to 3 years of age were greater off British Columbia than off Washington. Yearlings were scarce by comparison with the spring and summer of 1958 and 1959; 2- and 3-year-olds were abundant by comparison with 1958 and 1959. Four-year-olds, representing the weak 1956 year-class, were relatively scarce in 1960.

Concentrations of seals were found along the 100-fathom contour where deep canyons cause indentations in the continental shelf. Older seals were found usually farther from shore than younger seals. The main herd, consisting of pregnant females, seems to have passed along the west coast of Vancouver Island in late April and early May as in 1959. Some mature females appear to winter in Hecate Strait.

The pregnancy rate among females 4 years and older was 65 per cent in 1960 as compared to 81 per cent in 1959 and 64 per cent in 1958. The greatest cause of reproductive failure is the abortion of a fetus near mid-term. This occurs in all age classes of mature females. Interrupted pregnancies occurred in 71 per cent of all non-pregnant but mature females taken in 1960, as compared to 57 per cent in 1959. Ovulation without subsequent implantation occurs mostly in young females recently matured. Failure to ovulate is uncommon in females older than 6 years of age. Double ovulation occurs occasionally, mostly in young females which have not previously undergone a pregnancy. The 1960 data provide one example where double ovulation resulted in twins.

Careful study of female reproductive tracts in the laboratory in 1959 and 1960 has provided a more reliable basis for determining reproductive condition and for judging causes of reproductive failure. The results of this study are described in detail in the 1960 Canadian Report to the Commission.

Food occurred in 51 per cent of all stomachs examined in 1960. Volumes of food and incidence of full stomachs show that feeding is at a maximum during early morning hours. Younger seals select small schooling fish such as clupeids and osmerids which they swallow whole; older seals also accept larger fish such as salmon, rockfish and gadids which may be swallowed piecemeal. In 1960, rockfish, squid and herring predominated in the stomachs of seals taken off Washington; herring, sandlance and rockfish predominated in the stomachs of seals taken off British Columbia. Sandlance, which contributed 61 per cent by volume to the total contents of stomachs collected in April from southern British Columbia, were not found in stomachs from this area in 1958 or 1959. Herring continue to be the most important food item in the diet of seals in waters off British Columbia. A progressive decline in the relative importance of herring from 1958 to 1960 is correlated with a decrease in their abundance in this locality.

2. Sea lions

Surveys by vessel and air in 1956 and 1957 show that approximately 12,000 sea lions inhabited the British Columbia coast immediately after recruitment. During the summer breeding and pupping season, 60 to 70 per cent of this population concentrates in two major rookery areas: the Scott Islands and Cape St. James. These areas account for 90 per cent of the annual recruitment of about 3,000 pups. Near the end of August, sea lions other than mothers and their pups disperse widely throughout coastal waters of the province.

The 1960 sea lion research program was carried out in conjunction with fur seal work during the months of June and September from the chartered vessel "Pacific Ocean". A 10-day field trip to Queen Charlotte Sound and adjacent inlets in December was unsuccessful in obtaining specimens of sea lions or fur seals. Fifty sea lions, 15 male and 35 female, were taken in June and September from Scott Islands, Cape St. James and Isnor Rock.

Stomachs collected in June from hauling grounds contained mostly ratfish and rockfish; those taken in late September near rookeries contained mostly dogfish, flatfish and grey cod. Three specimens, taken in Cumshewa Inlet, October 3, were feeding exclusively on pink and chum salmon.

Pups were again tagged on the Sartine Island rookery which has been set aside as a study area. Tags were applied to the foreflippers of 192 newborn pups on June 3 to 4. The area was revisited on June 14 by which time the pup population had increased from about 200 to 1,000. An additional 127 pups were marked at this time. Increased numbers of sea lions on this rookery in 1960 suggests that the animals are taking refuge here to avoid disturbances caused by killing activities in other parts of the Scott Islands. Few yearlings were encountered and only one animal tagged the previous year was recovered. This animal, a female, had increased in weight from 45 to 187 pounds during the 15 months since it was tagged and had emigrated to nearby Beresford Island.

Progress is being made in the use of sectioned upper canine teeth for age determination. Tagging is designed to provide known age specimens for studies on growth and reproduction and knowledge of migration and local movements. It is planned to continue tagging pups on Sartine Island each June for the next 3 or 4 years.

Reproductive studies based upon collected specimens of reproductive organs will be carried out as fur seal commitments are met and resources released.

3. Whales

Analysis and study of data and specimens accumulated while the Coal Harbour whaling station was in operation are being continued. This material relates chiefly to age, growth, and reproduction in blue, fin, hump, sei and sperm whales.

FISHING GEAR RESEARCH

P.J.G. Carrothers

The emphasis in fishing gear research has shifted considerably during the past year. Previously, activity was primarily to maintain a watching brief on developments elsewhere, to provide a consulting and information service on request, and to develop a program of original research. Today, the program for a better understanding and for further development of the midwater trawl is in active progress, participation in the F.A.O. working group to develop standard test procedures for fishing gear materials is requiring considerable time, and data are being accumulated to support recommendation of a universal twine designation as a necessary preliminary step in the development of trade standards for fishing gear materials as requested by the fishing industry. Previous work is being sustained in that reference files have been noticeably increased and many requests for information, advice, and materials tests have been filled. The Gear Research building is nearing completion, and a full-time technician, who was appointed to this investigation in September, has been involved primarily with the midwater trawl project.

Special mention should be made of the midwater trawl project. First, the Barraclough-Johnson otter boards were modified so that they now remain stable up to the maximum towing speed of M.V. "A.P. Knight" with the standard No. 4 midwater trawl. However, they cannot be used for bottom fishing while thus modified. Second, RCN No. 5 minesweeping kites were modified for use as otters without the need for Oropesa floats as required by the Navy. Third, hydrodynamic data were taken on the performance of the kites and otters and of the standard No. 4 trawl variously rigged with these kites, otters, and boards. Fourth, analysis of these data has shown that considerable improvement in the mechanical efficiency of the trawl can be achieved by developing efficient hydrofoils and by modifying the rigging of the trawl lines. At the present time, instrumentation is being assembled and developed for a more accurate measurement of the mechanical performance of experimental trawls and their components. The next step is to develop efficient hydrofoils for kites and otters. Annular, high-aspect-ratio hydrofoils, planar hydrofoils with end plates, and multi-plane hydrofoils will be considered. Finally it is planned to study experimental modifications of the trawl, including work on the effect of hanging variables and netting dimensions on trawl performance. Considering the high probability of success, the increasing acceptance of midwater trawls, and the need for both exploratory and commercial gear for capturing pelagic species of fish, this project is well worth the time and effort it requires.

1. <u>Midwater trawl development</u>

P.J.G. Carrothers and M. A. Pope

While using the Barraclough-Johnson (B-J) midwater trawl (see F.R.B. Bulletin No. 123) as a tool for biological research and while attempting to make this trawl fish deeper by suspending RCN Patt. No. 8762 minesweeping kites from the lower wings, the Herring Investigation at this Station was frustrated by the tendency for the B-J dihedral boards to "porpoise" and surface at higher towing speeds. Since rectification of this tendency was within the scope of the Midwater Trawl Development project of the Fishing Gear Research Investigation, this problem was tackled immediately although consideration of the boards was originally planned as a later part of the project.

The original suspension of the B-J dihedral boards was as indicated in Fig. 1. Each warp from the trawl winch on the vessel was fastened to the centre

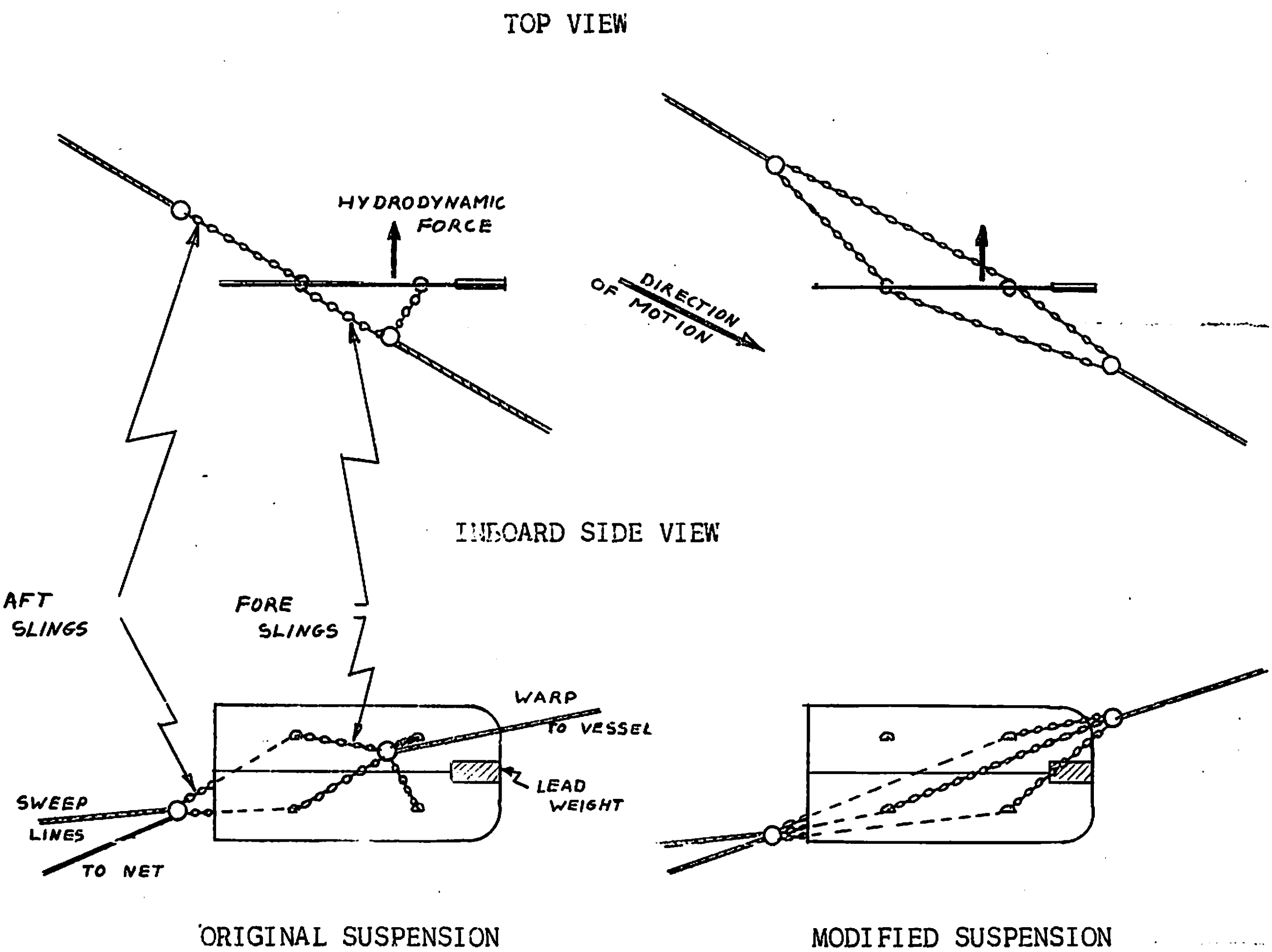


Fig. 1. Port dihedral midwater otter board.

ring of the four-leg fore sling of its respective board and sweep lines from the upper and lower wings of the trawl were fastened to the centre ring of the two-leg aft sling. While under tow, the board was free to rotate about an imaginary line through the centre rings of the fore and aft slings. This line will be called the axis of rotation. Since the aft sling contained only two legs, the position of its centre ring and hence also of the axis of rotation was not fixed with respect to the board but varied somewhat with towing speed. However, the boards were suspended in such a way that, at all towing speeds, their respective axes of rotation passed through their aft halves.

Whenever a board is towed through water at an angle to its direction of motion, the water exerts a push on the leading face of the board and a pull on the trailing face in addition to the static pressure of the water on the board. This push and pull which results from the motion of the board through the water is known as the hydrodynamic force. All other things being constant, the magnitude of this force varies as the square of the velocity of the board through the water, and, since surface friction is usually negligible compared with dynamic pressure under most towing conditions, the hydrodynamic force acts nearly at right angles to the plane of the board. For purposes of calculation, the hydrodynamic forces may be regarded as an equivalent single force acting at one point on the board, just as the weight of a body may be regarded as a single force acting at the centre of gravity of that body. The point at which the hydrodynamic force on the board may be considered to act is called the centre of pressure. The position of the centre of pressure on the board varies with the angle of the board to the direction of motion, but it is always in the forward half of the board.

In the original suspension, since the axis of rotation passed through the aft half of the board and the centre of pressure was in the fore half of the board, the hydrodynamic force on the board exerted a moment about the axis of rotation and tried to turn the board about its axis of rotation until the back of the board was uppermost. In this position the board lifted and brought the net to the surface.

To counter-balance the upturning moment of the hydrodynamic force about the axis of rotation, a lead weight had been placed in the nose of the board. Unfortunately, the hydrodynamic force increases approximately with the square of the towing speed whereas the weight of the lead remains constant. Thus, the board could be balanced for only one towing speed at a time, and at all speeds above this the board tended to turn back side up and to "porpoise".

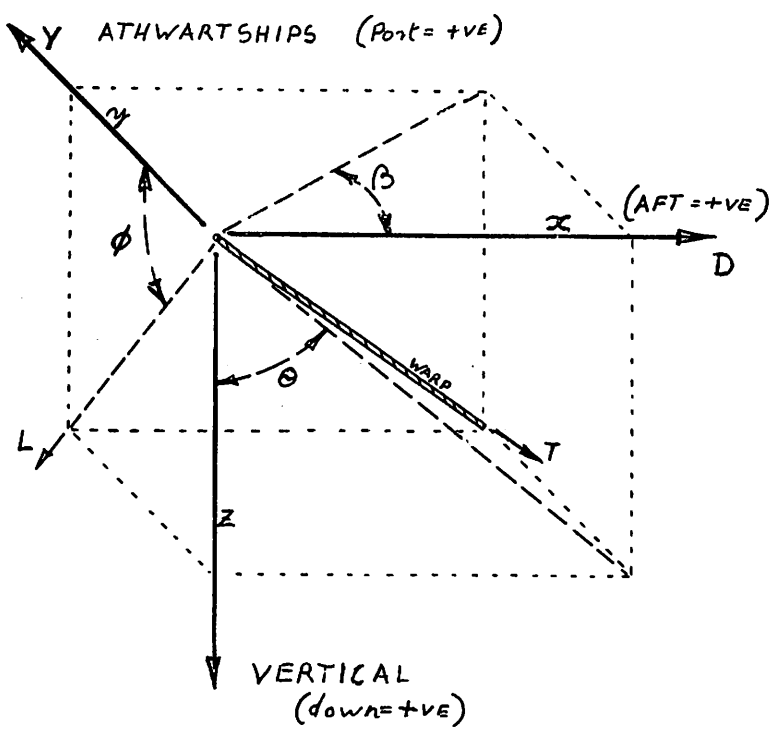
The solution was, firstly, to use three-leg slings both fore and aft to orient the axis of rotation positively with respect to the board and, secondly, to adjust the lengths of the sling legs so that the axis of rotation passed through the hydrodynamic force vector. By this means, the moment of the hydrodynamic force about the axis of rotation was eliminated and the boards could be trimmed at once for all speeds. As shown in Fig. 1, the modified suspension uses only the lower and forward tie points so that the centre of hydrodynamic pressure lies within the triangle established by the tie points, and the sling legs remain taut. The required leg lengths were estimated _a priori_ but some trimming was required in the field because the hydrodynamic characteristics of the two boards differed slightly from one another and were not known sufficiently accurately for precise computation. The final leg lengths used for proper trim of the 80" alumunum, dihedral boards is given in Table I.

Table I. Lengths of sling legs for modified suspension of boards.

Sling leg	Upper fore	Lower fore	Lower aft
Port Board			
Fore sling	28 1/2"	35 5/8"	55"
Aft sling	65 1/2"	59"	29 1/2"
Starboard Board			
Fore sling	28 1/4"	35"	50"
Aft sling	64 3/8"	58 3/4"	28 1/4"

The angle of the board to the direction of motion (45°) and the angle of the axis of rotation to horizontal (20°) were essentially the same in both suspensions. The hydrodynamic efficiency of the boards, as measured by the lift-to-drag ratio, can be improved by reducing the angle of the board to the direction of motion. However, this also causes a reduction in spreading force. Subsequent calculations have shown that for appreciable reduction of drag of the whole trawl assembly, the boards should have a lift-to-drag ratio of at least three and preferably about five. Since this cannot be achieved practically with boards of such low width to length ratio as this (Ar = 42/80 = 0.53), further work with these boards is not planned.

In order to assess the possibilities for improving the hydrodynamic efficiency of the midwater trawl, preliminary measurements have been taken from the present No. 4 trawl variously rigged with the above modified dihedral boards, with RCN Patt. No. 8762 minesweeping kites, and with modified RCN kite-otters (christened "kotters"). The tension in one of the trawl warps (usually starboard) was measured at the vessel with a Dillon 5,000 lb dynamometer. Three angles of the warps, projected on the planes established by three-dimensional rectangular co-ordinates, were measured with a bubble protractor and with a pendulum-type inclinometer. These projected warp angles (Fig. 2)



α = angle of inclination
β = angle of yaw
ϕ = angle of roll
θ = angle of pitch
T = tension vector
D = drag vector
L = lift vector
Y = lateral lift component
Z = vertical lift component
O = origin of reference axes X, Y, Z

Fig. 2. Reference axes for warp angles used to resolve warp tension into drag, spreading force and depressing force.

were first 90-θ (measured from horizontal in the vertical plane parallel to the direction of motion), second ϕ (measured from horizontal in the vertical plane normal to the direction of motion) and third β (measured from the direction of motion in the horizontal plane). The angle of inclination, α, of the warp to the direction of motion at the vessel was estimated from the equation

$$\sin \alpha = \frac{1}{\sqrt{1 + \sin^2 \phi . \tan^2 \theta}}$$

The angle of inclination, α_o, of the warp to the direction of motion and the tension, T_o, in the warp, both at the outboard end of the warp, were estimated according to the method of Landweber and Protter (the David W. Taylor Model Basin, Washington 7, D. C., Report 533, October, 1944), using the warp drag equation $R = 0.34V^2d$ pounds drag per foot length, where d = cable diameter in inches and V = speed in knots, as given by Pode (ibid., Report 717, April, 1950). The components of the tension in warp at its outboard end were then estimated from the equations:

$$\text{Lift} = L_o = T_o \sin \alpha_o$$

$$\text{Drag} = D_o = L_o \sin \phi \tan \theta$$

$$\text{Lateral (spreading) force} = Y_o = L_o \cos \phi$$

$$\text{Downward (depressing) force} = Z_o = L_o \sin \phi$$

The vessel speed was estimated by immersing a 3" Rigosha current meter in the water about four feet from the side of the vessel and by recording the current flow against time as measured by a stop watch. Because this instrumentation was relatively crude and because M.V. "A.P. Knight" tended to "hunt" on automatic pilot, the results are subject to some error. However, the measured warp angles were corrected so that $(\tan \theta)(\tan \beta)(\tan \phi) = 1$ to minimize error, and the overall results give us the general towing characteristics of the net and auxiliary equipment, and show where considerable increase in hydrodynamic efficiency can be effected.

First, a minesweeping kite was towed alone at the end of the warp only deep enough to avoid surface effects. The results of these measurements are given in Fig. 3. Then a minesweeping kite was modified by fastening a cedar plank for buoyancy to one side of the kite and a steel plate for weight and equivalent drag to the other. This made the kite tilt to one side and exert appreciable lateral force (Y-component). Good stability was achieved without the use of Oropesa floats, contrary to predictions of navy personnel. This kite was further modified by fitting a smaller, streamlined, fibreglass-polyester-covered balsa float and a correspondingly smaller iron plate. This second modification gave stable operation with considerably less drag than the first modification, and will hereafter be referred to as the "kotter". The kite and the kotter were both mounted on short pennants at the end of warp and the towing characteristics of the combination were measured. The characteristics of the kite alone, as previously determined, were subtracted vectorially from the characteristics of the combination, and the differences, taken as the characteristics of the kotter, are given in Fig. 3.

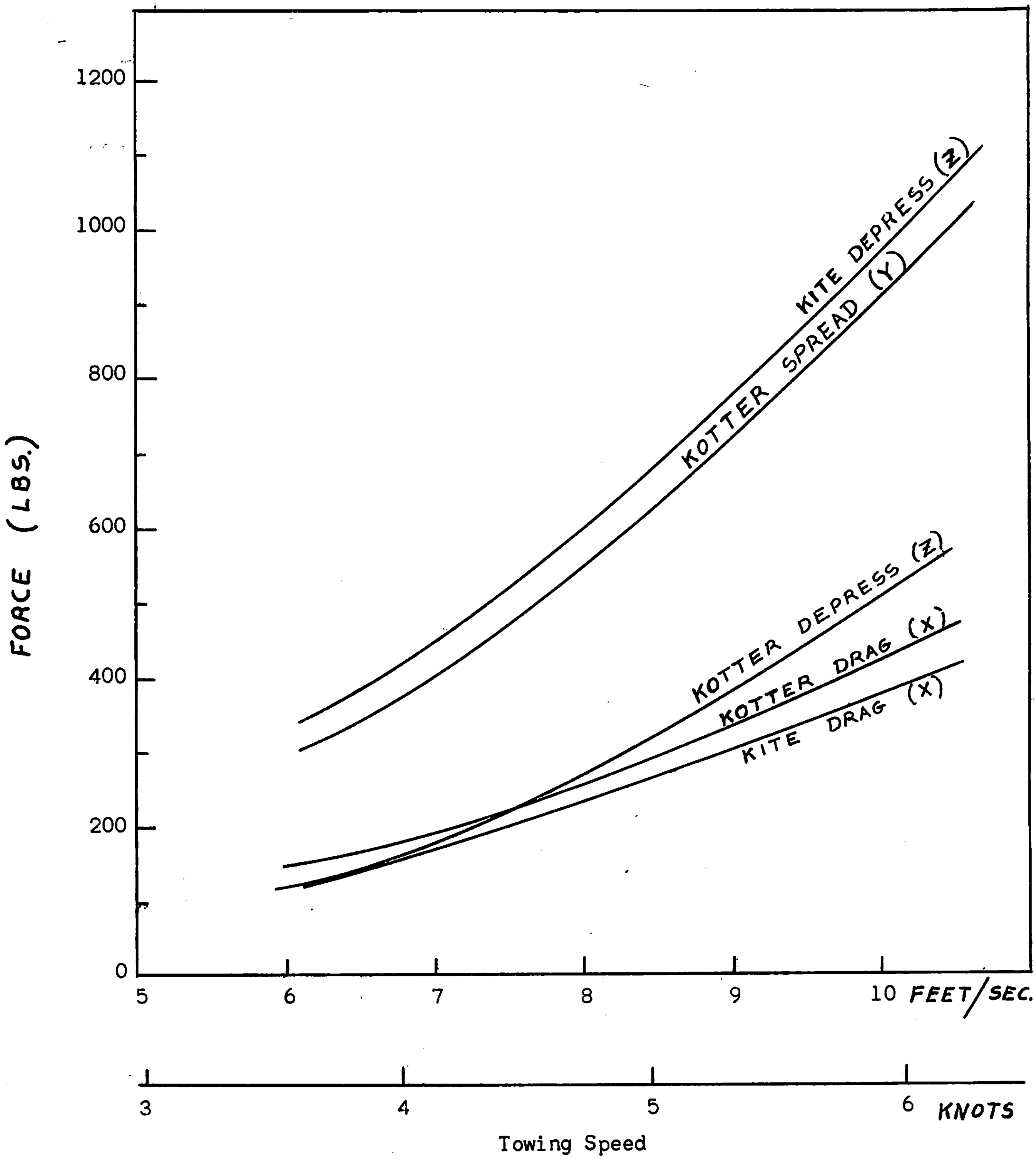


Fig. 3. Towing characteristics of kite and kotter.

Second, the No. 4 midwater trawl was rigged with a kite from each lower wing and a kotter from each of the junctions of warp and trawl sweep lines, and the towing characteristics of the whole were measured. The drag results are given in Fig. 4 (curve A). Then the known characteristics of the kites and kotters were subtracted vectorially from those of the whole assembly and the difference, attributed to the net and head-line floats, is also plotted in Fig. 4 (curve B). The hydrodynamic drag of the thirteen spherical head-line floats was estimated from data given by Hoerner (Fluid Dynamic Drag, 1958) and this too subtracted to give the drag of the net alone.

Finally, for comparison the trawl was rigged with kites and the modified B-J dihedral boards and the towing characteristics of the whole assembly determined. The drag component is plotted in Fig. 4 (curve C). The advantage gained through reduced drag by using more efficient hydrofoils to spread the net is obvious. In both cases, the distance between the boards or kotters while the net was under tow was estimated from warp length, angle, and tension to be between 60 and 70 feet.

The power required to tow the No. 4 midwater trawl at various speeds while fitted with the B-J boards and kites and while fitted with kotters and kites is given in Fig. 5. At full engine speed, less than 1/3 of the power from the engines is available for towing the net. Probably M.V. "A.P. Knight" could be fitted with propulsion equipment to tow more efficiently than at present.

The lift-to-drag ratio of a hydrofoil may be taken as a measure of its hydrodynamic efficiency. From the above data, it was estimated that this ratio for the B-J boards was about 0.5 and for the kites and kotters was about 2. As shown in Fig. 5, this four-fold advantage in lift-to-drag ratio has increased the maximum towing speed of M.V. "A.P. Knight" with this trawl by nearly two knots. Conversely, it has nearly halved the power required to tow the net at any given speed. It should be possible to develop practical hydrofoils having a lift-to-drag ratio of nearly five, with correspondingly greater available towing speeds, lower fuel consumption, or larger trawl for a given vessel.

The crude instrumentation used above, which was adequate to show that this project is worthy of further attention, is not sufficiently accurate or comprehensive for rational trawl development. (It is preferable to use a knowledge of fluid dynamics gained in other fields to obtain a better understanding of the physical principles underlying the functioning of the midwater trawl, and thence to improve the trawl logically, than to use the time-honoured trial-and-error procedures.) Since limitations prevent contracting with specialists for the design and construction of the instruments required for this study, Gear Research personnel, with advice from the Electronics staff, are actively involved with the acquisition and development of instrumentation for an adequate quantitative assessment of midwater trawls and their components. This instrumentation includes underwater warp angle meters, underwater recording dynamometers and depth recorders, sonic distance recorders and current meters for measuring at the net the velocity of the trawl through the water. Also under development is an optical method for measuring twine and knot diameters as required for hydrodynamic studies of the netting. With the sacrifice of some sophistication, the instruments are being assembled with available components where expedient, and parts are being fabricated only where necessary to reach our goal in minimum time and at minimum cost.

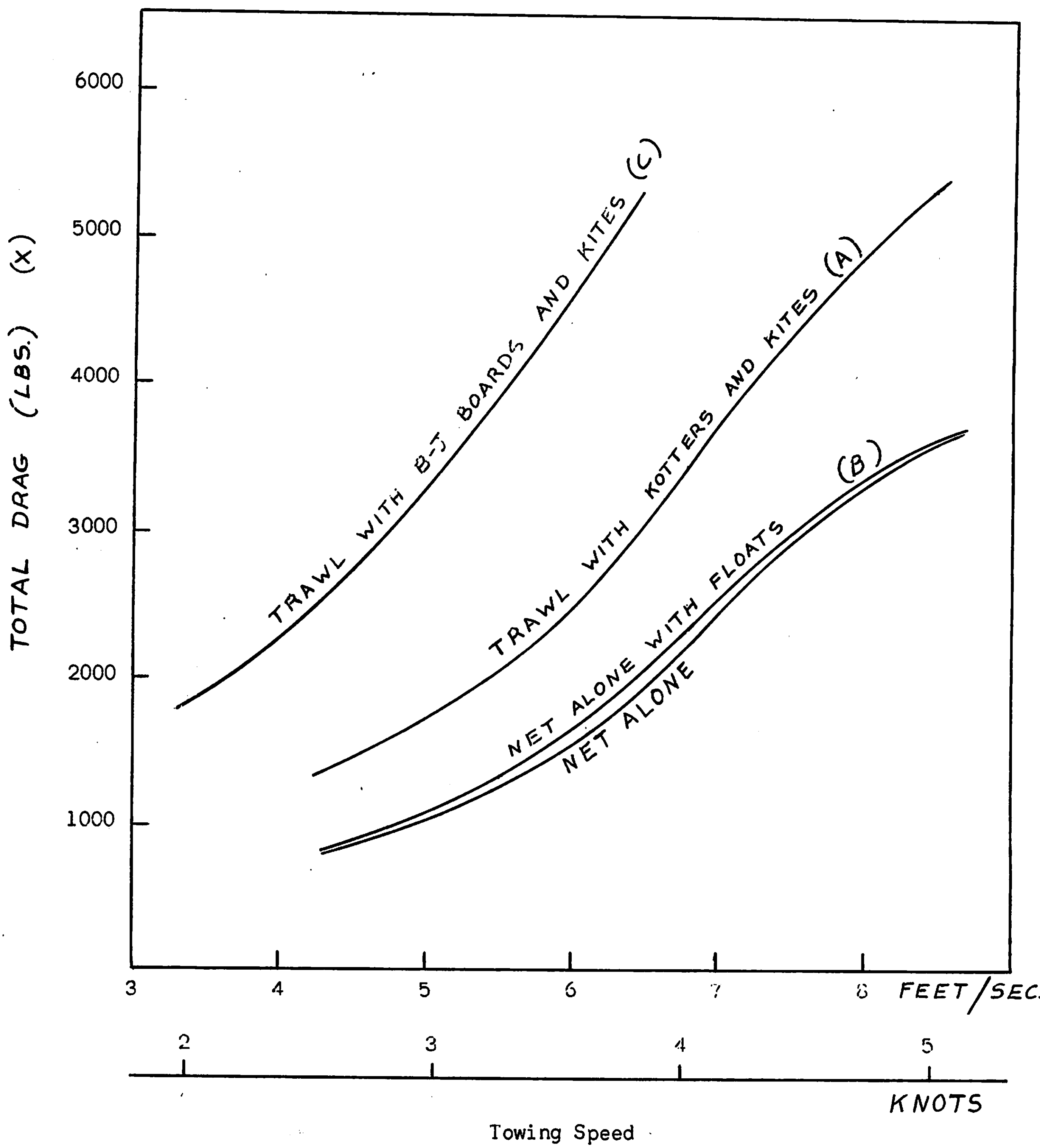


Fig. 4. Drag of midwater trawl variously rigged with kites, kotters, and B-J boards.

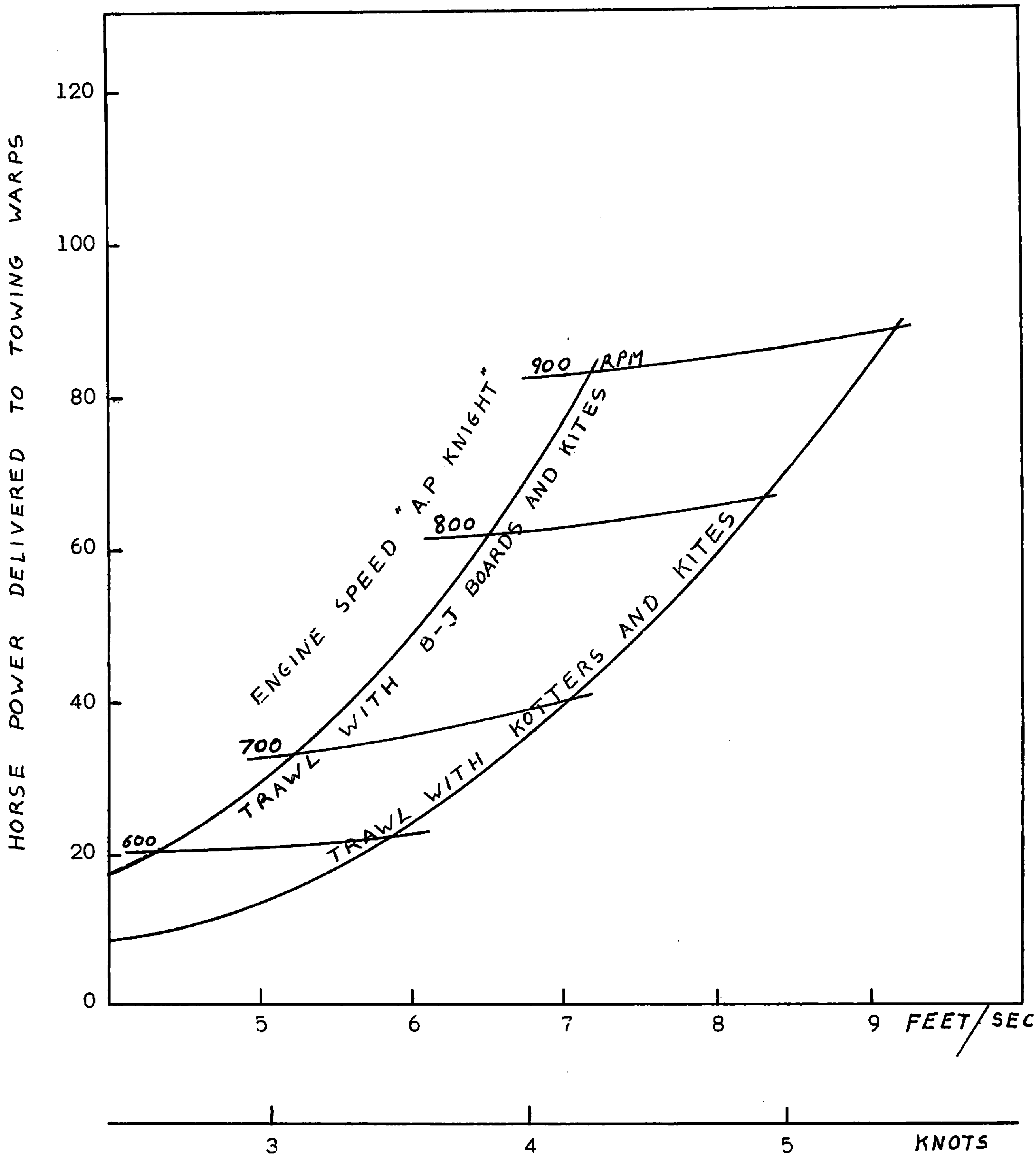


Fig. 5. Power required to tow the No. 4 midwater trawl while fitted with kites and B-J otters and with kites and kotters.

Also, efficient hydrofoils for use as otters, kites, and depressors are being developed. For this, annular hydrofoils, plane hydrofoils with end plates, and multi-plane hydrofoils are under consideration.

Next, it is planned to analyse the trawl rigging systematically with a view to greater towing efficiency, and finally, it is planned to study the effect of netting variables on trawl performance so that midwater trawls may be designed from first principles rather than by trial and error as at present.

There is considerable work to be done in this project, but the path toward achieving mechanically efficient trawls is quite clear.

2. Trade standards for fishing gear materials — P.J.G. Carrothers

On April 26, 1960, a meeting of representatives of the British Columbia fishing industry, a netting manufacturer, and the writer was held in Vancouver at the request of the first-mentioned to discuss the development of trade standards for twines and netting for commercial fishing gear. The need for such standards is becoming increasingly acute, firstly, because a confusing multitude of arbitrary numbering systems for twine identification exists and, secondly, because quality standards differ between different sources of supply, and even between different lots from the same source of supply in some cases. It is becoming almost impossible for a purchasing agent to specify goods on paper for purchase without referring to samples submitted specifically for each order. It was greed that the writer, being in a position to take an unbiased stand and having experience with properties of net materials, should attempt to guide the development of such standards. It was understood that this project would have to take low priority, and agreed that the fishing industry would provide the testing service required to provide data on which to base the standards.

Because it is impossible to specify properties without identifying the material, the first problem concerns twine designation. Correspondence has been undertaken with the Canadian Standards Association (Canadian member of the International Standards Organization - ISO), the International Bureau for the Standardization of Man-Made Fibres, the F.A.O. working group on twine designation, and the British Cotton Industry Research Association and reference has been made to standards published by the Canadian Government Specifications Board, the British Standards Institution, the U. S. Federal Government, and the American Society for Testing Materials, so that our recommendations will be in keeping, as much as possible, with standards which have already been established.

In 1958, the Canadian Government Specifications Board recommended a simplified twine designation in its "Specification for Nets; Fishing", No. 55-GP-1. This consisted of the yarn size as described by the recognized yarn number for the fibre in question, the number of yarns per ply, and the number of plies, each descriptive number being separated by oblique strokes. For example, a three-ply nylon twine in which each ply contains five yarns each weighing 210 denier is labelled 210d/5/3. However, this designation is not in general use (1) because it does not have international recognition (imported goods are described otherwise), (2) because the yarn numbering systems are not adequately understood by the fishing industry and such an understanding is necessary to realize twine size from this designation, (3) because twines of the same size but of different construction require different designations (210d/4/3 nylon twine is the same as 840d/3 nylon twine for all practical purposes yet it requires a different designation according to this specification), (4) because a twine containing yarns of different sizes cannot conveniently be described by this designation (for example, a three-ply twine in which each ply contains two 210 denier yarns and one 100 denier yarn is in wide commercial use), (5) because nominal yarn sizes are quoted whereas actual yarn sizes vary ± 15% with corresponding variation in twine size, and (6) because there is no provision for distinguishing between twines having different lay hardnesses (for example, medium-laid seine twines are described identically with soft-laid gill-net twines according to this designation).

Considerable data has been collected and more is being collected in support of a "universal" twine designation in which the twine number is related to twine weight alone and in the same way regardless of type of fibre or twine construction, and in which the type of fibre and hardness of lay are described verbally in addition to the weight number. Thus, all twines of the same size would have the same number, regardless of the type of twine.

In the autumn of 1960, ISO/TC38 approved the Tex Universal Yarn Count System to supercede the multitude of different yarn size designations now in use. This is an international recommendation. Our recommendation for a universal twine designation is based on this same Tex numbering system which identifies the twine by its weight in grams per kilometre of length. ISO/TC38 has also recommended a series of forty-four standard Tex numbers in each decade to be used for yarn designation. In 1956, ISO/TC38/SC4 passed Resolution 16 which states in part "A more restricted series of numbers will be prepared for each section of the textile industry to suit its own requirements". The Secretary of the Canadian Advisory Committee on ISO/TC38 has no record of action on this resolution, so we have presumed to prepare such a restricted series of twenty standard Tex numbers for use by the fishing gear materials industry. These twenty standard twine designation numbers are sufficiently close to one another to separate adjacent twines in any series of twine sizes, yet do not clutter the designation with an unnecessary quantity of numbers. These standard numbers and the weight range each encompasses are given in the first three columns of Table II. These numbers are recommended for all styles of twine, not just for seine twine.

Table II shows how these recommended standard designation numbers would be assigned to four brands of nylon seine twine and one brand of gill-net twine now on the market. All the twines in any given line, being assigned the same standard Tex number, are within ± 7% of the same weight, and usually much closer than this, yet, the present trade numbers differ quite widely. The need for this recommended standard twine designation is further illustrated in Table III where the published weights and strengths of different brands of twine having the same present trade number are given. According to the runnage (yd/lb) data: Brands A and C are more or less the same size but are enough different that the present designation is misleading, Brand D is 1/3 to 1/4 as large as Brands A and C, and Brand B is about 1/12 as large as Brands A and C. The strength data have a corresponding relationship between brands, and breaking length data show that the quality of all brands is fairly similar, even though the sizes vary widely. It is obvious how trade in these materials is unnecessarily complicated and how orders are sometimes filled with wrong goods.

Table II. Standard universal designation for existing nylon twines.

Standard universal number	Actual runnage (yd/lb)		Present seine twine designation				Gill-net twines Brand A
	below	down to (inclusive)	Brand A (Canada)	Brand B (Britain)	Brand C (U.S.A.)	Brand D (Japan)	
160 Tex	3307	2918	2 Med.	24			
180	2918	2611			3		
200	2611	2362					No. 28
220	2362	2111		36		210d/9	No. 33
250	2111	1872	3 Med.		4		
280	1872	1654				210d/12	No. 43
320	1654	1459	4 Med.	48	5		
360	1459	1305				210d/15	No. 53
400	1305	1181	5 Med.	60	6		
440	1181	1055				210d/18	No. 63
500	1055	936	6 Med.	72	7		No. 73
560	936	827	7 Med.	84	8	210d/21	No. 83
640	827	729	8 Med.	96		210d/24	No. 93
720	729	653	9 Med.	108	9	210d/27	No. 103
800	653	591	10 Med.	120		210d/30	
880	591	528			12	33 + 36	
1000	527.7	472.4		144	15	210d/39	
1100	472.4	431.4	12 Med.			210d/42	
1200	431.4	381.6				210d/45	
1400	381.6	330.7	15 Med.		18	210d/51	
1600	330.7	291.8				210d/60	
1800	291.8	261.1	18 Med.	240	21	210d/66	
2000	261.1	236.2				210d/75	
2200	236.2	211.1	21 Med.	300	24	210d/81	
2500	211.1	187.2	24 Med.		30		
2800	187.2	165.4	27 Med.		36		
3200	165.4	145.9	30 Med.	360			
3600	145.9	130.5	36 Med.				
4000	130.5	118.1	42 Med.		48		
4400	118.1	105.5	48 + 54				
5000	105.5	93.6	60 Med.		60		

Table III. Runnage (yd/lb) and dry twine strength (lb) and breaking length (km) of existing nylon seine twines.

Present Trade No.	24	30	36	48	60
Brand A-runnage	200	155	140	117	105
-strength	250	323	359	425	524
breaking length	46	46	46	46	50
Brand B-runnage	3010		2150	1520	1250
-strength	19		29	35	45
breaking length	52		57	49	51
Brand C-runnage	220	192	174	120	98
-strength	220	254	280	363	420
breaking length	44	45	45	40	38
Brand D-runnage	814	650			304
-strength	59.4	79.9			136.2
breaking length	44	48			38

For implementing the Universal Yarn Count System, ISO/TC38 Document 285E recommends that the standard Tex number of the yarn be "put in brackets after the (present) count or number". Further, at its meetings in London in May, 1960, ISO/TC38 instructed SC4 to draft a recommendation for twine designation based on twine construction (this would be similar in principle to the designation described in the fourth paragraph above, but different in detail) and to include the resultant Tex of the twine, probably in parenthesis, after the structural designation. Therefore, in keeping with the philosophy of this international standards body, we recommend that the "universal" twine designation (Tex) described above be placed in parenthesis after other twine designations, whether they be existing trade numbers or designations already described in national standards. Thus, a nylon twine commonly used in salmon seines would be marked:

Brand A	:	18 Med. (1800 Tex) nylon twine
Brand B	:	No. 240 (1800 Tex) medium-laid nylon twine
Brand D	:	No. 21 (1800 Tex) " " " "
Brand E	:	210d/66 (1800 Tex) " " " "
C.G.S.B., 55-GP-1	:	840d/5/3 (1800 Tex) " " " "

Since all these designations include "(1800 Tex)", anyone can quickly see that all these twines are of equivalent size, even though their present trade numbers differ widely.

After such a "universal" twine designation has been adopted, and only then, will it be possible to develop quality standards for fishing gear materials. Therefore, our immediate plans are to draft a brief supporting the "universal" twine designation described above and to circulate it to interested parties for comment. The draft will include an expanded version of Table I covering as many types and brands of fishing gear twines as possible. It is proposed to submit the final draft to the Canadian Government Specifications Board for appropriate amendment to "Specification 55-GP-1 for Nets; Fishing" and to send a copy to ISO/TC38/SC4 for their consideration.

Since the "universal" twine designation is based on twine weight, it will eventually become necessary to develop a more sophisticated method for determining this property. Present standard procedures are used primarily for quality control and are not sufficiently accurate for commercial designation of the twine. For this development, it will be necessary to have access to a room having closely-controlled atmospheric conditions - present standards are 70° ± 2°F temperature and 65 ± 2% relative humidity. Such a room was planned for the new Fishing Gear Research building at this Station, but since the Board has approved consolidation of fishing gear research in the Maritimes, the necessary conditioning equipment has been deleted as not being worth the cost considering the limited time remaining for its use.

3. Test methods for evaluating fishing gear materials P.J.G. Carrothers

At the F.A.O. Fishing Gear Congress held in Hamburg in 1957, a working group was formed under the chairmanship of Dr. A. v. Brandt of Germany to study test procedures required to evaluate textile materials for use in fishing gear. There already exist many standard test procedures for evaluating textiles but, unfortunately, many of these measure properties which have little or no significance to fishing gear requirements, or measure them in such a way that the results have limited significance. As a result, organizations throughout the world have individually devised procedures for measuring those properties of fishing gear materials for which they must have data before they can contemplate the rational design of gear. As is usual with textile materials, the test result is a function of the test procedure so that results of tests performed in different laboratories are generally not comparable. It is, therefore, highly desirable that a single, generally accepted procedure be described for testing each property so that valid comparisons may be made between results originating from different sources.

Dr. v. Brandt first requested contributing organizations to submit a description of their test procedures. These were circulated to members of the working group and critical comments solicited. Our contribution consisted initially of a 15-page, single-spaced report and extensive subsequent correspondence. Dr. v. Brandt has edited a document describing present methods with comments and this is now in the hands of members of the working group for critical study. The next step is to attempt to resolve differences so that a single test procedure for each property may be recommended. This step may require considerable laboratory evaluation by members of the working group, but the achievement of universal standards will be worth the effort.

The test procedures under active consideration are for the following properties:

A. Tests for twine and netting

a. Physical tests

1. Breaking strength - including the evaluation of testing machines, procedures for measuring wet twine strength and wet knot strength, and mathematical procedures for comparing results.

2. Extensibility under load - including extension at rupture, load-elongation characteristics, and elastic recovery.

3. Stiffness and softness.

4. Abrasion resistance - against hard objects and twine against twine.

5. Weight - including dry weight for commerce, wet weight for handling, buoyed weight in the water, and ability to sink or billow in the water.

6. Diameter - required particularly for hydrodynamic studies and estimates of net bulk.

7. Surface roughness.

8. Shrinking and lengthening - as a result of wetting, heating, drying, etc.

9. Reactions to heat - both wet and dry.

10. Weather resistance - with particular reference to the effect of light.

b. Chemical tests

11. Resistance to chemicals - for example, cleaning agents, polluted water, air-borne gases.

c. Biological tests

12. Rotting resistance - tests under fishing conditions, sea water immersion, and laboratory soil immersion tests.

13. Resistance to macro-organisms.

14. Fouling resistance.

d. "Work-up" tests

15. Processing.

16. Dyeing.

17. Storing.

B. Tests for netting alone

18. Physical dimensioning - including mesh length and panel or unit size.

19. Mesh strength and extensibility under load - including strength and dimensional stability of the net as a whole.

20. Knot stability - including resistances to loosening, to slip under load, and to knot inversion.

21. Weight - cf. test 5 above.

22. Pollution or fouling of nets - cf. test 14.

23. Visibility of nets under water.

24. Hydrodynamic resistance of nets.

The quantitative assessment of fishing gear materials must be undertaken before rational gear design can supercede the trial-and-error development methods now widely in use. Further, the development of trade standards for fishing gear materials, as requested by the fishing industry (see preceding summary) will require prior development of acceptable test procedures. Therefore, it is well worth while for the Board to participate actively in the F.A.O. working group.

4. <u>Consulting, information, and materials research and testing service</u> P.J.G. Carrothers

As in past years, information, consulting services, and a research and testing service for fishing gear materials have been provided on request from fishermen, fishing companies, fishing gear manufacturers, and government and other institutional representatives. In all, some 45 such requests involving original laboratory or engineering work have been filled. Only those of more general interest are treated below.

F.A.O. is preparing a "Handbook of Fishing Gear" which will describe in detail commercial fishing gear used throughout the world. This will be similar in scope to their "Handbook of Fishing Vessels" which gives detailed data on hull contours, numerical parameters used in naval architecture, performance data, etc. We have been requested to provide the data sheets and detail drawings for commercial fishing gear used in British Columbia. The necessary information has been assembled concerning a herring purse seine, a salmon purse seine, a salmon drum seine, the B. C. midwater trawl, and surface drift salmon gill-nets. The formal data sheets and detail drawings are being prepared as quickly as space and time from other gear work will permit.

Imperial Chemical Industries Limited of England has requested that we co-operate in an experiment to evaluate polypropylene twine for salmon gill-nets. Information at hand shows that this fibre has very good potential as a fishing gear material. Compared with nylon, polypropylene is considerably stronger at the wet knot permitting lighter netting for a given job, is more resistant to damage by acids, has slightly less extension under load, and is buoyant in water. This last property should give polypropylene an advantage for gill-nets, tangle nets, and trawls, but a disadvantage for purse seines, etc. Like nylon, polypropylene is not rotted by bacteria and can be dyed in the field, although factory dyeing gives better results. Nylon and polypropylene twines are so similar in appearance and feel that few, if any, persons can tell the difference by sight or touch. The odour of fumes resulting from burning is the quickest means for making this distinction in the field. Properties still to be assessed are wear and weather resistances, elastic recovery and dimensional stability, and such subjective attributes as handling characteristics and "fishability". The potential of polypropylene as a fishing gear material is so great that it may well replace nylon in many applications. Therefore, the Board should at least keep abreast of developments with polypropylene and, preferably, should actively contribute to such developments, both to assure that its own experimental gear is as effective as possible and to provide a source of information concerning polypropylene for the fishing industry.

Three requests have been received for tests and information on knotless netting of various types. Basically, there are two types of knotless netting. In the manufacture of one type, the two-ply twine is laid at the same time as the netting is made, and the meshes are constructed by interweaving the plies at the twine intersections. There are three ways in which the twines are interwoven at their intersections, those of greater complexity giving less tendency to slip under tension but also resulting in greater bulk. In the manufacture of the other type of knotless netting, three yarns are looped together by a lace machine to form each mesh bar and the yarns in each bar are further interlooped at the mesh corners. For reference, the former type of knotless netting will be called "laid" and the latter called "laced". The laid knotless netting is made in Japan and, since the machines are not available for export, Japan is the only source of supply for this netting. The laced netting is known as "Raschel" in Germany and as "Tri-lock" in the United States. According to our measurements, laid netting made of continuous filament plies has a strong tendency to slip at the twine intersections when the mesh is stressed with consequent distortion and reduced strength. Sometimes a hard lay is used to minimize slip, but this makes the twine stiffer and more prone to kinking. On the other hand, laid netting whose plies are made of staple fibre are satisfactorily resistant to slip. For a given size of staple fibre twine, the netting is lighter and the mesh stronger in laid knotless netting than in conventional knotted netting. Regardless of the type of fibre, the laid knotless netting should be selvedged and tears mended as soon as practical to prevent unravelling. On the other hand, the laced knotless netting has no tendency to slip at the mesh corners, even under breaking stresses, but the twine is very bulky and open with consequently large hydrodynamic drag and large capacity to hold dirt. Also, as a result of the looped yarn geometry, the strength of the laced knotless netting is noticeably less than that of conventional knotted netting made of the same fibre and of equal weight. As with the laid knotless netting, laced knotless netting should be selvedged and tears mended promptly to eliminate unravelling. The unique characteristics of knotless netting make it useful for certain applications such as catching gear for fish tagging purposes, but the advantages are not such that it is likely to be used extensively in existing commercial gear in Canada.

In connection with our information service, it should be mentioned that two talks were delivered to the Fishermen's Short Course at the University of

British Columbia and a paper was presented to the annual meeting of the Pacific Fisheries Technologists in an effort to share our knowledge of fishing gear materials with those who can use such information to advantage. Also, considerable time has been devoted to the design of the new Fishing Gear Research building and the proposed Technical Services building.