RESTRICTED

FISHERIES RESEARCH BOARD OF CANADA

BIOLOGICAL STATION
NANAIMO, B.C.

ANNUAL REPORT

and

INVESTIGATORS' SUMMARIES

1969

K. Radway Allen, Director

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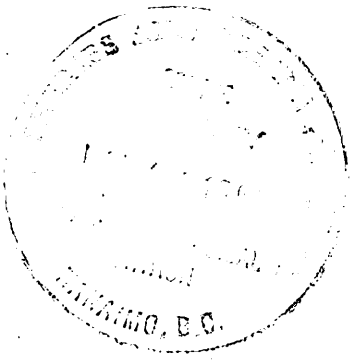

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TABLE OF CONTENTS

		Page
INTRODUCTION	Section A	1-5
INVESTIGATORS' SUMMARIES	Section B	
FISHERIES BIOLOGY GROUP		1-44
EXPERIMENTAL BIOLOGY & PATHOLOGY GROUP		45-68
ENVIRONMENTAL RESEARCH GROUP		69-85
PACIFIC OCEANOGRAPHIC GROUP		87-115
SCIENTIFIC SERVICES	Section C	
ENGINEERING RESEARCH AND DEVELOPMENT GROUP		1-2
FISH CULTURE		2-3
HISTOLOGY		3-4
STATISTICS AND COMPUTATIONS		4-5
STAFF LIST	Section D	1-10
PUBLICATIONS	Section E	
PRIMARY PUBLICATIONS		1-5
INTERPRETIVE PUBLICATIONS		5
SUB-PUBLICATIONS		6-1

INTRODUCTION

I N T R O D U C T I O N

K. Radway Allen

The dominant feature of the year 1969 was the struggle to maintain the effectiveness of the Station's operations in the face of increasing financial stringency. The need to maintain a proper balance between salaries and other operational expenditures caused the Fisheries Research Board to review its staff situation as a whole: as a result the Nanaimo Biological Station suffered a 10% reduction in established strength. Fortunately most of this reduction could be achieved by elimination of vacant positions and transfers of certain personnel from low priority to vacant high priority positions. Regrettably, however, it was not entirely possible to avoid dispensing with the services of members of the staff whose positions had become redundant.

In these circumstances it was of course impossible to make any appointments to new scientific positions, despite the pressing need to increase the Station's strength in certain important areas.

The Station's difficulties were also increased by the need to provide the services of senior members of its staff on a temporary basis to assist the work of the Board's Headquarters in Ottawa. The Director, Assistant Director and Head of the Pacific Oceanographic Group all spent a substantial part of the year in Ottawa on duties of this kind.

However, although these difficulties did curtail a number of the Station's activities, particularly as far as the amount of field work was concerned, it was possible to maintain an active and effective program and important advances were made in several investigations.

A feature of the year was the continued development of the multi-disciplinary approach in which scientists working in a variety of disciplines are brought together on a temporary and sometimes informal basis to contribute from their diverse points of view to the study of a common problem. This technique, by making wider use of specialist skill and knowledge, increases the general level of research effectiveness; it also increases flexibility in meeting urgent and unforeseen problems as they arise.

As a step in the same direction a further re-organization of the scientific staff was undertaken towards the end of the year. Under the new system the staff are still divided into four groups, but the grouping is now primarily on a disciplinary basis and the species studied are no longer a primary factor.

The Fisheries Biology Group consists of those investigations which are primarily concerned with the general biology of the animals of commercial importance and its relation to their utilization and management. Activities include various salmon programs which are directly concerned with the management of the resources, including the identification and assessment of the

various stocks. They also include the work on marine fishes and invertebrates. The assessment of the results of the Babine Lake Sockeye Development Program has continued to be an important part of this work. As a result of the financial stringency, discussions are in progress with the Fisheries Service aimed both at identifying more precisely the lines of research which will contribute most directly to good assessment, and at achieving an appropriate allocation of responsibilities between the Service and the Fisheries Research Board. Studies connected with international aspects of the exploitation of salmon stocks have continued to be an important part of the program, particular attention being paid to the coho and chinook stocks at the southern end of the British Columbia coast. The regular monitoring of the composition of commercial catches of sockeye and chum salmon have also been continued. Other work on salmon has included the studies on the characteristics of various salmon hybrids, on possible techniques for the storage of salmon sperm, and on the effect of environmental factors on scale formation. In the marine field, the work on herring has been expanded in an effort to elucidate further the causes of the recent decline in stocks. A multi-disciplinary study is now in progress. This is centered on the continuation of the previous investigations, but includes a number of scientists in other disciplines including some outside the Fisheries Biology Group. Further exploration of offshore herring resources was conducted in cooperation with the Industrial Development Service; the results still provide no indication of the existence of any offshore stocks distinct from those now fished in inshore waters. The investigations on other marine fishes and invertebrates have been continued. A population dynamics investigation has been established in this group which will be able to apply these techniques to problems arising from various fisheries as required.

The Environmental Research Group is concerned with the study of productive processes in the aquatic environment, particularly as they affect the yield of aquatic resources. Practical applications of this work are directed both toward the development of techniques by which the yields may be increased and towards the identification and prevention of environmental changes which tend to reduce these yields. A major event of 1969 was a cruise in CNAV Endeavour across the North Pacific to Japan and back. The purpose of this cruise was to provide a baseline for a study of factors affecting productivity in this area, which is to be undertaken in cooperation with the University of Washington. Detailed observations were made, often on a continuous basis, of many of the factors affecting productivity, including nutrients, temperature, salinity, chlorophyll, zooplankton, and small fish. Other work in the marine environment was the continuation of the study of trophic processes in the Strait of Georgia; this was concentrated on the identification of food chains and the efficiency of transfer of energy between successive levels in them. In the freshwater environment a new study was commenced on the possibility of increasing the production of sockeye salmon from a highly oligotrophic lake by the addition of carefully controlled quantities of nutrients. In addition, studies have been concerned with the production of young salmon from streams, including the effects of food supply and of interspecific relationships between several species of salmonids. Also with respect to the stream environment, a study has been commenced on the effects of logging on fish production.

The Experimental Biology and Pathology Group concludes a range of investigations dealing with specific aspects of the biology of aquatic animals and with the diseases affecting them. Its general objective is to add to the understanding of the factors governing survival, abundance, distribution and health of the aquatic animals important to the commercial and recreational fisheries. The behaviour studies are at present concerned with the mechanisms which enable migrating salmon to find their way to the spawning stream as adults and to the sea as smolts. The current work is being done with sockeye salmon in the Lake Babine system. The genetics investigation, working with pink and sockeye salmon, is studying genetic influences on the difference in a wide variety of characters between the fish inhabiting different waters. As a by-product, this work is leading to the development of new chemical marking methods which seem likely to have wide applicability to the marking of small fish. A major part of the micro-biological studies continues to be concerned with bacterial kidney disease in salmon, a serious and widespread hatchery problem. This section also provides a diagnostic service for other parts of the Station and for other fisheries organizations in British Columbia. The use of parasites as a means of distinguishing between different stocks of fish is still a highly important part of the program of the parasitological section. Studies are also being undertaken on the effects of parasites on the well-being and survival of both cultured and wild fish. The work in physiological ecology is concerned with the detailed study of the effects on fish of variations in a number of environmental factors and combinations of factors. The work is following two main lines: the effect of natural factors such as salinity and temperature on the early development of marine fishes as a possible cause of changes in year-class strength; the development of performance standards for young salmon as a means of measuring adverse effects due to pollution and other causes. The work in physiology has continued to be concerned with the bio-energetics of salmon, particularly the relations between metabolism, growth and feeding. This work is reaching the point where it is likely to have significant applications to the improvements in fish culture techniques.

The Pacific Oceanographic Group is concerned with physical and chemical oceanography and with certain pollution problems. The oceanographic studies include both the waters of the Strait of Georgia and those of the eastern Pacific Ocean extending to about 200 miles off the British Columbia coast. Within the Strait of Georgia studies have included continuous current observations from moored buoys, study of the surface circulation in the vicinity of the Fraser River plume, and development of a hydro-dynamical-numerical model of the system. All this work is gradually building up a valuable understanding of the complex events which occur within the Strait of Georgia and the associated waters. The offshore program has included both several special cruises, and cooperation with the staff of the Department of Energy, Mines and Resources in observations from the weatherships. The group has continued to be responsible for routine observations of temperature and salinity at a number of light stations along the British Columbia coast. It has also collaborated with other sections of the Station in providing oceano-graphic data needed for biological studies. The pollution studies of the group have included special investigations of water movements in certain

areas where present or potential pulpmill wastes could create problems. Studies have also been undertaken on chemical aspects of pollution by water-borne wood solids.

The Station's Annual Report continues in the format adopted in 1967: it includes summaries by the investigators of the projects in progress at the Station in 1969 arranged within the four major Groups outlined above. The work of each Group is preceded by a more general statement of its activities.

The Station's work continues to be reported in a large number of publications, and at a variety of levels. Primary publications numbered 60, of which 37 were published by the Board and the remainder in other journals, many of which were produced outside North America. In addition to these primary publications, 2 Interpretive and 81 Sub-Publications were produced by the Station staff.

The year 1969 has been an eventful one for visitors. As in previous years the Station has welcomed a great number of scientists and fishery workers from both Canada and foreign countries. Several of the most important events should be mentioned here. On March 15th, the Station was visited by the Science Council led by its Chairman, Dr. O. M. Solandt. The Council had held meetings in Vancouver during the week commencing March 10th, and took the opportunity to tour the campus and discuss current research projects with the scientific staff. The Science Council was followed on April 24th by the Parliamentary Committee for Fisheries and Forestry under its Chairman Mr. G. Crossman, M.P. The Committee toured the Station's facilities, including the new addition which was nearing completion at this time, and discussed the Station's current research programs. We were pleased to welcome the Russian Oceanographic vessel Vityaz on May 30th. It spent the best part of two days at Nanaimo. The vessel, owned by the Institute of Oceanology of the Academy of Sciences of the USSR, carried a total complement of 133 of which 66 were research personnel. The captain of the vessel was Captain P. A. Poll, the expedition leader, Dr. Z. A. Filatova, and her second in command, Dr. A. P. Kuznetzov. The Vityaz was carrying out oceanographic research in the North Pacific and our staff benefitted a great deal from contact with the Russian scientists both at work and at leisure. For the period July 7th - 11th we welcomed Dr. O. Kibezaki of the Japanese Fishery Agency and Mr. H. Kawaguchi from the Japanese Fishing Industry when they visited Nanaimo to obtain samples of Pacific dogfish species and to discuss research and management problems.

During the year we also received visits from the Scientific Advisors to the British and French Governments. Dr. D. Downing, Scientific Advisor to the British High Commissioner in Canada, visited the Station on February 20th, and Dr. J. C. Corbel, Le Conseiller Scientifique à l'Ambassade de France au Canada on October 23rd.

The new addition was completed in late September, and the staff moved in officially in the first week of October. In honour of the first

Director of the Station, the Reverend G. W. Taylor (1908-12), the new addition was named the Taylor Building to distinguish it from the former main building. The latter, now named the Clemens Building, also in honour of a former Director, Dr. W. A. Clemens (1924-40), was vacated in October, so that a renovation program could be begun. The building will be reoccupied in the spring of 1970. Many adjustments had to be made to equipment, but by the end of the year many of the laboratories were in use. The additional laboratories and office space, plus the new library, seminar and conference rooms have relieved the congestion of the previous few years, and will enable the Station to meet more effectively its research commitments.

The Scientific Services Group was enlarged in 1969 when the Histology Department and the Chemistry Stores were added. This should lead to a more efficient service group and ease administration problems. The use of the services was increased in 1969 over 1968, but demands were met in spite of reduced budgets and personnel.

The control of the Rosewall facility was handed over to the Scientific Services Group in August, and it now falls within the jurisdiction of the Fish Culture Department. No major developments occurred in 1969 except that preparations were made to bring in electric power to the site - power is presently supplied by diesel generators.

Overall it was an eventful year for the Nanaimo Biological Station whose new addition now dominates the shoreline at Departure Bay and serves as an "introduction" to Nanaimo for visitors arriving on the British Columbia Government ferries from Vancouver.

INVESTIGATORS' SUMMARIES

FISHERIES BIOLOGY GROUP

S. J. Westrheim

The Fisheries Biology Group was formed in August 1969 by combining the Marine Fisheries Group with those of the investigations of the Anadromous Fishes Group which were not incorporated into the Environmental Research Group. The Fisheries Biology Group consists of those investigations which are primarily concerned with the biology of aquatic organisms in relation to the problems of fisheries management associated with them. The Group comprises 12 investigations: Groundfish; Hatchery Evaluation; Pelagic Fish; International Salmon Studies; Lobster; Molluscs (excluding Crustacea); Population Dynamics; Salmon Stock Assessment; Shrimp and Crab; Sockeye Populations; Sockeye Production; and Salmon Hybrids.

Almost all investigations in this Group have a close connection with the needs of industry and the Fisheries Service. However, the Fisheries Biology Group is not restricted to problems of immediate practical importance. Fundamental biological studies, with long-term objectives, assume considerable importance in most investigations, and include studies on species which at present contribute little or nothing to the fisheries economy, but constitute an important potential for future expansion and diversification of the fishing industry.

GROUNDFISH

1. Near Seas Investigation

C. R. Forrester

A large part of the effort of the investigation continued to be directed towards the collection and analysis of catch and effort statistics for the purpose of measuring changes in abundance of the more important species (Pacific cod, rock sole, lingcod). Routine sampling was conducted at the major ports of landing to determine the size and age composition of catches and thus provide information on changes in recruitment, growth, and mortality.

Total production of trawl-caught groundfish by British Columbia vessels in 1969 was approximately 37 million lb, about 8% lower than in 1968. Pacific cod remained the single dominant species in landings with a total catch of over 10 million lb - 33% lower than 1968. Landings of various species of flatfish totaled about 10 million lb and the major species was rock sole, as was the case in 1968.

Age and growth studies were continued with the emphasis on rock

sole from waters off the northern end of Vancouver Island. Results continue to indicate that rock sole in this area have a slighter slower rate of growth than those from northern Hecate Strait waters.

In cooperation with the Physiological Ecology Investigation, laboratory experiments on the effects of salinity and temperature on embryonic development of flathead sole were completed. Further laboratory work has been postponed pending completion of four manuscripts summarizing results to date.

Routine sampling for Pacific cod scales, to determine age composition of commercial landings, has begun.

A modest investigation has begun concerning reproduction and tagging of dogfish shark.

2. Rockfish Investigation — S. J. Westrheim

This program began in 1962 and was directed to studies of Pacific ocean perch (Sebastodes alutus) and other rockfish species in the northeast Pacific Ocean, from Oregon to the western Gulf of Alaska. Its purpose was to obtain biological information on these little-known species, and to establish a basis for determining the effects of the expanding USSR and Japanese fisheries.

During 1969, field studies consisted of:

(1) Establishing the bathymetric distribution of Pacific ocean perch off southwest Vancouver Island (February) and in Queen Charlotte Sound (September).

(2) Determining the length-weight relationship for Pacific ocean perch, by season, off southwest Vancouver Island and in Queen Charlotte Sound.

(3) Investigating rockfish spawning seasons off Vancouver Island.

(4) Rockfish taxonomic studies using biochemical and physical criteria.

Laboratory studies include:

(1) Ocean perch (and other rockfish) otolith reading.

(2) Ocean perch age determination and growth analysis.

(3) Ocean perch distribution.

(4) Rockfish pre-extrusion larvae identification studies.

(5) Rockfish distribution and taxonomy.

All ocean perch otoliths collected aboard the G.B. Reed in 1968 and 1969 have been read, as well as all those collected from British Columbia commercial landings for the years 1961, 1963, 1965, 1967, and 1969. In addition, 4,456 otoliths from 23 other rockfish species have been read.

Analysis of the ocean perch age determination and growth data is nearing completion. Ocean perch growth varies bathymetrically within areas, as well as latitudinally among areas.

Preliminary ocean perch studies, based on the 1963-66 trawl survey, have been completed and a manuscript has been submitted to the Editor for publication. Those general studies indicated substantial variations in distribution with respect to latitude, depth, type of bottom, and season. More detailed studies are now underway in two major areas off British Columbia.

Rockfish larvae identification studies are continuing, but progress is slow. Considerable difficulty has been encountered in establishing diagnostic characters for each species.

Rockfish distribution studies involve summarizing the G.B. Reed trawl data for 1963-69 to establish aerial and bathymetric patterns of distribution of the numerous species. Compilation of these data is now virtually complete. Taxonomic studies are continuing at a modest level. One more new species has been defined, primarily due to the biochemical analyses conducted by Vancouver Laboratory personnel, and a manuscript describing the new species is nearing completion.

3. Special Studies — W. A. Kennedy

Sablefish Culture. In an experiment to assess, from a biological viewpoint, the feasibility of a commercial operation based on capturing young sablefish Anoplopoma fimbria and rearing them to commercial size for slaughter, further progress was made in developing techniques for keeping the fish alive and healthy. In addition, a better method was developed for procuring young sablefish and for delivering them alive and unharmed at the rearing facilities.

Until early 1969 all sablefish used in the project had been taken by trawls fished from the G.B. Reed, A.P. Knight, or Investigator No. 1. On

a trip with the Caligus to Bull Harbour in April it was found possible to catch them with the floating longline gear that had been used for high seas salmon investigations. Further evolution during trips in April and June with the Investigator No. 1 and Caligus, respectively, developed the following method. The gear is set close inshore, being fixed by securing the two ends to the headlands on either side of a minor embayment. It is tended by a small boat. Fish are lifted aboard by dipnet, gangions being cut so that the hooks are left in the fish. The majority shed their hooks within a month or so. In contrast to mixed sizes (and ages) taken by trawl, the longline gear yielded only fish in their second year, of uniform size, somewhat less than 500 grams early in the season and somewhat more later.

The Caligus proved excellent for transporting live sablefish because of her built-in tanks. In one trip she moved about 270 fish, without loss, from Minstrel Island to Nanaimo.

A tank with 32 sablefish fed on chunks of frozen dressed dogfish had been started in March 1968. Apart from temporary difficulties with infection from tags used to distinguish individual fish, they progressed satisfactorily until April 1969. Meanwhile they gained about 0.13 kg per fish per month and were fed about 5.5 kg for every kg gained. During this period 8 died, 7 as a result of infection from tags. However, after April they developed symptoms which were diagnosed as a dietary deficiency. In order to test whether thiamine was the deficient item, thiamine was injected into 5 fish, the rest being controls. There was no response to the injection, which indicated that thiamine was not the item in which the diet was deficient. When frozen herring were fed instead of dogfish, deficiency symptoms disappeared in less than two months.

A tank of 30 trawl-caught sablefish fed one part of dogfish to one part of herring was started in January 1969. They are still thriving as of December 1969, having gained about 0.17 kg per fish per month, and having been fed about 4.7 kg for every kg gained. Four have died, apparently all from tag-induced infection.

Fish captured by longline gear were used to start a tank of 30 fish in August and two tanks of 35 fish each in September. Each lot has been fed an untried diet, consisting of some combination of marine organisms. All three lots are thriving as of December.

Scale Reading. During 1969 a scale reading method was perfected for determining the ages of Pacific cod, Gadus macrocephalus. Until this breakthrough, the development of a scientifically-based resource management plan had been hampered by lack of a reliable method for determining the ages of Pacific cod in catches made by Canadian fishermen. The validity of the technique used was established by a unique method based on considering distances between annuli along with distances between outer annulus and scale edge through a growing season. A paper on the subject has been submitted for publication.

A technician has been trained to recognize annuli on Pacific cod scales. A system for collecting cod scales regularly, and for reading them, was established in November 1969.

HATCHERY EVALUATION

H. Godfrey,
E.A.R. Ball

4. Studies of Hatchery Production of Chinook and Coho Salmon

These studies have been continuing since 1964, and have been reported on in earlier Annual Reports.

(a) Columbia River Fall Chinook Salmon

Preliminary estimates (not adjusted for marking mortality) of total U.S.-Canadian catches of these fish from the 1961, 1962 and 1963 brood years were 213,000; 76,000 and 217,000, respectively. The data for the 1964 brood year are incomplete.

For the 1961 brood, it was estimated that the survival of the marked fish was about 70% that of the unmarked. Thus, the estimate of total catch of that brood would be increased by a factor of 1.43 approximately (213,415 × 1.43 = 305,183).

Each year during 1964-68, the catch of these hatchery fish by Canadian fishermen amounted to roughly 1/3 of the total U.S.-Canadian catch of hatchery fish. Almost all of the Canadian catch of the hatchery fish was made in the troll fishery off the west coast of Vancouver Island, where in those years it amounted to 10-20% of the total troll catch there (adjusting for marking mortality).

Allowing for marking mortality, the total U.S.-Canadian catch of the hatchery fish from the four broods will have amounted to between 0.2 and 0.5% of the total number of marked and unmarked juveniles released from the hatcheries. For the 1961-63 brood years, the average (for all hatcheries) catch-to-escapement ratios (unadjusted for marking mortality) were 4.4, 6.3 and 3.3 to 1.

The additional data obtained in 1969 confirm that considerable variation in survival occurred among broods and hatcheries, and that there were marked differences among hatcheries in ocean distribution and in size and age composition.

(b) Coho Salmon

The total U.S.-Canadian catch of 1964 brood Puget Sound-Washington coast hatchery coho in 1967 cannot be determined (with precision). However, the proportions of the total catch taken in different fisheries in 1967 could be computed (by determining the estimated catches of marked fish). These are summarized below. (Releases of marked smolts from 10 Puget Sound and two coastal hatcheries totalled 1,249,560.)

Southeast Alaska troll		0.0%
Canada - west coast Vancouver Island troll	18.2%	
central British Columbia troll	0.3	
Georgia Strait troll	0.1	
Area C troll	4.0	
Area 20 gillnet and purse seine	27.1	
Total		49.7
Washington State - total		49.2
Oregon State - total		1.1
California State - total		0.0
		100.0%

Coho salmon from Washington State and Columbia River hatcheries of the 1965-66 brood years were taken as adult fish in 1968-69. Data for United States catches are not yet available, but preliminary estimates have been made of catches by Canadian fishermen. The estimated catches in the two principal fisheries, the troll fishery off the west coast of Vancouver Island and the gillnet and purse seine fishery in the Strait of Juan de Fuca (Statistical Area 20) are summarized below. A few thousand additional hatchery fish were caught in other areas (Georgia Strait and central and northern British Columbia).

Estimates and comparisons of Canadian catches of coho salmon in 1968-69 (unadjusted for marking mortality).[1]

	1968	1969	Catch of hatchery fish as per cents of releases 1968	1969
A. West Coast Vancouver Island - Troll				
Total coho catch	1,840,785	942,626		
Estimated catch of hatchery coho				
Puget Sound hatcheries	191,508	89,532	2.35	0.90
Washington coast hatcheries	47,351	7,694	1.87	0.43
Columbia River hatcheries	48,272	20,156	0.22	0.12
Total	287,131	117,382	0.87	0.41

cont'd.....

[1]Based on preliminary data; subject to minor revision.

	1968	1969	Catch of hatchery fish as per cents of releases 1968	1969
B. Area 20 - Gillnet-Purse Seine				
Total coho catch	398,333	249,158		
Estimated catch of hatchery coho				
Puget Sound hatcheries	62,579	43,695	0.77	0.44
Washington coast hatcheries	2,891	388	0.11	0.02
Columbia River hatcheries	6,560	1,123	0.03	0.01
Total	72,030	45,206	0.22	0.16

The 1969 total Canadian catch of coho salmon was less than that of 1968 by 49% in the west coast Vancouver Island troll fishery, and by 37% in the Area 20 net fishery. Comparable decreases in the catches of hatchery coho (from all hatcheries) were 61.2% and 47.4%, respectively (after adjusting for differences between the two brood years in total numbers of fish released). Although it is not known whether the proportions of the total catch taken by United States fisheries differed significantly in the two years, it is considered most unlikely that a higher fraction in 1969 would account for the much lower rates of catch that year in the two Canadian fisheries. Thus it appears that the production of hatchery fish as well as the total production of coho salmon in 1969 was much below that of 1968. This suggests lower survival during and/or after seaward migration, probably particularly during estuarine residence. This hypothesis is postulated, even though it is known to have been likely that production of natural stocks in 1969 suffered from conditions of low precipitation during 1967, when the fry of the 1966 brood were resident in their streams.

5. Ages and Sizes of Chinook Salmon taken in British Columbia Commercial Fisheries in 1968

These data are presented in Manuscript Report Series No. 1073. Data for 1964-67 were presented in Manuscript Report Series Nos. 947, 952, 954 and 998, respectively.

6. Informal Committee on Chinook and Coho

Combined reports by the Canadian and United States Sections of the Committee have been prepared under the title "Reports by the United States and Canada on the status, ocean migration and exploitation of northeast Pacific stocks of chinook and coho salmon, to 1964." The reports have been accepted by the two governments, and approval has been given for their publication and limited distribution. The Technical Working Group of the Committee has also prepared a "Proposed coordinated research program for chinook and coho", which, after further study, the Committee will submit to the two governments, together with recommendations on priorities to be given to particular projects.

7. Salmon Identification According to Origin by Emission Spectroscopy

Dr. Calaprice is developing procedures using emission spectroscopy in conjunction with multivariate techniques to achieve discrimination to identify organisms according to their origin. Assistance was given him in 1969 in the collection of coho samples, and a cooperative project for developing the application of this technique in fisheries research investigations is being planned for 1970. In initial tests in 1969, samples of coho smolts from several streams were distinguished and identified as to area of origin with less than 1% error.

PELAGIC FISH

8. The Herring Fishery F.H.C. Taylor

1968-69. The total catch was 1,465 tons, taken for bait and for the fresh fish market. No reduction fishery was permitted. The catch was mainly from the northern and the Strait of Georgia stocks.

1969-70. No reduction fishery was permitted. The catch for food and bait is expected to be of the same order as in 1968-69.

9. Herring Sampling

F.H.C. Taylor

1968-69. Because there was no regular winter fishery, samples were collected almost entirely from drum seiners chartered for the purpose by the Fisheries Service. These vessels used a herring seine, shorter and shallower than the regular table seine. The Station drum seiner Caligus using a shallow experimental young salmon net provided six of the lower east coast samples. In all, 60 samples were obtained, 42 before Christmas from the lower east coast and 3 from the middle east coast stocks. Unusually cold weather after Christmas hampered this program, 2 samples were obtained from the northern stock, 9 from the lower central, 4 from the lower west coast, 3 from the upper west coast, and 2 from the Howe Sound region. There were 2 samples from the March bait fishery in the middle east coast. The samples were considerably larger than normal, averaging 250-500 fish.

In the northern subdistrict in the main inshore stock, the 1966 year-class (Age 2^+ or III), followed by the 1965 year-class (Age 3^+ or IV), was dominant for the second successive season. However in the Nass River area the 1967 year-class (Age 1^+ or II), followed by the 1966 year-class, was dominant. In the lower central stock, fish from the 1967, 1966, and 1965 year-classes were about equally numerous (20-25%). In the middle east coast, one-year-olds (the 1967 year-class) formed 56% of the fish sampled, while juveniles and two-year-olds (the 1968 and 1966 year-classes, respectively) formed about 20% each. In the lower east coast the proportion of juveniles was 26%, of one-year-olds 38%, and of two-year-olds 22%. In both the upper and lower west coast populations, two-year-olds (the 1966 year-class) were dominant forming 43-45% of the stock; in the lower west coast one- and three-year-olds were about equally represented (25 and 21% respectively) while in the upper west coast, three-year-olds were a little better represented than one-year-olds (25 and 16% respectively). In the Howe Sound samples, 78% of the fish were juveniles.

In summary, in the northern stock and on the west coast, the 1966 year-class was dominant, while in the Strait of Georgia the 1967 year-class was dominant. In the lower central stock, three year-classes (1965 to 1967) were about equally represented.

10. The Time and Extent of Herring Spawning in British Columbia

D. Outram

During the 1969 herring spawning season 124 miles of spawn were deposited, a 20% increase from the 1968 level but still well below the

25-year (1940-64) average of 199 miles. While spawn abundance increased in all three Queen Charotte Islands and five southern British Columbia stocks, it decreased sharply to very low levels in the northern and central stocks.

Despite increases in all stocks in the Queen Charlotte Islands, spawning remained at below-average levels. In the upper east coast Queen Charlotte Islands, 1.6 miles of spawn were found compared to one-half mile in 1968. In the lower east coast Queen Charlotte Islands, 2.8 miles of spawn were found, almost double that recorded in 1968. On the west coast Queen Charlotte Islands, seven depositions produced 2.6 miles of spawn as compared to less than one-half mile in 1968.

In northern and central British Columbia, spawn abundance decreased to almost unprecedented low levels in 1969. Little more than 2 miles of spawn were found in the northern and upper central stocks in 1969 compared to an average of 26 and 18 miles, respectively. In the lower central stock, the 11.7 miles of spawn recorded was about one-third average and 10 miles less than in 1968.

In southern British Columbia five major stocks showed increases in spawn abundance from the 1968 level. Spawn deposition returned to above-average levels in both the upper east and upper west coast of Vancouver Island stocks. In these areas 30 and 18 miles of spawn were recorded, respectively. From the lowest deposition on record, 6.2 miles in 1968, spawning in the middle east coast of Vancouver Island rose to 22.8 miles, about 6 miles below average. In the lower east coast of Vancouver Island stock, although a 15% increase in spawning occurred from the 1968 level the 17.1 miles found remained well below the 25-year (1940-64) average of 26 miles. In the lower west coast of Vancouver Island subdistrict, spawn abundance (8.7 miles) was only slightly greater than in 1968 and still only about one-half average.

Localities in the Boundary Bay region (Area 29) and nearby American waters produced almost 8 miles of spawn in 1969. A post-season survey by Biological Station personnel located two fairly extensive depositions in U.S. waters, one at Birch Bay on May 17, the other at Hale Pass on May 22.

Herring spawned along the British Columbia coast during a 5-month period from January 15 to June 23, 1969. In the Queen Charlotte Islands, although the spawning season extended for 10 weeks (April 5 to June 23) the peak spawning period (the interval during which from 25 to 75% of the total mileage was deposited) was brief, 15 days from April 15-30. In northern British Columbia the peak spawning period extended for 11 days from March 25 to April 5. In southern British Columbia the peak spawning period occurred during a 12-day interval from March 15-27.

Generally speaking, in 1969 the peak spawning period, the mean spawning time and the date of the first and last spawning became progressively later from south to north. A latitudinal variation of 6 weeks in mean spawning times (March 8-9 to April 20-21) occurred between the two most southerly

stocks, the lower east and west coasts of Vancouver Island and the two most northerly, the Queen Charlotte Islands and northern stocks. In fact, the spawning season was completed in the lower east coast of Vancouver Island subdistrict (April 1) before spawning had begun in the Queen Charlotte Island subdistricts (April 5).

11. Late Herring Spawnings in American Waters

D. Outram

Numbers of small herring larvae (24 mm) have been found in plankton tows from the southern Strait of Georgia in early July in recent years. Larvae hatched from spawnings during the usual peak spawning period (March) would have metamorphosed by this time. The size composition of these small larvae from the Boundary Bay-Fraser River delta region suggests a spawning 5 to 6 weeks earlier, in May.

To determine if late unobserved spawnings were taking place in the southern waters of the Strait of Georgia, a spawn survey was carried out with Station vessels in May and early June, covering the mainland shore from Sechelt south across the international boundary to Anacortes and including many localities in the San Juan Islands.

Two spawnings were found in American waters which might contribute to the Strait of Georgia herring stocks. One medium intensity spawning took place on May 17 in Birch Bay, measuring 5,600 yds × 50 yds. Unlike March spawnings, few sea birds were present, thus mortality from bird predation would be almost negligible. Another medium intensity deposition was found further south in Hale Passage. This spawning occurred on May 22 and produced 1,600 yds × 100 yds of spawn. A large body of diving ducks was actively feeding on the spawn-laden eelgrass in this area.

The amount of spawn deposited in American waters totalled 4 miles. Altogether the extent of spawning along the lower mainland from Boundary Bay to Hale Passage during the period March 2 to May 22 totalled over 7 miles; a larger spawning than that recorded in five British Columbia herring subdistricts in 1969, the northern, the upper central, and three Queen Charlotte Islands subdistricts.

Southeast surface winds and the counterclockwise gyral in the Strait of Georgia could transport the planktonic larval herring from spawning grounds in nearby American waters north to the Fraser River delta area. Further surveys should be carried out in both Canadian and American waters to determine the time and extent of such late, previously unreported, herring spawnings.

12. Status of the Herring Stocks

F.H.C. Taylor

1968-69. In 1968-69 there was virtually no catch. Spawn deposition, while somewhat greater than in 1967-68, was still below average. Substantial increases in the upper and middle east coast and upper west coast stocks, and smaller increases in the lower east and lower west coast stocks, were offset by large decreases in the northern, upper and lower central stocks. Abundance in 1968-69, while greater than in 1967-68, still remained below average in southern British Columbia stocks. In the upper east coast stock abundance may have been average. In northern and central British Columbia abundance declined sharply.

In 1967-68 it was considered that in northern and probably also in central British Columbia the 1965 and the two preceding year-classes were weak. It would now appear that the 1966 year-class and possibly the 1967 are also weak. In the two Strait of Georgia stocks, the 1967 year-class which showed well as juveniles in 1967-68 may be stronger than the preceding two very weak year-classes, but is probably still of below-average strength. On the west coast of Vancouver Island the 1966 year-class, while stronger than the 1965, is probably relatively weak. The 1967 year-class was not as well represented on the west coast as in the Strait of Georgia.

13. The Effect of Diet on Survival and Growth of Laboratory-Reared Herring Larvae

D. Outram

The critical period during which year-class strength is determined is thought to occur during the larval stage. The type, density and availability of food organisms in the ocean may be one of the main factors affecting larval survival and growth. To acquire some understanding of food requirements, herring larvae were reared in the laboratory from artificially-fertilized eggs and provided with five different diets.

Rearing tanks were arranged in four replicate groups and stocked each morning with the following diets: (1) newly-hatched Artemia nauplii, (2) newly-hatched Balanus nauplii, (3) ocean plankton (<350 microns), (4) ocean plankton plus Artemia nauplii, (5) ocean plankton plus Balanus nauplii, and (6) no food (control tanks). Tanks were supplied with daily rations of from 8,000 to 10,000 food organisms, providing about 7-9 organisms per day per larvae. The 8-inch diameter black circular 10-liter tanks contained about 1,200 herring larvae each. Salt water was exchanged at the rate of 100 ml/min and kept at 9 C and 20‰. Each tank was illuminated from above with fluorescent lighting (20 watts) for two-thirds of each day.

The most favourable growth and survival rates were obtained from feedings with a mixed diet of ocean plankton and Artemia nauplii; the least with Balanus nauplii. Larval herring reared in control units survived for

19 days, growing very little in length (0.5 mm) from an average hatching size of 9.3 mm (Table I). On the other hand, some larval herring fed ocean plankton supplemented with Artemia nauplii survived over 14 weeks reaching a length of 38.0 mm. At this size (38.0 mm) metamorphosis had begun, the body had deepened, becoming silvery below and heavily-pigmented above. Survival and growth was also fairly good amongst larvae fed ocean plankton. From an average hatching length of 9.1 mm some larvae grew over 21 mm in 97 days to a length of 31.0 mm.

During the initial 3-4 days after hatching, when the yolk sac was being absorbed, few larvae died, thereafter up to 50% of the larvae in nearly all tanks died within 2 weeks. Although each tank was well stocked with food organisms, it would appear that a large proportion of the larvae were unable to initiate feeding and starved to death. As might be expected, the larval period was shortest and mortality greatest amongst unfed larval herring. By the 12th and 18th day of the 19-day larval period, 50% and 90%, respectively, of the unfed larvae had died. Balanus nauplii-fed larval fish did not survive much longer; 50% and 90% of the losses had occurred by the 12th and 20th day of the 22-day larval period. Amongst larvae fed Artemia nauplii, and ocean plankton plus Artemia nauplii mortality levelled off after the initial 2-week 50% loss. Small but consistent losses in the order of 5% or less occurred daily for the remainder of the experiment. Herring larvae fed ocean plankton and ocean plankton plus Balanus larvae continued to show high mortalities after the initial 2-week 50% loss phase. Only 10% of these larvae survived until the 22nd day but then mortality levelled off with small daily losses of 1 to 2% until the end of the experiment. The relatively small losses which occurred from day to day resulted primarily from swellings in the anal portion of the intestine caused either by a blockage or a misfunction of the digestive system of feeding larvae.

It would appear that herring larvae can be reared to and past metamorphosis on a mixed diet containing a wide variety of ocean plankton (<351 microns) and enriched with Artemia nauplii. The low survival rates experienced is probably not uncommon in the sea. It should be possible to reduce this mortality by improving rearing conditions, i.e., transferring larvae >20 mm to larger tanks, by increasing the water flow and by making available sufficient stocks of small ocean organisms, particularly diatoms and early copepod stages for food purposes.

14. Distribution of Larvae in the Strait of Georgia

J. S. Rees

The program to determine the distribution and relative abundance of larval herring in the lower part of the Strait of Georgia begun in 1967 was continued in 1969. The same 10 stations covering the full width of the strait from Nanoose Bay to Boundary Bay was covered at 2-week intervals from March 26 to June 23. As in 1968 a small 2-boat surface trawl was used. In 1968 larvae were less numerous than in 1967. While the collections for 1969

Table 1. Growth rate and survival time of larval herring reared under controlled laboratory conditions and fed different diets.

Diet	Length at hatching (average)	Final length (average)	Amount of growth	Larval period (days)
			(mm)	
Controls - unfed	9.3	9.8	0.5	19
Balanus nauplii	9.2	13.3	4.1	22
Artemia nauplii	9.2	16.2	7.0	38
Ocean plankton + Balanus nauplii	9.2	25.0	15.8	76
Ocean plankton	9.1	31.0	21.9	97
Ocean plankton + Artemia nauplii	9.2	38.0	28.8	104 (14+ weeks)

have not yet been fully worked up, a cursory inspection suggests that larvae were very much more numerous than in 1968.

15. Dispersion of Herring Larvae from a Spawning Site J. S. Rees

Larval herring have been presumed to be dispersed widely by wind and tide from the spawning sites. The distribution of larvae in the southern Strait of Georgia region raised some questions about the validity of this assumption. An attempt was therefore made to follow the dispersion of larvae from a known reasonably isolated, clearly defined spawning site, preferably with a relatively smooth bottom and eelgrass substrate (to facilitate bottom tows). The site chosen was Evening Cove where a spawning occurred on March 15, 1968. Results were complicated by a spawning while the survey was in progress in the immediately adjacent Coffin Point area.

To obtain larvae both anchored and towed, Hensen plankton nets (57 cm in diameter) were used. The 4 or 5 anchored nets were fixed across the mouth of the cove and at its head. At each turn of the tide these nets were cleared, and tows on the bottom with a sled-mounted Hensen net made around the perimeter of the cove in as shallow water as possible, and close to the bottom across the mouth of the bay in about 10 fms of water. Surveys were carried out on the first 3 days of each week.

Higher priority in the disposition of available staff had to be given to other programs. Analyses of the data are not complete but are proceeding as opportunity offers. Preliminary results show that a total of 4,671 herring larvae were caught in 70 sled tows. Of these, 87% were taken in the series around the perimeter of the cove. In this series of tows, 91% of the larvae were caught at higher high tide, 8% during the next tide phase, higher low tide, and less than 1% each at lower high tide and lower low tide. In the series of tows across the mouth in deeper water, 50% of the larvae were taken at higher high tide, 27% at higher low tide, 5% at lower high tide, and 12% at lower low tide. At the time of the investigation all higher high tides and 40% of the lower low tides occurred during the hours of darkness, all the lower high tides and 71% of the higher low tides occurred during daylight. The distribution pattern obtained is hard to interpret, not only because the effects of tidal height and light are confounded, but also because catches were highly variable. Looking only at the totals for each series it would appear that larvae are carried offshore with the falling tide.

The anchored nets caught 799 larvae in 135 hauls. Of these, 28% were taken at higher high tide, 42% at the succeeding higher low tide, 17% at the lower high tide, and 13% at lower low tide. The net immediately adjacent to the later spawning on Coffin Point provided a large proportion of the anchor net catches.

Further work is required to determine whether the effects of tidal

height and time of day can be separated to determine what effect size of larvae has on apparent movement, and to determine how intrusion of larvae from neighbouring spawnings affects the results.

16. Juvenile Herring Surveys along the Lower East Coast of Vancouver Island — D. Outram

An assessment of the abundance of a year-class in advance of recruitment to the fishable stocks is necessary for the effective management of the fishery. The initial stages of a program designed to estimate abundance during the juvenile stage was begun in 1969. The lower east coast stock was selected for preliminary investigation. Before useful estimates of abundance can be made the distribution of young herring throughout the lower east coast of Vancouver Island and the pattern of migration must be understood. In 1969 attempts were made to (a) develop efficient fishing methods for capturing young herring, (b) locate centres of juvenile herring abundance which could be used as "key" areas to estimate abundance from year to year, and (c) ascertain the time of seaward migration.

(a) Fishing Methods

With the M.V. Caligus, herring schools were located by echo sounding and samples taken by drum seine, beach seine, midwater trawl, night fishing with lights and lift net or dipnet. A 220-fm long, 20-fm deep drum seine proved to be the most efficient and least harmful method for capturing large numbers of juvenile herring close to shore at any time of the day. From 10,000 to 30,000 or more young herring were taken per set in localities from Northwest Bay to Sooke Harbour during September. During October, night fishing with electric lights and a lift net captured young herring although the number taken were small, less than 100 per locality.

(b) Target Identification

An underwater TV camera was used in conjunction with the echo sounder to identify the organisms responsible for any large schools encountered. In many cases dense schools seen on the sounder were proved to be jellyfish and not young herring. The camera could be used without artificial light to depths of 20 fm. Unfortunately the focal length was only 3-6 feet. It could be seen on the sounder that lowering the camera into schools did not scare the fish or other organisms.

(c) Areas of Concentration

It is believed that schools of young herring in the Strait of Georgia emigrate seaward each fall through the Strait of Juan de Fuca. The

region from Albert Head to Sheringham Point was monitored for indications of the time and occurrence of this migration. It was found that several localities in this region, Pedder Bay, Race Passage, Becher Bay and Sooke Basin, were centres of very high abundance of juvenile herring. Herring schools were present in these localities throughout all of October and the early part of November at which time they disappeared. The bays and headlands from Pedder Bay to Sooke Harbour may form a "holding" area where young herring congregate for a period in the late fall. This region could serve as a "key" area for monitoring young herring abundance just prior to a seaward migration.

17. Offshore Herring Survey

F.H.C. Taylor

In 1968 a program to determine the offshore distribution of herring and whether stocks distinct from the known inshore spawning stocks exist was initiated with the support of the Industrial Development Branch of the Fisheries Service. This program was confined to the lower west coast of Vancouver Island for the period June to October. In 1969 the program was extended to Hecate Strait and Queen Charlotte Sound as well, and to last a year from June 1969. The 80-ft steel trawler Sharlene K was chartered and rigged for midwater trawling. A modified 1160-mesh Canadian Diamond trawl with 4 m^2 süberkrüb otter boards was used. The vessel was fitted with an Elac sonar and netsounder system.

To December 31, 1969, 10 cruises had been carried out; 8 regular 17-day cruises, 3 each to the west coast and Hecate Strait and 2 to Queen Charlotte Sound, and 2 shore 5-day cruises to the Strait of Georgia. On each cruise approximately half the period is spent running a trackline covering sections of the coastal banks and gullies of the continental shelf, the continental slope and the area beyond to depths of 1000-1500 fm. The remaining period was spent in intensive coverage of areas where herring were located or known to occur. Herring schools were found in general along the "edges" of the gullies and the slope usually at 40-60 fm. Scattered schools occurred on the banks. No herring schools were found beyond the edge of the shelf.

On the west coast of Vancouver Island, herring concentrations were found in the same five general areas as in 1968, on Swiftsure Bank, on the southeast and southwest corners of La Perouse Bank, on the Firing Range off Amphitrite Point, and off Sydney Inlet. The quantity located was about the same or perhaps a little greater than in 1968. One-year-olds (Age 1+ or II) of the 1968 year-class were again dominant although two-year-olds (Age 2+ or III) of the 1967 year-class were somewhat more numerous than in 1968. Two-year-olds were more numerous on the southeast corner of La Pérouse Bank than elsewhere. Juveniles (Age 0+ or I) did not appear as numerous as in 1968.

In Hecate Strait herring were not as numerous as on the west coast. Two concentrations were found; one in the area between Stephens Island and

Browning Entrance formed by the gully running south from Dixon Entrance and by the head of the main northward-running Hecate Strait gully, the other along the 50-fm edge from the Horseshoe Bank to the Queen Charlotte Islands. Fish in this latter southern group were appreciably larger at each age than those in the northern group. In both groups in July two- and three-year-olds were dominant; however in September one-year-olds had become more numerous and in the southern group slightly outnumbered the two- and three-year-olds. There were more older fish (>Age 4+) in the southern group.

In Queen Charlotte Sound no concentrations were found. Scattered schools were located in Bates Pass and Queen Charlotte Strait. In October small schools of juveniles were located in 50-60 fm of water on the Steamer grounds off Cape Scott.

Stomachs of the more common predators, dogfish, hake and chinook salmon, were examined as time permitted. Dogfish and hake fed principally on euphausiids and other invertebrates in all regions. These two species were very much more numerous on the west coast than in Hecate Strait or Queen Charlotte Sound. Chinook salmon, taken again, as in 1968, in greater numbers on the west coast than elsewhere, were feeding on fish, mainly herring. Too few coho salmon were taken for adequate analysis.

18. The Anchovy (Engraulis mordax) in Southern British Columbia — D. Outram

While there have always been reports of scattered schools of anchovies in southern British Columbia, the number of reports from various parts of the Strait of Georgia in 1969 (Table 2) suggests that this species has perhaps increased in abundance. The last report of an abundance of anchovies appears to be 1951 when one-year-olds were present in large schools. It is not known whether this increase is associated in any way with the present low level of abundance of herring. Both species could compete for food at some stage in their life history.

The anchovy has never been present in large enough numbers to support a major fishery. The species was exploited to some extent for a specialty pack in the 1940's, generally only by one company. The catch for a 9-year period (1939-47) varied between 70 and 6,836 tons, averaging 2,183 tons. One estimate put the total size of the stock in southern British Columbia at that time at 125,000 tons.

Some information is available on the life history of the species. In southern British Columbia the population fished consisted mainly of fish in their second and third years of life in the proportion of 80:20. Fish in their first year of life do not join the adult schools before autumn. Anchovy mature in their third year when 120 to 130 mm in length. The female produces three or more batches of eggs a season. Spawning occurs in the bays and inlets from late June to August.

A 50-fish sample from a set made in Departure Bay in mid-November 1969, by drum seiner, showed that fish in their third year were dominant (60%), followed by fish in their fourth year (29%). The average length of the dominant age-group was 129 mm, the average weight 29 grams. The gonads were undeveloped, indicating spawning had probably occurred some weeks earlier.

Table 2. Major anchovy fishing localities of the 1940's, together with a list of regions where anchovies were observed in 1969.

Area	1940's fishing localities	1969 anchovy localities
10	Smith Inlet	..
13	Loughborough Inlet	..
14	..	Tribune Bay, French Creek, Jenkins Island
15	Pendrell Sound	Pendrell Sound
16	Jervis Inlet	Jervis Inlet
	Pender Harbour	Pender Harbour, False Bay
	Sechelt Inlet	
17	Departure Bay	Departure Bay
	..	Pylades Channel, Nanoose Bay
18	..	Todd Inlet, Finlayson Arm
19	..	Oak Bay, Pedder Bay, Becher Bay
20	..	Sooke Harbour, Port San Juan
23	Barkley Sound	Off and in Barkley Sound, Effingham Inlet
28	Burrard Inlet	Gibson's Landing, Squamish, Pt. Grey

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19. INTERNATIONAL SALMON STUDIES

K. V. Aro and D. P. Giovando

On September 1, 1968, Dr. M. P. Shepard, scientist in charge of this investigation, was seconded to the Department of Fisheries, Pacific Region, in Vancouver for a period of 1-2 years to prepare a review of information on Pacific salmon migrations and to participate in all aspects of the Department's involvement in international commitments regarding Pacific salmon. Work done in Nanaimo has been primarily in support of Dr. Shepard's assignment. Background information has been provided also for meetings of the International North Pacific Fisheries Commission, for the Informal Committee on Chinook and Coho, and for meetings with the Deputy Minister and Industry regarding reciprocal fishing rights.

Amongst information provided to the International North Pacific Fisheries Commission was Manuscript Report No. 1038 in which are tabulated, by species and by set, the numbers of Pacific salmon and steelhead tagged and released by Canada in the eastern North Pacific Ocean in the years 1960 to 1967, and in which are listed all tag recoveries with detailed recovery information. In these years a total of 54,630 Pacific salmon (23,872 sockeye, 10,340 chum, 18,431 pink, 1,835 coho, 152 chinook) and 795 steelhead were tagged and released. By June 1969 information had been received on 4,147 tag recoveries (2,231 sockeye, 394 chum, 1,209 pink, 244 coho, 23 chinook, and 46 steelhead).

20. LOBSTER

R. J. Ghelardi and C. T. Shoop

Plankton tows at Fatty Basin during May and early June confirmed that wild lobsters conceive, embryos develop, and larvae hatch, alive, in the Pacific. Returns from tows were small and for a number of reasons it was not possible to estimate the size of the hatch, or survival beyond the first stage.

Monthly trapping, capture-recapture estimates of survival, growth,

and fecundity of adults were continued through a second year. More than 75% of females carrying eggs from the previous year hatched these during a 3-week interval from late May to early June. Females with newly extruded (1969) eggs began appearing in July, and by October about 60% of trapped females were berried; most, possibly all, are attributable to Pacific matings.

Juveniles hatched at Fatty Basin are now entering their third and fourth years of life in cages and pens. Survival is relatively high (20% in groups at large in pens, almost 100% in individual cages), and there is marked variability in the size of animals from the same year-class.

Work on ancillary projects related to a lobster introduction was begun and, in some cases, completed. These included a new, detailed hydrographic map of the Fatty Basin area; physical, geological, biological (including microbiology) oceanographic surveys; use of radioisotopes for mass-marking; use of sonic tags in behavioural studies; a study of adult lobster ethology in tanks, and initial contacts that may lead to a comparison of European and American lobsters.

MOLLUSCS — D. B. Quayle

21. Oysters

(a) Pacific Oyster Breeding in 1969

Pacific oyster breeding in British Columbia in 1969 was a commercial failure as it was in the State of Washington. Production in Japan was considerably less than average.

As early as May 24 the water temperature in Pendrell Sound exceeded 68°F to a depth of 10 feet and in mid-June it was as high as 75°F. The salinity at this time was satisfactory in Pendrell Sound itself (20‰) but outside in Waddington Channel it was down to 10‰. As a result of a small spawning on June 15 there were early-stage larvae in the water. Plankton sampling on June 24 indicated another small spawning had occurred and from the total number of larvae a modest commercial set was predicted. Partly because the industry was still in preparation and major spawnings were yet to come, the advice was against cultching for this set.

By June 30, larvae from the earliest spawning were up to 250 microns in length or 5/6 grown. Test cultch exposed July 8 had collected 6 spat per shell by July 14, and 36 spat per shell by July 17, indicating a relatively long larval period. Salinity during the period July 1-17 had dropped from 15‰ to 12‰ for on July 14 a considerable amount of white

glacier water from Toba Inlet was observed in Waddington Channel and a large cloud inside the entrance to the sound. It wasn't until about July 24 that salinity had increased to 16‰.

By July 21, the larvae from the early spawnings had disappeared from the plankton, but there were 1,000 per gal of early stage larvae spawned about July 15. The industry was advised to cultch for all conditions appeared satisfactory. However, by August 7, larval numbers were reduced considerably but there were still enough for a commercial set. They were slightly more than two-thirds grown at this time. By August 13, however, there were few larvae remaining in the plankton and only a very few spat were collected. From this time on the weather deteriorated and no further spawning occurred. Thus there was a complete commercial failure.

The early set which amounted to 50 spat per shell had reached a diameter of only 1/8 inch by the end of summer when normally it would have been at least 1 inch. This indicates the possibility of a food problem. Associated with the freshwater influx was a significant phytoplankton bloom, an abnormal situation in Pendrell Sound in summer. This bloom may have inhibited the production of the particular food organisms required by advanced stage larvae and small spat. There is little doubt the influx of fresh water in the sound was in some way responsible for the failure.

The snow pack and its water equivalent, in the Powell River area (likely representative of the Toba Inlet drainage area), on the standard April sampling date indicates that 1967 and 1969 were well above the average, coinciding with the low salinity years in Pendrell Sound. This may be a means of indicating when salinity problems might occur. Detailed analysis, including weather conditions, is underway.

There was no significant setting in Ladysmith Harbour in spite of several good spawnings.

It is doubtful if British Columbia growers will be seriously affected by the lack of seed in 1969, but there may be an impact on the export market, particularly to Europe.

(b) Raft Culture — D. B. Quayle

Repeat confirmatory experiments were instituted on a raft in Ladysmith Harbour in the fall of 1969. However, this raft was lost, likely due to vandalism, shortly before the termination of the experiment in November 1969.

The report of the coast-wise studies is now in manuscript form and should be ready for publication early in 1970.

The Provincial Commercial Fisheries Branch expects to obtain funds for a pilot-sized raft culture operation in 1970-71 when the use of ferro-concrete flotation will be investigated. It is likely we will participate in a modest way.

(c) Artificial Cultch — D. B. Quayle

Final tests of the artificial development with B.C. Research Council are underway and the completion of this will conclude the research phase of the program. Conclusions are as follows:

(1) Sufficient work has been done to conclude that the artificial cultch developed by the B.C. Research Council is attractive to oyster larvae and the development of such attached larvae is normal during its life on the cultch.

(2) The ideal composition for self-destruction of the cultch may be determined by the present experiments.

(3) The use of 0.5% of zinc stearate in the cultch was found to be adequate for the prevention of slime.

(4) The advantages of the artificial cultch over shell are:

(i) Lower weight, reducing freight and hauling cost, as well as requiring less flotation.

(ii) Reduced tendency to slime.

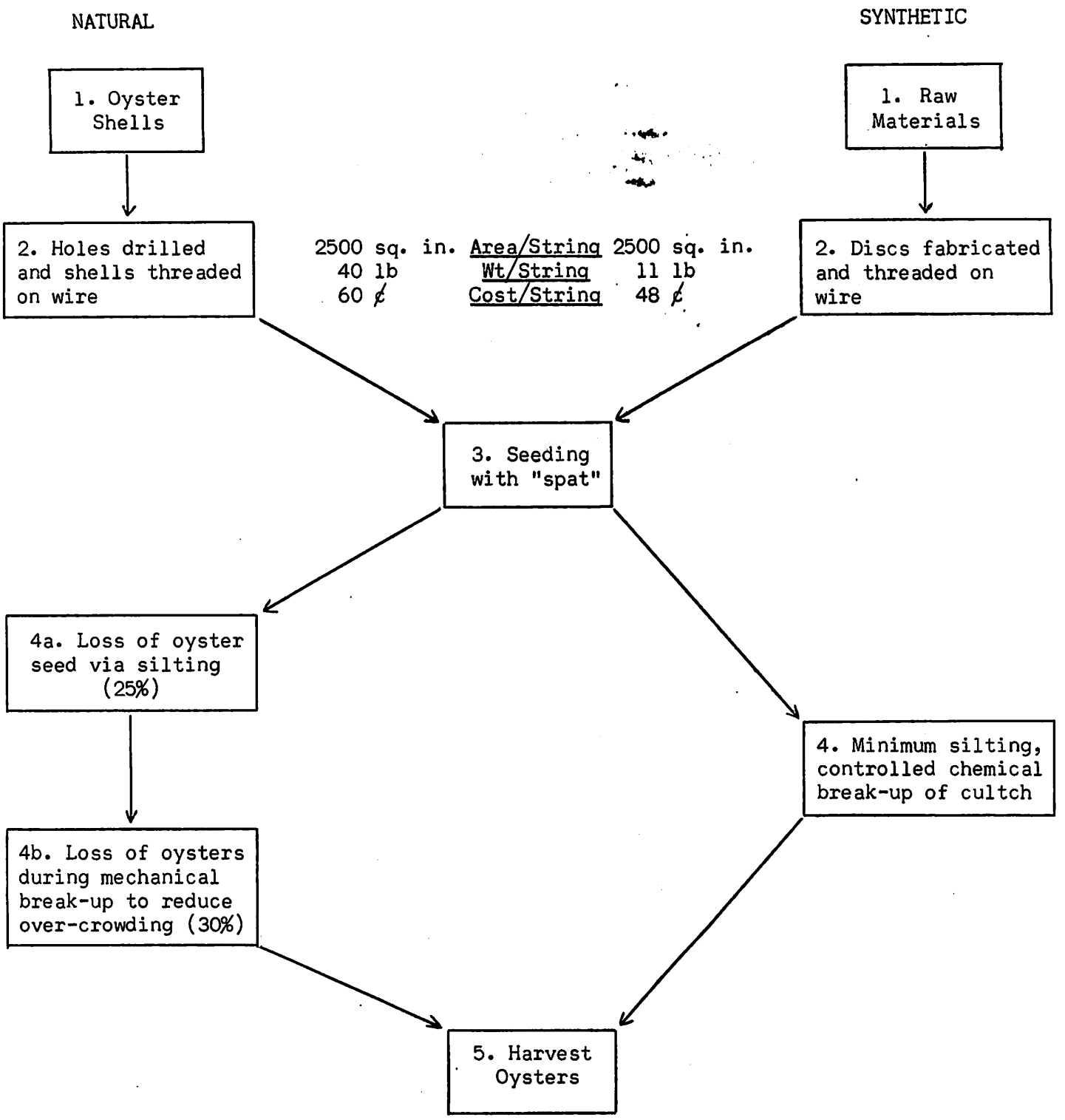
(iii) Breakup of clusters by controlled chemical reaction instead of by mechanical means, thus eliminating a mortality which may be as high as 30%, and at the same time eliminating or reducing the cost of this breaking.

The diagrammatic comparison of natural and synthetic cultch in Fig. 1 shows clearly the differences between the two.

Patent applications are still pending.

The next stage in the development of the use of the cultch is the manufacture of enough for a commercial scale test and this requires the acquisition of a moulding machine. Tentative approaches have been made to the Industrial Development Branch; B.C. Research Council may be interested in becoming involved if they can acquire certain patent rights. It is felt the role of the Fisheries Research Board in the project is nearly completed, except for a final report when the patent applications have been finalized.

Fig. 1. Natural and synthetic oyster cultch.



(d) Bacteriology of Oysters D. B. Quayle and F. Bernard

Purification. The oyster purification experiments using the basket relaying technique was continued and four tests were made under different temperature regimes. Samples with 8 replicates run on successive days showed satisfactory purification within 24 hours even at the lowest temperatures encountered. This study will be continued through another low temperature period. The results are confirmed by the few tests that have been made at the purification plant at Ladysmith. There is every indication the basket technique may supplement artificial purification methods and in some cases may be more economical.

Ecology. A bacteriological survey of oysters in selected areas on the west coast of Vancouver Island, far removed from human habitation and human pollution possibilities, showed relatively high coliform bacteria counts. Coliform biotypes were isolated and submitted to IMVIC characterization by which bacteria of fecal origin may be distinguished from those from soil and other sources. Coliform bacteria include aerobic and facultative anaerobic non-spore-forming Gram negative rods which ferment lactose with gas production at 35 C in 48 ± 3 hours. Currently the fecal group is characterized by lactose fermentation and gas production within 24 hours at 44.5 C. It is accepted that spurious results are obtained particularly from biotypes having an IMVIC reaction --++ and -+--. E.C. gas negative and gas positive types occurred in over half the number of samples. It is evident that a wide spectrum of coliforms are present in presumably pollution-free regions, and high MPN counts must be interpreted with caution.

22. Faunal Studies D. B. Quayle and F. Bernard

The faunal survey was continued at a reduced level of effort. Five short trips with a total of 40 stations from all areas of British Columbia were undertaken. A major point was the collection of the rare fissurellid Scelidotoma bella (Gabb, 1865) off Triangle Island in 60 fathoms. The backlog of collected molluscan material was indexed and 400 record cards added to the punch card file.

Opportunity was taken to collect material with the Parizeau on the Bowie Sea Mount. Fauna and flora generally associated with intertidal or immediately subtidal areas were found on the sea mount in 20 fathoms, 115 nautical miles west of the Queen Charlotte Islands.

Systematic studies were continued with the publication in the Journal of six new species of septibranch bivalves from the eastern Pacific. A review of the bivalve genus Thyasira in western Canada with a detailed anatomical description of Thyasira disjuncta has been submitted for publication.

Continued progress has been made in the general systematics of west coast bibalves. Approximately 5,000 references have been abstracted and the compilation of a final draft of a nomenclaturally up-to-date check list of British Columbia molluscan species is in preparation.

A further study has been completed on the anatomy of the clam predator Polinices lewisi (Gold). The histology, enzymatic activity, and fine structure of the accessory was published and work is in progress on the supra-oesophageal gland.

A survey of the spirochaete genus Cristispira occurring in 63 species of British Columbia bivalves indicates that infection is not limited to the crystalline style and that the organisms are probably of no digestive significance. An account of this study has been accepted for publication.

23. Clams

N. Bourne

(a) Razor Clams

Following the trend of recent years, landings of razor clams in the commercial fishery at Masset were very small, due again to the difficulty in finding people to dig clams. Because of this perpetual problem, construction of a mechanical digger to harvest these clams will probably begin in 1970. When this harvester becomes operational, landings of razor clams should increase.

In 1969 a program was begun to take bi-monthly beach-screening samples on the Masset beaches to study changes in the density, growth, and mortality of the incoming year-class. Two transects were established on North Beach and one each on Horseshoe and South beaches. In 1969 the density of small clams (under 20 mm) in the lower half of the intertidal beach was the lowest recorded in four years of sampling; in September densities ranged from 0 to 13 per sq. ft, a mean of 5; in November, from 0 to 9 per sq. ft, a mean of 3. As in previous years, greatest numbers of small clams occurred on North Beach, moderate numbers were found on Horseshoe Beach and virtually none on South Beach.

The small clams found in September came from a spring (May) spawning as was observed in previous years. However in 1969 recruitment from the major summer (July) spawning was also observed in the November screenings. Moderate numbers of the 1968 set were found in the fall screenings on both Horseshoe and North beaches.

(b) Butter Clam Growth

The first part of a project begun in 1968 to assess the growth rate of butter clams latitudinally along the British Columbia coast, and at

different tidal levels on the intertidal beach, was completed. Seventeen of the 18 plots established in 1968 were re-dug; one plot at Seal Island was lost. Recoveries of tagged clams ranged from 68 to 90%.

Incomplete analyses of the data indicate that clam growth was faster in the southern part of the province than in the northern area. However, growth of tagged clams was generally slower than had been expected from results obtained by measuring the growth increment between annual rings. This reduction in growth may be due to disturbances to the clams suffered at the time of tagging, or to the extremely cold winter of 1968-69.

Almost no growth was recorded in clams larger than 60 mm shell length in the farthest north plot at Dundas Island (just north of Prince Rupert) and growth of clams smaller than this was very slow. Clam growth was more rapid in the plots between Dundas Island and Alert Bay: generally the further south the plot the faster the growth rate. The fastest clam growth rates in the province were recorded in the Strait of Georgia. Growth of butter clams was more rapid at the zero tide line than higher up on the intertidal beach.

Mortalities in the Strait of Georgia, particularly at the zero tide line, were much higher than recorded in other areas. Mortalities of tagged clams in the plots from Alert Bay north were generally under 5%. At the zero tide line in the Strait of Georgia the mortality of tagged clams was 70%. Most mortalities were due to the moon snail (Polinices lewisi); six of these gastropods were found in a single plot.

A group of clams from Seal Island (Strait of Georgia) was planted at Dundas Island and a group of Dundas Island clams was planted at Seal Island. The growth rates of the transplanted clams were the same as clams indigenous to the two areas.

Half of the plots were replanted and will be revisited in the next two years to obtain further information on growth and mortality rates.

As in 1968, surveys of beaches in the areas of the plots showed that small butter clams (under 30 mm shell length) were common north of Alert Bay but rare in the Strait of Georgia.

(c) Clam Ecology Studies

A continuing project begun in 1968 to study the ecology of clam beaches, with specific interest at Seal Island, was continued in 1969. Monthly histological samples of butter, little neck, and horse clam gonads were continued at Seal Island and also undertaken on clams from Brandon Island where initial work was begun on a clam farming experiment. Continuous temperature records were made, 15 to 20 cm below the surface of the intertidal beach at the 2.5 ft tide level at both Seal and Brandon Islands. In the period May to September, daily temperature fluctuations were observed

during periods of low tides. In the remainder of the year there were no daily temperature fluctuations, only a gradual increase or decrease in temperature depending on the season.

Mass spawning of butter clams was observed for the first time, occurring at Seal Island on May 8. Spawning began as the tide receded and continued even on the dry beach. Some clams continued to spawn even after being dug out of the soil. Some clams were brought back to the lab where they spawned and the larvae were reared to settlement.

This mass spawning may have been triggered by the combination of low tides and large daily temperature fluctuations (see table below). Spawning occurred at the end of a series of low tides and on a day when the greatest temperature fluctuation of the tidal cycle was observed, 7.5 C. The weather during the period was hot with little wind.

Height of low tide and temperature range recorded 15-20 cm below the surface of the intertidal beach at the 2.5 ft tide level at Seal Island, 1969.

Date	Range of temperature (°C)	Height of low tide (feet)
May 1	10	2.8
May 2	10.5	1.7
May 3	10.0 - 11.5	0.8
May 4	10.5 - 11.5	0.4
May 5	10.5 - 13.5	0.5
May 6	10.5 - 13.5	1.0
May 7	10.5 - 13.5	1.9
May 8	10.5 - 18.0	3.0
May 9	11.0 - 15.5	4.3

Regular samples of the plankton were taken in spring and summer at Seal Island, Departure Bay, False Narrows, and Ladysmith Harbour to: follow the development of larvae from this mass spawning; determine if similar spawnings of butter clams had occurred in other areas; and observe periods of abundance of other bivalve larvae.

The larvae from the mass spawning at Seal Island developed for 12 days, attained a shell length of about 180 microns and then disappeared. No

evidence of settlement from this spawning has been found on beaches in the Baynes Sound region. Butter clam larvae were also found in plankton tows in May at the other three locations, particularly Departure Bay, although the numbers were much less than observed at Seal Island.

Larvae of the shipworm (Bankia setacea) were common at all four stations in March and April, and horse clam larvae (Tresus capax) were also moderately abundant at this time. Mussel (Mytilus edulis) larvae were common from April through July at all four stations; larvae of soft shell clams (Mya arenaria) occurred commonly from May to July at all stations; cockle (Clinocardium nuttalli) larvae were only found in Departure Bay in June and July; and little neck clams (Protothaca staminea) were very abundant in late June and early July at all four locations.

A particularly strong year-class of cockles settled on Seal Island in 1969 and at the end of August measured about 20 mm shell length. The strong 1968 year-class of horse clams was sampled throughout 1969 but was much reduced by the end of the year.

24. Molluscan Larvae Studies

N. Bourne and D. W. Smith

The laboratory program investigating the larval development of British Columbia molluscs was continued in 1969. Major emphasis was again on butter clams and in particular raising mass quantities of larvae for clam farming experiments.

Conditioning adult butter clams during the period December to April improved the state of the gonad, but attempts to spawn them proved unsuccessful. As an alternative to spawning, the method of obtaining larvae by stripping eggs and sperm was further investigated and refined. Fertilization was more successful when eggs and sperm were stripped from conditioned rather than unconditioned clams. The optimum concentration of eggs, amount of 0.1 N ammonium hydroxide, and the length of time the eggs are treated was investigated. Egg concentrations from 340,000 to 2,700,000 eggs per liter were treated with 1, 3, and 5 ml of 0.1 N ammonium hydroxide per 100 ml of egg solution for periods of 5, 10 and 15 minutes. Maximum fertilization was obtained when 0.5 to 1 million eggs per liter were treated with 3 ml of 0.1 N ammonium hydroxide per 100 ml of egg solution for 10 minutes.

Butter clam larvae were raised at two temperatures, 15 and 20 C in all experiments. Results obtained in 1969, when much larger numbers of larvae were cultured to settlement, confirmed the 1968 results. Although larvae raised at 15 C had a wider size distribution than those raised at 20 C, growth at the two temperatures was about the same and initial settlement occurred in 20 to 25 days. However, survival was much better at the lower temperature.

Larvae held at concentrations of 6 per ml and not fed, lived for

about 10 days, grew slowly to a length of 125 microns and died. Larvae held at similar concentrations but fed daily with Isochrysis galbana at a rate of 6,000 algal cells per larva attained a settlement size of 250 microns in 20 to 25 days.

Optimum food concentrations for growth and survival were investigated using I. galbana and Chaetoceros calcitrans and a mixture of the two algae as food. Larvae were held at concentrations of 8 and 16 per ml and fed at rates of 6, 12, and 18 thousand algal cells per larvae per day. Best growth and survival was obtained in those cultures kept at a larval concentration of 8 per ml and fed 6 to 12 thousand cells of a mixture of the two algae per day.

Larvae in cultures with air bubbled through them had a faster growth rate and lower mortalities than those in cultures without air. Agitation with a plunger, built by the Engineering Research and Development Group, gave inconclusive results probably because the agitation was too slow. A plunger giving more vigorous agitation is being investigated.

The larval development of the rock borer, Zirphae pilsbryi was determined. Development was faster at 20 C than 15 C, and in 32 days larvae had settled at shell length 325-335 microns.

Larvae from brown colour phase mussels (Mytilus edulis) were raised to settlement and are being cultured to adult size. These adults will be spawned and the larvae cultured to determine if this colour phase is a recessive characteristic.

A major difficulty in the proposed clam farming experiments is holding and handling quantities of newly settled larvae (spat) until they are old enough to transplant; i.e. holding butter clam spat until it is 3-5 mm in shell length. Holding spat in the laboratory is impractical and too expensive. The simplest method of maintaining spat is to hold them in the surface water and allow them to feed on natural foods. Two methods of holding spat in the surface waters were tried in 1969 and although growth was good, mortalities were very high due to a set of starfish which settled inside the containers and killed most of the spat. Further work on handling large quantities of spat is being undertaken in 1970.

POPULATION DYNAMICS — A. S. Hourston

The basic objective of the Population Dynamics Investigation is the development and extension of concepts and methods for determining the population biology of fish stocks for direct application in assessing the status of specific stocks. Using computer facilities to cope with the large volumes of data and extensive calculations involved in a multipath analysis, theoretical

population simulation and analysis techniques are being adapted and applied to stocks supporting major commercial fisheries.

Analyses of this type require a time series of data for several of a number of population characteristics (age, growth, catch, effort, escapement, natural mortality measures of environmental conditions, etc.). This information is usually available from routine monitoring programs. If these data are not in the form of computer input, they must be transferred into this form and procedures for compiling and summarizing them have to be developed and programmed. With a limited amount of additional effort, the continuing requirements of the monitoring group for summary tabulations can be programmed directly from basic data at this stage.

25. Newfoundland Herring

Using data gathered by a monitoring program established by the writer during a two-year posting to the St. John's Station, K. R. Allen's methods for assessing recruitment rates and population abundance were adapted for the population analysis of herring stocks. Measures of catch per unit of effort were developed and the calculations involved were programmed (7 programs), along with those for the determination of age composition (2 programs) to convert the raw data directly into card input for the Allen analysis (11 programs). The abundance of the five major stocks (defined in 1968 from differences in spawning time, vertebral numbers and age composition, and geographic distribution) was estimated using four different measures of effort, three sets of time series and four levels of survival rates. The results obtained using catch data by fishing season, an adjusted measure of days fishing for effort and survival rates of 0.4 to 0.6 were most compatible with the known age composition and trends in catch.

Population estimates indicate that by the 1967-68 season, the rapidly expanding Newfoundland herring fishery was exploiting the resource beyond the extent compatible with sustainable yields under present conditions. The recruitment of the apparently abundant 1963 year-class could, however, dampen a decline in the catches for the next season or two. A confidential report to the Deputy Chairman (June 1969) summarized the salient features of the results for the information of the Herring Task Force.

Basic monitoring data (age, maturity, size, catch, effort and spawning season) were tabulated, summarized and compared for the 1964-65 to 1967-68 seasons in a series of five technical reports, five manuscript reports, and a circular, most of which were published by the St. John's Station.

An analysis of the relationship of otolith nucleus type to spawning season (related for populations but not for individual fish) was published as a Technical Report from the St. John's Station. Assessments of spawning season from spawning observations, maturity data, and otolith nucleus types

(mainly autumn or winter spawners in the major southwest coast stock and the west coast stock, and mainly spring spawners in the other three stocks) have been written up for submission as a Technical Report.

26. British Columbia Herring

Ten years of data on catch, spawning and age composition for the lower east coast and lower west coast populations were examined for features related to the abrupt decline in abundance which led to the closure of the fishery in 1967-68. These gross analyses suggest that the decline could be directly attributed to the interaction of reduced recruitment and increased fishing pressure which may be reconstructed as follows:

1963-64. The recruitment of a series of strong year-classes (1959 to 1961) resulted in relatively high abundance during the 1961-62 to 1963-64 fishing seasons.

1964-65. The recruitment of the mediocre 1962 year-class resulted in a considerable reduction in overall abundance from that in the preceding seasons. In an apparent effort to maintain the catch, fishing intensity increased and the spawning escapement was reduced. This situation was aggravated on the lower east coast where an additional quota extension in the previous season had already appreciably reduced the abundance of the previously recruited year-classes; consequently the spawning escapement for this population dropped to about one-third of the level in the preceding five years.

1965-66. With the recruitment of the poor 1963 year-class, the abundance of all of the mature year-classes was at a low level. The fishery then turned to the immature and newly maturing 0^+ and 1^+ fish which provided half (in numbers) of a still appreciable catch. However, the numbers of mature fish escaping to the spawning grounds was reduced to about one-third that of the relatively stable level observed from 1961 to 1964.

1966-67. Although the 1964 year-class appears to have been more abundant than the 1963 year-class, large numbers had been removed as immature fish in the previous season and the recruitment of maturing fish was relatively small for the second year in a row. The young 0^+ and 1^+ fish again provided much of the catch, and the spawning escapement did not improve.

1967-68. By now the numbers of all but the fish of the year had been decimated by fishing pressure on the lower east coast. Three-quarters of the fish taken by a small fishery were immature fish in their first year. On the lower west coast, where exploitation had been less intense, the situation was not as acute but was tending in the same direction. Relief from fishing pressure from 1967-68 to 1970-71 has restored the age balance to a considerable extent and by 1970-71 the age distribution in these two populations should

again be similar to that in the early 1960's. Spawn deposition (to which older fish make a contribution which is disproportionately large for their numbers) appears to have been recovering more slowly. However, the quantitative assessments involved are very gross and the increase in abundance could be greater than that indicated by the miles of spawn recorded.

To further investigate and quantify the status of these populations mathematical models are being developed for application to these and other British Columbia herring stocks. Concurrently, information required as input for these models is being assembled in cooperation with the Pelagic Fish Investigation. Programming to array these data for computer analyses has begun and incorporates provisions for the production of summary tabulations of the data in the form prepared annually for stock assessment by the Pelagic Fish Investigation.

27. Pink Salmon in Southern British Columbia

Assessments of the current status of these (and other) stocks are required as background reports for the U.S.-Canadian reciprocal agreement negotiations scheduled to reconvene in February 1970. At the request of Dr. Shepard, who is preparing these reports, the writer has been involved in an advisory capacity in the preparation of assessments of pink salmon stocks in southern British Columbia.

SALMON STOCK ASSESSMENT

28. Sampling of Salmon Catches — H. T. Bilton, D. W. Jenkinson and M. M. Aarts

Sampling of the British Columbia commercial catches of sockeye and chum salmon was continued in 1969. All major stocks were sampled weekly throughout the fishing season for length, weight and sex, while ages were determined from scales. Reporting is now on a current basis.

29. New-Growth on Scales of Seaward-Migrating Sockeye Smolts from the Early and Late Parts of the Babine Run — H. T. Bilton & F. P. Jordan

A comparison of the occurrence of circuli formed after the annulus (referred to here as "new-growth") on the scales of early and late yearling migrants was made for the years 1958 and 1960-65. A total of 7,193 scales of

yearling sockeye from the seven emigrant runs was examined. The number of circuli laid down prior to annulus formation and after the annulus were recorded. The scales of early-run migrants (originating from the North Arm - Nilkitkwa areas), for most years, had fewer circuli prior to the annulus than did scales of the late-run migrants (originating from the main lake), indicating they had grown less up to the time they had formed their annulus. On the other hand, for most years, there was some tendency for scales of the early-run migrants to have more new-growth circuli than scales of migrants from the late run, indicating that the early-run migrants from the North Arm - Nilkitkwa areas tended to grow more in their second year up to the time of their migration than the late-run migrants from the main lake. In most years, the number of new-growth circuli on the scales of late-run yearlings from the main lake tended to increase as the migration season progressed, indicating they had continued to grow until the time of their migration from the lake. In most years, for both the early- and late-run yearlings there was an inverse relationship between the number of circuli prior to the annulus and the number of new-growth circuli.

30. The Effect of Environmental Factors on Circulus Formation

H. T. Bilton and G. L. Robins

The main objective of this research is to study the influence of various environmental factors on circulus formation. It is anticipated the results of this study will provide a firmer basis for, and increased accuracy in, the method of aging salmon from their scales, and determine whether or not the examination of scales can be a useful tool to assess the degree of environmental stress arising from both natural and artificial factors (pollutants). During the past year the first of a series of experiments was completed. Circulus formation on scales of young sockeye reared under constant light and temperature conditions but at three feeding levels were compared. The data are presently being analyzed. Preliminary results of this study suggest there may be a maternal influence because of correlations between the radius of the nucleus and the size of the fish and the number of circuli. There were significant differences in the mean number of circuli between fish reared at different feeding levels. When feeding levels were changed from a low to a high level a check was observed on the scales. On the other hand, when feeding levels were changed from a high to a low level, a check was not apparent. Cross sections of scales from fish in each experimental lot are being made. Three test sections have been examined and it seems that the shape of the individual circuli vary appreciably from the nucleus to the edge of the scale. The shape of each circulus tended to reflect the growth conditions of the fish at the time of the formation of the circulus: Fish growing rapidly tended to form circuli with broad bases and shallow slopes; circuli formed when the fish was growing slowly, tended to have narrow bases and steep slopes.

31. Comparison of the Fecundity of Sockeye Salmon in the Skeena River Catch with the Fecundity of those in the Escapement — H. T. Bilton

Skeena River sockeye are caught mainly with gillnets, which tend to select the larger fish. The object of this study was to compare the fecundity of sockeye of the catch with that of the escapement. For the period 1962-66, 5,262 and 9,869 sockeye from the Skeena catch and escapement (Babine Lake), respectively, were sampled for age, sex and length. From these samples the number and lengths of 4- and 5-year-old female sockeye in each year's catch and escapement were estimated. The average number of eggs and average weight per egg contained by females of each age and length category in the catch and escapement annually were estimated. The results indicated the catch selected significantly larger 4- and 5-year-old female sockeye containing significantly more and larger eggs. For all years, estimates of the average difference in length of 4- and 5-year-olds in the catch and escapement were 2.88 and 2.52 cm, respectively. For 4's the estimated average difference in numbers of eggs per female was 302.8 and for 5's,258.8. The estimated average difference in weight per egg for 4's was 0.0093 g, and for 5's, 0.0083 g. For the years 1962-66, estimates of total number of eggs contained by 4- and 5-year-olds in the selective catch were compared with estimates of the total number of eggs caught if the catch had not been selective. For 4's the selective catch accounted for from 10.9 to 19.8 million eggs more than the non-selective catch, and for 5's from 4.8 to 44.2 million eggs. Similar differences in the total weight of eggs were indicated.

SHRIMP AND CRAB

T. H. Butler and A. N. Yates

A detailed study has been completed on the dynamics of shrimp populations, off Comox, to determine need for regulation. An investigation is being conducted on the crab stocks in the Fraser River-Boundary Bay region, consisting of a biological survey on the effects of the Roberts Bank superport and an assessment of the need for closures during the soft-shell season. Much information has been provided the industry on the results of exploration for unfished shrimp resources, experimental shrimp trawls and construction and fishing efficiency of prawn traps. T. H. Butler, the investigation head, is on a 12-month sabbatical leave which will terminate September 1, 1970.

32. Comox Shrimp Investigation

Prior to the completion of the Comox shrimp project on July 7, 1969, there were three cruises with the Investigator No. 1. Experimental shrimp

trawling revealed the presence, first as 0-group individuals and later as yearlings, of a strong 1968 year-class. Catches of 0-group per 10-minute tow in 1969 were: 27 individuals in February, 1,441 in March, and 2,580 in May. Commercial records and supplemental sampling in October revealed that the shrimp had persisted to support a successful fall fishery. The age-group then consisted of males, 16-20 mm (carapace length), and females with some transitionals ("near females"), 18-20 mm. All the latter, comprising about a quarter of the year-class, would carry eggs late in 1969, without first being males. There has been a tendency, since the start of the project in 1965, for individuals of a strong year-class to bypass the male phase. By the time of breeding the transitionals will be in the early maturing female group.

Collections of shrimp larvae made in 1968 and 1969 have been sorted by the Canadian Oceanographic Identification Centre in Ottawa and identification of the larvae is underway.

33. Fraser River-Boundary Bay Crab Investigation

Three crab cruises have been completed in the Roberts Bank area, the last cruise being extended to include Boundary Bay. The objective was to survey the distribution, abundance and condition of crabs in a fairly important fishing region. Information is being collected to assess the need for a closure during the moulting and soft-shell season. The program was revised to study the effects on crabs of the construction, dredging and operation of the Roberts Bank superport.

During low tides on April 17 and 18, a survey of the Roberts Bank flats and shallows was made by boat and on foot. Cast shells from 1-year-old crabs were found on the west side of Tsawwassen causeway. Using the G.B. Reed as a base, a preliminary survey of Roberts Bank was carried out from May 5 to 9, 1969. Fishing with commercial crab traps and a 16-ft try net, 3,255 crabs were sampled from the intertidal zone to 9 fm. On the A.P. Knight from August 5 to 15, 1969, 1,933 crabs were sampled and 170 legal males (165 mm and larger) tagged for migration studies. Fifty-four tags have been returned to date: 16 recaptured 1-5 miles to the northwest, 16 in the immediate area of tagging, 18, 2-3 miles to the south, and 4 without data. On the November 3-14, 1969, cruise aboard the A.P. Knight, 2,030 crabs were sampled in Boundary Bay, 724 on south Roberts Bank. The carapace width-weight relationship for 65 legal crabs was recorded as a means of assessing condition.

Availability of legal males to traps and trawl was poor during all cruises due mainly to the concentration of commercial gear in the sampling area. Catches of sub-legal males and females (90-164 mm) were good. Absent from catches were the year-old group (11-83 mm), although evidence of their presence came with the finding of cast shells in April. In August, 4.7% of legal crabs were soft shelled, a level which would not warrant then a closure.

Reports prepared during the year included a Note in the Journal describing a trawl-board sediment sampler, and three file reports dealing with crab surveys in the Roberts Bank-Boundary Bay area.

SOCKEYE POPULATIONS — J. McDonald

34. Babine Evaluation

This study is part of a joint program with the Fisheries Service to assess the results of the Babine Lake Sockeye Development Project and to reveal reasons for its success or failure. A mark and recovery program began in 1966 with the objectives of: (1) comparing the distribution, growth, and survival of fry produced in the natural spawning beds of the Fulton River and in the Fulton River spawning channel; (2) defining the parts of the lake used as a nursery area by this important stock of sockeye. This last objective was considered a first step toward answering the question of how to fully develop the lake's potential to produce sockeye.

Three comparisons of channel and river fish from fry migrants to smolts have been made. Results of the first test (1966-67) have been reported (McDonald, 1969, J. Fish. Res. Bd. Canada, 26: 229-267). Analysis of data from the second test (1967-68) is complete and reporting is underway. Analysis of data from the third test (1968-69) is incomplete but results appear to confirm the conclusions drawn from the previous years. These are:

(1) Fry from the Fulton River and channel disperse widely into Babine Lake's main basin. Initially, most move into the southern half of the basin, but subsequently they concentrate in different parts of the lake at different times of the season.

(2) Channel-produced fry were similar in average size to river fry, at time of lake entry, but subsequently they were smaller and this difference persisted to the seaward migrant stage. The smaller size of channel fish was attributed in part to their later date of lake entry.

(3) Differences in survival to seaward migrant were indicated in two of the three years of comparisons. In one year (1967-68) river fish appeared to survive at a higher rate than channel fish, but in 1968-69 the order was reversed. In neither case was the difference large, and this, together with the variability in relative survival, suggests that some factor independent of quality is operative - possibly it is associated with lake entry.

The first recoveries of adult sockeye marked as fry (1966) were made this year in the commercial fishery and on the spawning grounds. These recoveries demonstrate that channel-produced fry survived to the adult stage and that they showed a substantial degree of homing to their natal stream.

An ecological study of underyearling sockeye in Babine Lake was completed. A paper describing their diel vertical movements and feeding habits has been submitted to the J. Fish. Res. Bd. Canada.

Two Manuscript Reports were completed. One describes Babine Lake temperature profiles in 1967, the other summarizes catches of sockeye and other species by purse-seining in Babine Lake, 1966-68.

35. SOCKEYE PRODUCTION H.W.D. Smith, F.P. Jordan, J. Martell and I. Miki

Progress was made on three research projects concerned with natural production of sockeye salmon, in the collection of routine data necessary for management of the Skeena River sockeye salmon runs, and assessment of the Babine Development program. Reports on individual projects are as follows:

(1) If there is a relationship between age of parents and age of progeny of sockeye of mixed age at return, yearly measurements of age composition would be helpful in managing the stocks. To assess any such relationships within the Babine stock, age composition on 10-13 substocks has been measured annually, 1962-69 (Table 3). One additional year of data is desired. Scale patterns, and fish size measured in the course of this work, appears useful for identifying the important Pinkut Creek and Babine River substocks as they pass through the estuary.

(2) Efforts to obtain efficient utilization of lake nursery areas and the forecasting of adult returning populations will be aided by an understanding of the relation between smolt size and post-lacustrine survival (program shared with J. G. McDonald - Sockeye Populations). Both the numbers and the age composition of returning sockeye may be adversely affected by increasing young salmon populations in lakes beyond some optimum level. To obtain appropriate measurements for Babine Lake sockeye, smolts in several size categories were tagged with Bergman-Jefferts coded wire magnetic tags in 1966, 1967, and 1968. Thus far about 600 recoveries have been made in the fishery and on the spawning grounds (Table 4). Survival has been best among the largest smolts from both the 1966 tagging, for which all returns are in, and from the 1967 tagging (3- and 4-year-olds only; 5-year-olds will return in 1970).

(3) Heavy infections of sockeye smolts by parasites could affect production. The cestode Eubothrium salvelini is common among underyearling

Table 3. Age composition of Babine sockeye 1962-1969 as determined by otolith readings.

Stream	1962		1963		1964		1965		1966		1967		1968	
	% 4_2	% 5_2	% 4_2	% 5_2	% 4_2	% 5_2	% 4_2	% 5_2	% 4_2	% 5_2	% 4_2	% 5_2	% 4_2	% 5_2
5 Mile	..	..	..	..	..	100.0	97.3	2.7	33.3	66.7	28.0	72.0	14.0	86.0
9 Mile	46.0	54.0	89.0	10.5	1.9	98.1	85.0	15.0	57.6	42.4	28.2	71.8	13.7	86.3
4 Mile	91.5	8.5	84.9	15.1	5.5	94.5	36.7	63.3	78.2	21.8	35.5	64.5	7.0	93.0
6 Mile	67.6	32.4	85.9	14.1	3.1	96.9	..	..	95.8	4.2	65.3	34.7	17.0	83.0
Sockeye	74.0	26.0	99.5	0.5	19.0	81.0	..	..	89.4	10.6	31.6	68.4	28.3	71.7
Tachek	51.0	49.0	98.1	1.9	19.9	80.1	8.6	91.4	90.7	9.3	34.4	65.6	28.8	71.2
Twin	60.4	39.6	99.5	0.5	13.1	86.9	12.1	87.9	85.4	14.6	56.5	43.5	21.1	78.9
Pierre	52.1	47.9	96.6	3.4	33.6	66.4	22.6	77.4	77.8	22.2	47.9	52.1	18.2	81.8
Grizzly	66.7	33.3	68.0	32.0	40.7	59.3	41.7	58.3	78.6	21.4	42.4	57.6	41.7	58.3
Tahlo	54.2	45.8	89.4	10.6	1.2	98.8	56.6	43.4	25.0	75.0	95.7	4.3	23.9	76.1
Morrison	71.9	28.1	88.9	11.1	4.7	95.3	83.2	16.8	83.1	16.9	86.3	13.7	9.3	90.7
15 Mile	78.2	21.8	93.8	6.2	67.7	32.3	8.7	91.3	97.6	2.4	91.8	8.2	34.3	65.7
Fulton	67.8	32.2	77.4	22.6	47.7	52.3	64.6	35.4	64.2	35.8	76.5	23.5	17.1	82.9
Lower Babine River	41.4	58.6	68.5	31.5	18.2	81.8	94.7	5.3	51.0	49.0	22.6	77.4	22.9	77.1
Upper Babine River	21.0	79.0	75.0	25.0	8.4	91.6	89.2	10.8	44.7	55.3	40.7	59.3	12.0	88.0
All streams weighted to abundance	56.9	43.1	80.9	19.1	31.8	68.2	78.8	21.2	58.1	41.9	56.4	43.6	16.3	83.7

Table 4. Recovery of coded wire tags from Babine sockeye.

Year tagged	1966			1967			1968		
Number tagged	45,000			70,000			80,000		
Fish age at recovery (years)	3	4	5	3	4	5	3	4	5
No. of recoveries in fishery	0	18	48	0	255		2	?	?
" " " on Babine L.	0	1	17	4	222		31	?	?
TOTAL	0	19	65	4	477		33	?	?

sockeye in Babine Lake and has been found in 30%, 21% and 25% of smolts sampled daily throughout the runs of 1966, 1967 and 1968, respectively. Infected smolts (averaging about 75 mm in length and 3.5 g in weight) carry an average worm "load" of about 5% of their wet body weight, though loads in excess of 25% occur occasionally (Fig. 2).

Underyearlings caught in townets in Nilkitkwa Lake in 1969 carried worms averaging 4 mm in length. On October 31, fish similarly caught in Nilkitkwa harboured worms averaging 24 mm. Since worms carried by smolts in May usually average about 50 mm, substantial parasite growth must take place during the winter months.

(4) A smolt run of about 46 million, and an adult sockeye escapement of 660,000 4- and 5-year-olds occurred in 1969. The smolt run represents an estimated survival of 5.6% from potential egg deposition and is the highest recorded during the past 12 years. However, a poor return of 5-year-olds in the adult return of 1969 reflected the calamitous survival of the 1964 brood. The total return (3's in 1967, 4's in 1968, and 5's in 1969) was about 83% of the parent escapement and ranks with the return from 1958 among the poorest ever. Particulars of the smolt and adult runs of 1969 are presented in Table 5.

36. SALMON HYBRIDS

F. C. Withler and R. B. Morley

The results of a 3 × 3 cross of sockeye, pink and chum salmon became available in 1969 and have been analyzed. In the fall of 1968 sockeye from Scully Creek at Lakelse Lake and pinks and chums from Humphry Creek, a tributary of Kitimat River, were crossed in all possible combinations, thusly:

♂ \ ♀	Sockeye	Pink	Chum
Sockeye	S♂ × S♀	S♂ × P♀	S♂ × C♀
Pink	P♂ × S♀	P♂ × P♀	P♂ × C♀
Chum	C♂ × S♀	C♂ × P♀	C♂ × C♀

Each replicate involved 3 males and 3 females as shown above; since the cross was replicated 4 times, 24 separate parents were employed. The progeny were reared under identical conditions until hatching. The results showed that among sockeye, pink and chum salmon there were pronounced differences in length of time from fertilization to hatching (incubation time), in size of

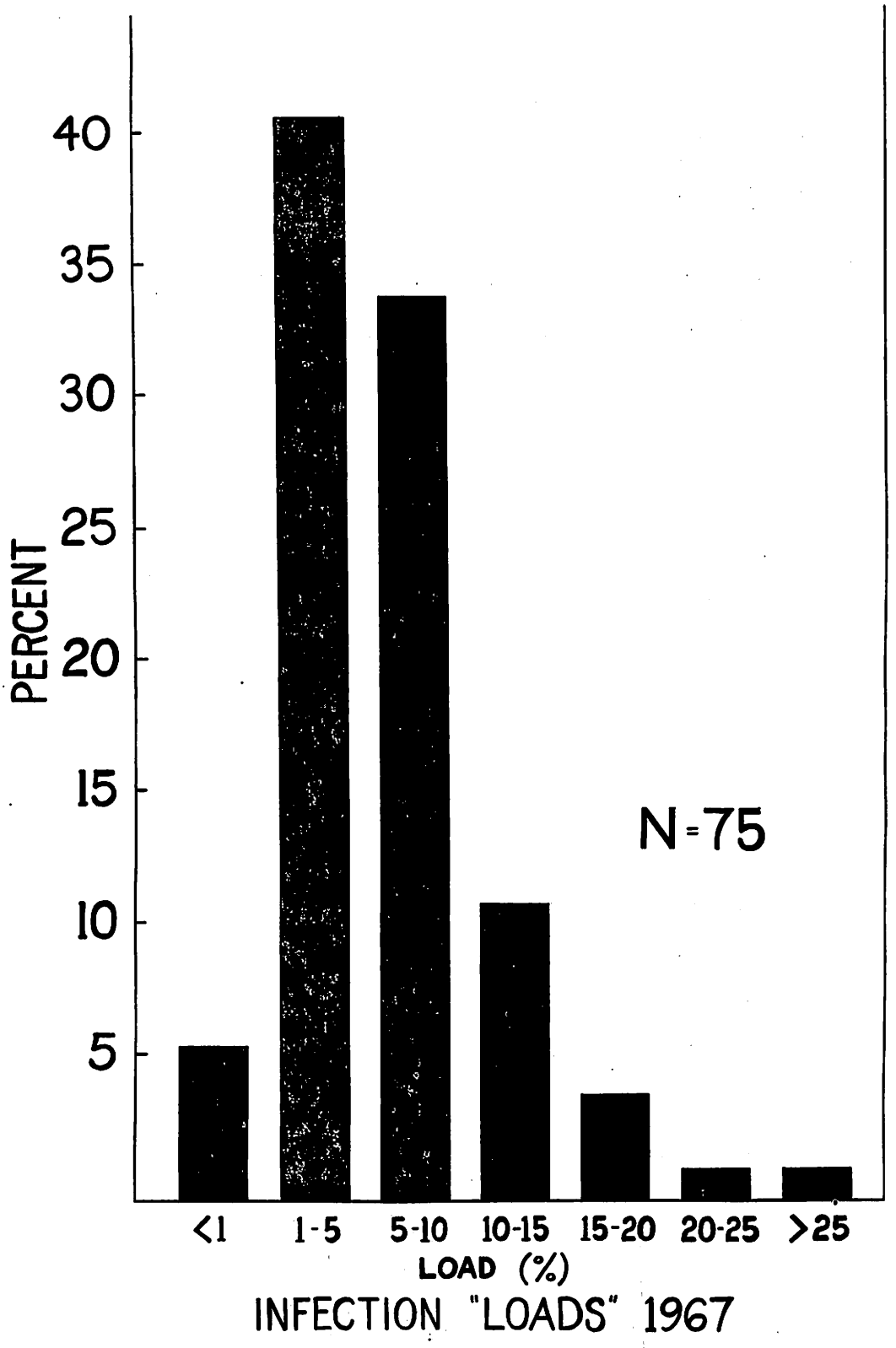


Fig. 2. Infection of Babine sockeye smolts by Eubothrium salvelini, May 23-27, 1967. Load is defined as:

$$\frac{\text{Wet weight of parasites} \times 100}{\text{Wet weight of fish} - \text{Wet weight of parasites}}$$

Table 5. Vital statistics of the Babine runs, 1969.

A. Smolt estimates from mark-recovery (1967 brood):

	Estimated numbers
Early run (North Arm-Nilkitkwa)	21,828,000
Late run	24,352,000
Total	46,180,000

B. Adult counts at fence:

Species			Count
Sockeye	-	jacks (3-year-olds)	154,000
	-	other (4- and 5-year-olds)	660,000
Pink			75,500
Coho			4,600
Chinook	-	jacks (3-year-olds)	1,000
	-	other	1,400
Chum			9

larvae at hatching, and in embryonic growth rate. Incubation time was governed mostly by the male parents, with chum and pink males associated with shorter incubation periods and sockeye males with longer. Among females, chums were associated with shorter incubation periods and pinks with longer; the effect of sockeye females was intermediate. Size of larvae at hatching was determined almost entirely by the females: chum females produced larger larvae, while pink and sockeye females produced smaller ones. Growth rate of the embryo up to hatching was governed mostly by the males: chum and pink males were associated with rapid embryonic growth as opposed to sockeye males which were associated with markedly slower growth. Among the females, chums were associated with rapid embryonic growth and pink females with slow; sockeye females were intermediate to the others. Gross malformation among hybrid offspring was not pronounced - only chum ♂ × sockeye ♀, chum ♂ × pink ♀, and pink ♂ × sockeye ♀ hybrids displayed significantly greater proportions of malformed individuals than did the combined pure crosses representing the parents. Identification of the parental determinants of early development of salmon should make it possible to create salmon forms capable of exploiting new or changed environments. A report of this work has been prepared for critical review.

In cooperation with Dr. L. V. Pienaar, a report is being prepared describing application of discriminant function analysis techniques to comparison of several meristic characters among purebred and hybrid offspring and their sockeye and pink salmon parents. Preliminary results suggest that on the basis of meristic characters considered (numbers of vertebrae and branchiostegals, and numbers of pectoral, pelvic, dorsal and anal fin rays) the reciprocal hybrid crosses, pink ♂ × sockeye ♀ and sockeye ♂ × pink ♀, resemble the pink parents more closely than they do the sockeye parents.

Observations on (1) the numbers of salmon ova which may be fertilized by the milt of one male, (2) the rate of "hardening" of sockeye ova, and (3) the depth to which unfertilized ova may be packed in containers during spawn-taking, were given in a Technical Report. A method for clearing and staining juvenile salmon for skeletal studies, developed by Mrs. L.D. Hunger, was reported in a Technical Report. A survey of Hokkaido chum salmon hatcheries in 1964 was published as a Manuscript Report.

Observations continued during 1969 on the survival, growth, teratology and meristics of the pure and hybrid progeny of a pink and chum salmon cross made in 1968. Observations are being made of sockeye × pink and sockeye × chum hybrids obtained from 1966 and 1967 crossings. Some pink ♂ × sockeye ♀ hybrids have matured at 2 and others at 3 years of age; all those maturing so far have been males, and their milt has been shown capable of fertilizing salmon ova.

EXPERIMENTAL BIOLOGY AND PATHOLOGY GROUP

L. Margolis

The Experimental Biology and Pathology Group was formed in the latter half of 1969 by the addition of the Genetics and Ethology investigations to the former Pathology and Physiology Group which consisted of the following four "Investigations": Microbiology, Parasitology, Physiology and Physiological Ecology. Thus, the Group now encompasses six "Investigations" consisting of a total of ten scientists.

The general objectives of the Group's research program are to gain an understanding of the factors governing survival, abundance, distribution, migration, growth, and health of important species utilized in the commercial and recreational fisheries through investigations of their behaviour, physiology, capacities, heritable characters, diseases and parasites; and to utilize knowledge in these areas to develop and improve methods of propagating aquatic organisms.

A brief review of the projects in each Investigation is given below and is followed by more detailed summaries prepared by the individual investigators.

Studies in Ethology are designed to determine the environmental and biological factors which control or influence the migration of salmon and to establish the sensory basis of direction finding. In 1969 work was concentrated on following the migrations of Skeena River-Babine Lake sockeye. Ultrasonic transmitters inserted in the stomachs of sockeye have been used to follow their tracks during the final stages of their homeward spawning migration and sonar has been used to follow downstream migration of smolts. In Babine Lake, for both returning adults and seaward migrating smolts, little difference has so far been found between migration during clear and overcast skies, indicating that celestial cues do not seem essential for migration. Migration of adults occurs primarily during the day whereas smolt migration occurs primarily at dusk and dawn. A complete picture of the migratory pattern of smolts is being obtained.

The Genetics Investigation is concerned with determining the relative importance of genetic (heritable) and environmental factors accounting for differences in survival, growth and behaviour among salmon stocks, and to determine the patterns and mechanisms of inheritance of the genetic factors. Experiments have been conducted with sockeye and pink salmon (still in progress). The sockeye experiments demonstrate the great importance of heritable factors in determining survival under optimum conditions, with maternal effects accounting for as much as 80% of early mortality. Mortality seems to be associated with the extent of parasitism of the female parent by the nematode Philonema. Associated with the genetic studies has been the development of important new chemical marking methods and new techniques of automatic data acquisition and data analysis.

The Microbiological studies were associated with various salmonid diseases. Techniques of immunizing sockeye salmon against bacterial kidney disease, a serious problem in the culture of salmonids, are being investigated. Sockeye salmon inoculated with heat-killed kidney disease bacteria in adjuvant produced high levels of specific antibody in their sera. Experiments are now in progress to determine if such inoculated fish are immune to kidney disease. Diagnostic services were provided to the Vancouver F.R.B. laboratory, the British Columbia Fish and Wildlife Branch, and other Station investigations. The diseases diagnosed were furunculosis in rainbow trout (Abbotsford, B.C. hatchery), vibriosis in chinook and pink salmon (West Vancouver F.R.B. laboratory), and myxobacterial disease in chum and chum-pink hybrids at the Station. Mortalities among a natural population of whitefish in Kootenay Lake were investigated but the cause remained undetermined. The identification of the bacteria associated with salmon eggs has been completed. There was no evidence obtained from this study that bacteria are a primary cause of salmon egg mortality.

Parasitological investigations continue to be mainly related to determining the effects of parasitism on wild and cultured fishes and to identifying and differentiating fish stocks (particularly salmon) in ocean areas of mixing, by means of parasite tags. Investigations were carried out on two parasitic copepods, Phrixocephalus cincinnatus from a marine flatfish and Salmincola californiensis from sockeye salmon, in relation to their effects on the host. Preliminary data on the geographic distribution of the protozoan Myxobolus neurobius in North American sockeye salmon stocks indicated the potential value of this organism as a stock discriminant. Information continues to be accumulated on the occurrence and distribution of parasites, particularly copepods, in and on British Columbia fishes. As part of a scientific exchange program with Japan, one of our scientists undertook a nine-month study (February-November, 1969) of the parasites of salmonid fishes in Japan.

The studies in Physiological Ecology continued to proceed along two lines: determination of the effect of various physical environmental factors on early development of marine fishes, and development of performance standards for young salmon to provide a baseline for assessing environmental suitability and stress from altered environments. Laboratory experiments on flathead sole eggs indicated that maximum hatching rates, survival, and larval size would result from incubation near 30‰ salinity and between 7 and 8.5 C. Swimming performance of juvenile coho salmon was investigated at various temperatures after acclimation at a number of different temperatures. Maximum swimming performance occurred at acclimation and test temperatures near 20 C. Comparison with sockeye juveniles suggests that coho perform better than sockeye in warm environments.

The work in Physiology is designed to gain an understanding of the bioenergetics of sockeye salmon through studies on metabolism, growth and

feeding in relation to various abiotic and biotic factors, and to use the results of these studies to develop improved means of artificial culture of salmon. Feeding studies included determination of satiation time (43 ± 8 minutes), time for return of appetite (full appetite in 25-30 hr), and maximum food intake for three sizes of sockeye (av. 1.9, 26, and 236 g) at 15°C. Growth-promoting qualities of several diets (natural and artificially prepared) were compared. Artificial diets gave better growth rates than a diet of frozen marine zooplankton (reinforced with vitamins) when fed in the same amounts. Using previously determined optimum environmental and dietary conditions, rapid growth of yearling sockeye, which almost doubled their weight every month during a 2-1/2 month test period (22 to 110 g), was obtained in an experiment on the feasibility of producing "marketable" size fish in artificial culture. This growth rate would produce a 1-lb sockeye in 21 weeks.

ETHOLOGY — C. Groot

1. Introduction

The main objective of the ethological investigation is to determine the environmental cues and sensory mechanisms utilized by Pacific salmon to direct their migration.

The orientation process resulting in the directional component is a complex interaction between environmental stimuli and sensory and integrating systems of the fish. This interaction is studied by detailed field observations of migration pathways and time patterns in relation to a wide variety of environmental conditions. Hypotheses resulting from these observations, indicating important environmental cues and sensory modalities used in direction finding, will then be tested under laboratory conditions. Since migration proper is a combination of orientation and locomotion, the laboratory studies will concentrate on both direction finding mechanisms and seasonal and daily activity rhythms.

2. Ultrasonic Tracking

A co-operative field project between the Fisheries Research Board (Nanaimo Station), the University of Wisconsin (USA) and the Fisheries Service (Vancouver establishment) was initiated in 1969 to study migration and orientation of sockeye salmon returning to their Skeena River system spawning grounds.

Sockeye salmon were intercepted during their migration through

Chatham Sound (by University of Wisconsin), the lower Skeena River (by Resource Development, Fisheries Service) and Babine Lake (by Fisheries Research Board) and marked with ultrasonic transmitters. These sonic tags, inserted through the mouth of the fish into their stomach (salmon stop feeding when reaching coastal waters), gave sound impulses between 65 and 75 KHz. Signal range varied between 1/4 to 1 mile, dependent on water, weather and bottom conditions. Marked sockeye were tracked with boats with suitable listening devices and their paths plotted. Various environmental conditions were continuously monitored during each track.

3. Sonic Tracking in Chatham Sound

(This study was performed by Drs. R. M. Horrall and A. B. Stasko of the University of Wisconsin, Madison, U.S.A., with financial and material assistance from the Nanaimo Station of the Fisheries Research Board.)

A total of 11 adult sockeye salmon were tracked in July and August of 1969 in the Chatham Sound area. Two of these 11 fish were lost soon after release. Duration of tracks ranged up to 32.5 hr. The longest distance covered was 44.5 km. Average speed of individual fish ranged from 1.4 to 3.6 km/hr (Table 6).

All fish were caught north of Dundas Island and either released close to the place of catching or displaced eastward between 6 and 14 km. Actual paths of the fish tracked are presented in Fig. 3. From these paths it is evident that sockeye salmon can travel in a straight direction over long distances. Initial movement after release is northward.

Measurements of water currents at 3, 10, and 30 m depth during tracking experiments showed that the observed movements of the fish cannot be explained in terms of passive drift. Detailed analysis of the tracks and correlations with data on environmental conditions gathered during the tracking experiments is in progress at the University of Wisconsin.

4. Sonic Tracking in Babine Lake

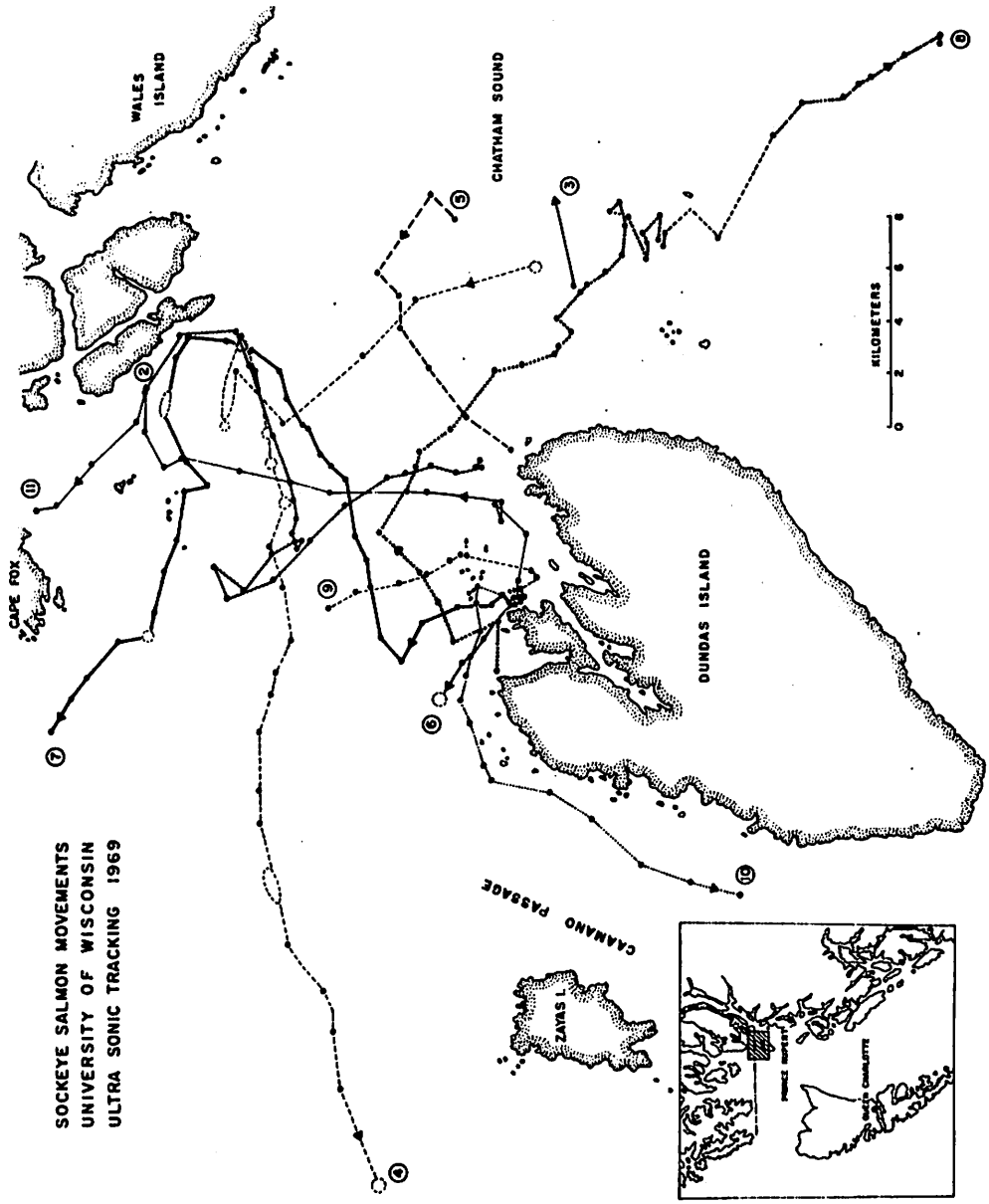
C. Groot and C. E. Turner

In the Babine Lake system 13 adult sockeye salmon were tracked in July and August, 1969, for a total duration of 302 hr, covering 522 km. Two of these 13 fish were lost within an hour of release; track duration for the remaining 11 ranged from 12 to 50 hr, with distances covered from 12 to 100 km (Table 7).

Results to date indicate that:

Table 6. Sonic tracking results of sockeye salmon intercepted during their migration in Chatham Sound. Drs. R.M. Horrall and A.B. Stasko, University of Wisconsin, 1969.

Track No.	Reclassed at capture site	Displaced from capture site	Duration of Track (hours)	Distance of Track (Naut.mi.)	(km)	Average Speed of fish (km/hr)	(cm/sec)
1		x	-	-	-	-	-
2		x	15.2	15.3	28.1	1.9	51
3		x	-	-	-	-	-
4		x	13.5	26.5	48.6	3.6	100
5		x	5.1	6.8	12.5	2.5	69
6	x		2.0	2.5	4.6	2.3	63
7	x		22.7	20.3	37.3	1.6	46
8	x		32.5	24.2	44.5	1.4	38
9	x		6.7	5.0	9.2	1.4	38
10	x		7.5	10.5	18.5	2.5	68
11	x		9.3	14.5	26.6	2.9	80



• Positions of fish. Numbers alongside indicate sequence of position determinations. Time intervals between positions are not necessarily equal.

——— Interpolated path of fish.

(- - -) Inexact position determination.

– – – Details of path not given.

Scale of maps with tracks is 1:19,430

Fig. 3. Movements of sockeye salmon in the Chatham Sound area determined by ultra-sonic tracking. The experimental fish were caught during their homing migration to Skeena and Mass River spawning grounds.

Table 7. Sonic tracking results of sockeye salmon intercepted during migration in Babine Lake, 1969. (night = civil twilight till civil twilight)

Track No.	Date	Origin fish	Place released	Tag freq. KH_z	Tag pulses. /sec	Time start	Time end	Duration track hrs	Distance track km	Average speed km/hr day	Average speed km/hr night	Tag recovery date	Tag recovery place	Sex
1	Jul 19	Babine Fence	Fort Babine	70	2.3	13.17 Jul 19	13.10 Jul 20	23.9	21.4	1.0	0.5	Aug 11	Twin Creek	♂ (5)
2	Jul 21	Babine Fence	Fort Babine	75	5.0	13.13 Jul 21	04.30 Jul 23	39.3	91.7	2.6	1.9	-	-	♂ (5)
3	Jul 28	Babine Fence	Fort Babine	75	2.6	10.00 Jul 28	09.47 Jul 29	23.8	20.3	1.1	0.3	Aug 29	Pierre Creek	♀ (4)
4	Jul 29	Morrison Fence	Halifax Camp	75	1.2	23.18 Jul 29	03.00 Jul 31	27.7	42.8	2.1	0.5	Jul 31 Ind.Net	Fort Babine	♂ (5)
5	Jul 31	Babine Fence	Fort Babine	75	1.2	08.51 Jul 31	21.51 Jul 31	13.0	19.4	1.4	-	Aug 29	Pierre Creek	♀
6	Aug 2	Morrison Fence	Old Fort	75	5.0	10.50 Aug 2	10.50 Aug 3	24.0	49.3	2.2	1.5	Aug 12	Pierre Creek	♂
7	Aug 4	9-Mile Creek	Old Fort	75	1.2	12.11 Aug 4	12.35 Aug 4	0.4	±1.6	-	-	heard Aug 10, caught Aug 12	9-Mile Creek	♂
8	Aug 4	9-Mile Creek	Old Fort	75	5.0	14.10 Aug 4	17.58 Aug 5	27.8	64.8	2.6	1.7	-	-	♂
9	Aug 7	9-Mile Creek	Old Fort	75	0.6	11.22 Aug 7	23.30 Aug 7	12.1	12.0	1.1	0.7	-	-	♂
10	Aug 9	Morrison Fence	Halifax Narrows	70	2.5	13.05 Aug 9	13.40 Aug 9	0.6	±1.6	-	-	-	-	?
11	Aug 9	Morrison Fence	Halifax Narrows	75	0.6	14.28 Aug 9	13.00 Aug 11	46.5	100.0	2.6	1.1	-	-	♂ ?
12	Aug 13	Halifax Narrows	Halifax Camp	75	1.2	09.40 Aug 13	12.00 Aug 15	50.3	73.1	1.9	0.6	-	-	♀
13	Aug 18	Morrison Fence	Old Fort	75	2.8	10.24 Aug 18	23.20 Aug 18	12.9	24.0	1.9	1.9	-	-	♂

Total 302.3 hrs - 522 kilometers

(a) Sockeye salmon released close to the place where they were caught perform better than ones that have been displaced some distance.

(b) Migration in the lake from outlet to spawning grounds occurs close to shore, as long as the shore runs in the migration direction.

(c) Migration in the lake occurs primarily during the day. During the night the salmon hardly moves, except when caught by darkness in the middle of the lake; it will then continue until it reaches shore again.

(d) Little difference has so far been found between migration during clear and overcast skies. Celestial cues therefore do not seem essential.

(e) Average speed of migration during the day for males ranges from 1.0 to 2.6 km/hr and for females from 1.1 to 1.9 km/hr. During the night males moved from 0.5 to 1.9 km/hr and females from 0.3 to 0.6 km/hr.

(f) Faster average speeds of migration were recorded in salt water in Chatham Sound by Drs. Horrall and Stasko (max. 3.6 km/hr) than in fresh water (max. 2.2 km/hr) in Babine Lake.

5. Sonar Observations

C. Groot and C. E. Turner

Detailed observations were made on sockeye smolt migration in Babine Lake during May and early June, 1969, using two Honeywell sea scanars. One unit was mounted on a barge and was used in combination with time-lapse photography to record horizontal movements of sockeye smolt schools. The 1,300 ft of movie film covering 165 hr of observations indicate that:

(a) Migration of sockeye smolts in the lake occurs primarily at dusk and dawn. Sometimes, however, movements are seen at other times of the day.

(b) Migration towards the outlet occurs with both clear and overcast skies.

(c) Directions of movement differ from day to day for as yet unknown reasons.

The second sonar unit was installed in a 19-ft cruiser and was used for regular high speed (20 knots) sounding surveys close to the sonar time-lapse photography observations. These surveys gave information on progress

of migration through the lake with time of season and on diel vertical movements. Results to date indicate that:

(a) Diel vertical movements of sockeye smolts range from the surface at dusk, dawn and night to about 40-50 ft depth during the day, which is much less than that found for juvenile sockeye during the fall.

(b) Migration early in the season in Morrison Arm and the main lake occurs primarily along the shores; later in the season fish are seen all across the lake.

(c) This following of shores leads sockeye smolts moving along the southeast shore of Morrison Arm into the main lake in a southward direction (opposite from the outlet). However, target concentrations do not proceed for more than 2 miles in this wrong direction, indicating that either the fish turn back or disperse. On the north side of Morrison Arm target concentrations indicative of sockeye smolts continued around Old Fort Village into the North Arm.

(d) In the main lake sockeye smolt target concentrations were first seen along the east shore. Available information strongly suggests that many of these fish must have ended up in Morrison Arm. It was impossible to determine if these smolts were able to get out again. Target concentrations in Morrison Arm stayed very high until the end of the season. This may be the result of (1) main lake fish not being able to get out, (2) local kokanee populations, and (3) increase in zooplankters towards the end of the season. Target concentrations along the west shore of the main lake moved into the North Arm without difficulty.

GENETICS

J. Calaprice

This investigation is primarily concerned with the heritable component of the population biology of marine organisms. Samples of mature male and female salmonids collected from different streams and areas within streams have been crossed and reared under uniform conditions. The progeny from these crosses are examined periodically and the resulting patterns of survival, growth, and behaviour is being used to determine genetic and environmental variation among and within populations.

6. Continuing Studies

The analysis of crosses made between samples of sockeye from different streams in the Babine Lake system continues. Several computer programs were written to facilitate the analysis. Polyallele analysis of survival data demonstrates the overshadowing importance of heritable factors in determining survival of fish under optimum conditions. Of the heritable factors studied, maternal effects account for as much as 80% of early mortality. Regression analysis of historical data in the Babine system suggests that parasitic load (Philonema) of the female is associated with mortality in the experiments. Statistical isolation of key environmental factors continues.

One of the sockeye streams compared is in the Morrison Lake system. Tagging studies at a temporary fence in the Morrison River were conducted in 1969-70 to determine the probable origin of samples used in the 1967-68, 1968-69 crossing study.

Pink salmon crosses from the Salmon River which were buried in the stream at Rosewall Creek in 1968 were transported to the Rosewall culture facility in the spring. Traps were mounted on the boxes which held crosses, and the fry were analyzed and marked after emerging from the gravel. 120 different groups were marked and are now being reared in salt water at Nanaimo.

7. Facets Completed

(a) Marking Methods

A method of tagging small organisms was developed to mark young salmonids. Chemical elements either foreign to the organism or normally present in trace quantities were suspended in silicone rubber and injected in the tissue in liquid form. The silicone rubber solidifies and appears to bind the chemicals in an innocuous form, whereupon the foreign body is encapsulated by the organism. The analytical technique of X-ray fluorescence spectroscopy is used to detect and measure the chemical elements in the tissue by non-destructive analysis. Mixtures of element either in equal or varying concentration are used to generate a code. Decoding is readily accomplished by irradiating the tagged organisms and monitoring the X-ray fluorescence produced. Using this technique, as many as 2^{25} or 4^{25} different combinations or tags are recognizable. Tags as small as 1 mm^3 are easily decoded in the tissue (Calaprice and Calaprice, 1970).

Analysis of natural micro-chemical constituents of coho smolts from six different streams in B.C. and sockeye smolts from five lake systems in B.C. and Alaska, demonstrated the likelihood of a form of collective natural tag. Discrimination analysis of the X-ray fluorescent patterns of specimens provided a means of identifying the area of origin of individuals with less than 1% error. (Manuscript is in final draft form.)

(b) Culture Facilities

The design and construction of rearing facilities for the genetics program has been completed at Rosewall. The 600 tank and incubator assemblies are arranged in four banks, each of which may receive water pumped from beneath the creek bed or from a well. The facilities as designed will accommodate a pollyallele analysis. The small tanks allow holding of crosses for a limited time, during which crosses may be marked, combined, and transferred to larger rearing facilities. Tests conducted during 1967-70 demonstrated the reliability of the physical plant. The incubators were modified to prevent trapping of air bubbles, a suspected cause of the mortality experienced.

(c) Data Acquisition System

Biometrical genetic data collected are processed by computers. Observations are usually written down, converted to IBM cards, and then checked for transcription errors before processing. Means of identifying marked organisms and accumulating data on growth and behaviour electronically and in a form which could be read directly by computers were designed in 1967-68. The equipment is now operational. An electronic measuring device has been described (Calaprice and Ford, 1969) and a description of the complete system is now in the final stages.

MICROBIOLOGY

8. Bacterial Flora of Stream-Incubating Salmon Eggs — G. R. Bell and G. E. Hoskins

Most of the year - to September - was spent on sabbatical leave at the Torry Research Station and Unilever Research Laboratories in Aberdeen, Scotland studying methods for the cultivation, identification and classification of common aquatic bacteria. Our cultures isolated from stream-incubating salmon eggs and streams themselves were subjected to the diagnostic methods used at Torry - including electron microscopy - and their probable identity determined. Further attempts to discover which, if any, bacteria are pathogenic to salmon eggs are considered fruitless because of presently insurmountable technical difficulties. Experimental work on egg microbiology has therefore been terminated and a manuscript concerning this investigation is being completed for publication. Tentatively, our results suggest that there are no obligate or primary bacterial pathogens of salmon eggs but that bacterial invasions probably follow debilitation of the egg by physical and chemical factors.

9. Whitefish Mortalities, Kootenay Lake

G. R. Bell and C. E. Hoskins

A short time was spent in investigating the cause of mass mortalities of whitefish in Kootenay Lake. There were no characteristic symptoms associated with the mortalities but the kidneys and heart were most frequently judged abnormal. Kidneys were liquified whereas hearts showed extensive fatty invasions and coatings. The etiological agent did not appear to be either microbiological or viral. (The Western Fish Disease Laboratory, Seattle, kindly tested for viruses.) Although pollution cannot be ruled out as a possible cause, it doesn't seem likely. A report of the investigation has been prepared and submitted to the B.C. Fish and Game Branch on whose behalf the work was undertaken.

10. Immunization against Bacterial Kidney Disease

T.P.T. Evelyn

In vitro tests with sockeye salmon (Oncorhynchus nerka) suggest that long-term protection against bacterial kidney disease may be obtained following a single intraperitoneal injection of heat-killed pathogen suspended in adjuvant. All fish so treated produced sera containing elevated levels of an antibody which agglutinated the pathogen. The response appeared to be specific for the kidney disease bacterium and the agglutinating protein fraction in the serum has been identified.

The magnitude of the antibody response varied among individual fish, but the average antibody titre three months post-treatment was 280 times that of the adjuvant-treated controls; by 15 months after treatment, the average antibody titre had decreased, but it still was 50 times that of the controls. These antibody levels compare favourably with those obtained by workers using different pathogens and other species of fish. It now remains to be determined whether the in vitro results do, in fact, indicate increased resistance to kidney disease. To this end, fish are now being challenged (by injection) with living pathogen (this pathogen injection appears to be the only method of obtaining uniform infections).

11. Diagnostic Services

T.P.T. Evelyn

During the year, diagnostic services were again provided on request. Three of the more serious disease outbreaks diagnosed are listed and the pathogens involved have been added to our culture collection.

(a) Furunculosis

The causative bacterium, Aeromonas salmonicida, was obtained in pure culture from juvenile and brood stock rainbow trout (Salmo gairdnerii) cultured at the Abbotsford Fish Hatchery. Mortalities were first observed in late May when the water temperature was 10 C.

(b) Vibriosis

The causative becterium, Vibrio anguillarum was identified after extensive diagnostic testing. It was isolated in pure culture from chinook (Oncorhynchus tshawytscha) and pink salmon (O. gorbuscha). These fish were being held in Fisheries Research Board fish culture facilities at West Vancouver. Peak mortalities occurred in September when water temperatures were 12-14 C.

(c) Myxobacterial Disease

Acute mortalities in juvenile chum salmon (O. keta) and chum-pink hybrids held in fresh water (10-12 C) at this Station were attributed to an unidentified species of myxobacterium. The micro-organism was isolated in pure culture from the kidneys and external lesions of the various specimens examined. Replicate stocks of these fish in sea water were not affected.

PARASITOLOGY — L. Margolis

Parasitological studies continue to be related to two overall objectives: (1) to determine the effects of parasitism, i.e., disease caused by parasitic organisms, on wild and cultured fishes; (2) to identify and differentiate fish stocks (particularly salmon) in ocean areas of mixing, by means of parasite tags. To achieve these general objectives it is necessary to acquire knowledge on the distribution, abundance, ecology, taxonomy, life histories, and general biology of parasites of aquatic animals on the west coast of Canada.

Accomplishments in individual projects are reported below.

12. Salmon Stock Identification

L. Margolis and T. McDonald

(a) Myxobolus neurobius

Preliminary studies on the distribution among North American sockeye salmon stocks of this myxosporidian (Protozoa) parasite of the hindbrain and anterior portion of the nerve cord demonstrated that it occurs more frequently and more abundantly in some stocks than in others. More than 75% of the sockeye sampled from Rivers Inlet, B. C. (50 smolts and 25 adults) and Auke Creek, Southeast Alaska (50 smolts) were infected with M. neurobius, whereas in 50 smolts sampled from each of Babine Lake (Skeena River) and Chilko River (Fraser River system),B. C., 10 and 20, respectively, were found to be infected. In the Babine and Chilko fish the intensity of infection was much lighter than in the Rivers Inlet or Auke Creek fish. In the latter, more than 10 spores were observed per vertical scan of wet mount slide preparations (18 mm square coverslip) when examined with a phase contrast microscope at 240X or 250X. In the Chilko smolts the number of spores per vertical scan was less than 0.22. These preliminary results are sufficiently encouraging to warrant extending the sampling to other areas to determine the usefulness of this parasite as a stock discriminant, particularly when used in combination with other stock discriminating characteristics.

(b) Diphyllobothrium Larva

Previously obtained results on the geographic distribution of this tapeworm larva in sockeye salmon stocks revealed that it was absent or scarce in a limited number of samples available from Southeastern Alaska but was consistently common in the Babine Lake (Skeena River) stocks in northern British Columbia. Diphyllobothrium is therefore potentially useful as a natural tag to distinguish northern B. C. sockeye from Southeastern Alaska sockeye and to determine rates of intermingling in coastal areas adjacent to northern B. C. and Southeast Alaska. Repeated attempts to obtain additional samples from Southeast Alaska have been unsuccessful. A sample of 105 smolts obtained in 1969 from a Canadian tributary (Klukshu River, Yukon Territory) of the Alsek River, which drains into the sea in northern Southeast Alaska, was free of Diphyllobothrium.

13. Parasite-caused Disease

Z. Kabata

(a) Effects of Phrixocephalus (Parasitic in the Eye) on the Population of Atherestes stomias

A 5-day cruise on board the G.B. Reed in May 1969 served to collect further data on the infection of the arrow-toothed flounder, Atherestes stomias, with the eye parasite, Phrixocephalus cincinnatus. More than 2,000 fish were examined with the following results: the host population was 18% infected; of the infected fish, 89.24% had the parasite in the right eye only, 6.72% in the left eye only, and 4.03% in both eyes. These findings bear out the facts reported on in a paper on this parasite, published in April 1969. It has also been confirmed that the infection leads to the complete destruction of the infected eye.

Examination of the stomach contents of both infected and uninfected fish produced results tabulated below (figures in per cent).

Stomach content	Infected	Uninfected
Vertebrates only	11.2	10.8
Invertebrates only	73.3	76.3
Mixed diet	15.5	12.8

It became clear that the loss of sight in one eye constituted no great impediment to the normal feeding of the host. While it seems equally clear that complete blindness leads to the rapid removal of the affected fish from the population, the number of fishes so affected is quite small (4% of 18% or 15 fish from the examined population of 2,068). It can be assumed therefore that the instances of total blindness caused by Phrixocephalus are few. Under the circumstances the parasite cannot be considered a serious danger to the population, or to exert a significant influence on its dynamics. For this reason, it has been decided to terminate this study. The data collected to date are now being prepared for publication.

(b) Investigation of the Biology of Salmincola Parasitic on the Gills and External Surfaces of Oncorhynchus

The progress was hampered by the deficiency in the facilities, concomitant with the major construction in progress on the campus during the period under report. A stock of about 100 smolts from Cultus Lake was used as the source of Salmincola. Most of the parasites were attached to the gills or to the inner surface of the operculum, so that direct observation was possible only when the operculum with the parasite was severed and placed in a specially designed observation chamber under the dissection microscope.

The most significant point discovered by direct observation was the fact that Salmincola appeared to feed selectively on the blood of its host. Parasites attached to relatively sparsely vascularized areas of the operculum very often had their intestinal tracts gorged with blood. This is in contrast to the prevailing views on the feeding methods of Salmincola, believed to be a surface browser. Should it be confirmed that blood is the preferred diet of Salmincola, its potentially harmful character will become much more serious.

The study concentrated on the gut of the parasite. The rate and the type of peristaltic movements were recorded with the aid of a tape recorder. The morphology and the anatomy of the gut were examined. It was discovered that the peristaltic movements are assisted by, and synchronized with, a pair of extrinsic muscles that run in narrow horizontal bands between the lateral walls of the intestine and the trunk walls, between the uterine folds.

Some preliminary observations were also made on the movements of the antennae and the mouth-parts of Salmincola. These observations, however, call for further work.

The results of this study are now being written up for publication.

14. General Studies

(a) Parasitic Copepod Fauna Z. Kabata

The collection of the parasitic copepods made during 1968 was augmented during the May cruise of the G.B. Reed. Some additional material was obtained also from outside sources (Dr. Templeman, St. John's, Newfoundland; Dr. Holmes, Edmonton; Mr. MacKenzie, Aberdeen, Scotland). The material contained nine species of the family Lernaeopodidae and these were selected to be the subject of a separate report. One species (Schistobrachia tertia) proved

to be new to science. Two species were new to the Canadian fauna (Dendrapta cameroni longiclavata and Lernaeopodina pacifica), both of them known to occur on the Asian side of the Pacific. Of particular importance was the study of the material of Brachiella robusta, known in the local waters since 1912. The species showed a degree of morphological polymorphism hitherto unknown in the family Lernaeopodidae and likely to call for extensive revision of our views on the taxonomy of the entire family. The report is now being prepared for the press.

One species belonging to the family Chondracanthidae was discovered in the nasal capsules of the lingcod, Ophiodon elongatus. This is the first record of a member of this family inhabiting such a confined space. In view of its large size (adult females over 1 cm long), the parasite might be harmful to its host. A description of the parasite was published in November 1969.

One short paper was published on a new family of parasitic Copepoda from the Canadian Atlantic and another one, on three species of copepods infecting fishes of the genus Lepidion, is now at the proof stage.

(b) In vitro Culture of Anisakis Larvae (Nematoda) — N. Boyce, L. Margolis and T. McDonald

Larval nematodes of the genus Anisakis commonly occur in marine fishes. In countries where raw fishes regularly form a part of the diet of man, an acute abdominal syndrome is caused by infection with Anisakis larvae. Attempts have been made to rear Anisakis larvae from British Columbia fish to the adult stage to permit their specific identification.

Anisakis larvae obtained from the viscera of herring were reared in modified standard Medium 199 at 36 C. The worms freed themselves of their membranous sheath within two hours, and moulting occurred on the fifth and sixth day of the experiment. A second moult was not achieved, although some worms survived up to 28 days in culture, during which time they increased in size considerably. A medium consisting mainly of a pepsin digest of beef liver produced results similar to those mentioned above.

Worms kept in physiological saline at 36 C exsheathed successfully in two hours, and survived up to 18 days but did not moult.

It was demonstrated that temperatures approximating mammalian body temperature are necessary for the moulting of these larvae. Adult Anisakis occur in various piscivorous marine mammals.

It appears that at least one more moult is required before the worms reach adulthood. Further work on Anisakis culture is suspended for the present.

(c) Parasites acquired by Salmonidae in Fresh Water in Japan — N. Boyce

As part of the scientist exchange program between the Japanese Fisheries Agency and the Fisheries Research Board, a study of the parasites of Japanese salmonids was carried out in 1969. Salmonidae from 49 freshwater localities in the islands of Hokkaido and Honshu were sampled during the months February to October, 1969. Non-salmonid species were also sampled, when available, to examine specificity and other parasite-host relationships.

Specific identification of the parasites obtained from Salmonidae is in progress.

PHYSIOLOGICAL ECOLOGY

15. Models for Prediction of Environmental Effects — J.K. Lindsey, J.A. Thomson, Arlene Sandnes and D.F. Alderdice

Laboratory evaluation of the effects of combinations of environmental variables on biological responses has led to the development of two programs based on non-linear response surface methodology. These programs, extensions of earlier versions, will handle four replicates of up to 99 sets of observations with either two (BOX 2) or three (BOX 3) environmental variables. They are designed for use on a 16K IBM 1130 computer with 1627 plotter attached. Computations based on analogous linear models are also provided, and the plausibility of the linear model is compared with that of the non-linear model by likelihood inference.

16. Effects of Acclimation and Acute Temperature Experience on Swimming Speeds of Juvenile Coho Salmon — J.S. Griffiths, D.F. Alderdice & F.P.J. Velsen

Critical swimming speeds of juvenile coho salmon between 7-1/2 and 9-1/2 cm total length have been determined at 3 C intervals over a field of acclimation temperatures (2 to 23 C) and test (acute) temperatures (2 to 26 C).

Regression of critical swimming speed on acclimation and test temperatures was computed by response surface analysis using a non-linear second degree polynomial as a model.

Maximum performance (5.8 lengths/second) occurred at acclimation and test temperatures near 20 C. At lower acclimation temperatures maximum

performance was found to occur at temperatures greater than those of acclimation, defining a ridge of near-maximum performance (Fig. 4). Thus, maximum performance over a range of test temperatures is not necessarily found at a test temperature equal to that of acclimation. In addition, maximum performance over a range of acclimation temperatures is not necessarily found at an acclimation temperature equal to that of testing. This lack of correspondence over the performance surface changes progressively, attenuating at acclimation and test temperatures in the vicinity of 20 C.

Comparison of performance of the coho with that of the sockeye juvenile suggests that the former is better able to perform in warm environments. In line with other laboratory and field findings the results suggest that the juvenile coho in a lucustrine environment may feed more effectively in the warmer surface layers while spending the greater portion of its time at deeper, colder temperatures to which it is largely acclimated.

17. Embryonic Development of the Flathead Sole — D.F. Alderdice, C.R. Forrester and F.P.J. Velsen

Studies on the incubation of eggs of the flathead sole (Hippoglossoides elassodon) were completed in 1969. Fourteen tests were conducted at 13 different combinations of salinity and temperatures between 10.42 and 39.58‰ S, and 3.36 and 10.65 C. Data were obtained on rate of development, total hatch, viable hatch and larval size at hatching.

Preliminary analysis indicates that total hatch, viable hatch and larval size would be maximized were eggs to be incubated at salinities near 30‰ and temperatures between 7 and 8-1/2 C. Nevertheless, appreciable hatches were obtained under all incubation conditions (average total hatch, 75%). Flathead sole eggs are both euryhaline and eurythermal.

Temperature compensation appears to occur in the flathead sole egg. At low temperatures small larvae hatch, apparently prematurely, with a comparatively large portion of the yolk sac contents unutilized. The opposite is the case at high temperatures. Nevertheless, low or high temperature larvae attain approximately the same total length when held to exhaustion of the yolk at their appropriate incubation temperatures.

PHYSIOLOGY — J.R. Brett, D.B. Sutherland and G.D. Heritage

18. Metabolic Rates

Energetic comparisons. Two efforts have been made to determine whether the method of measuring oxygen consumption (indirect calorimetry)

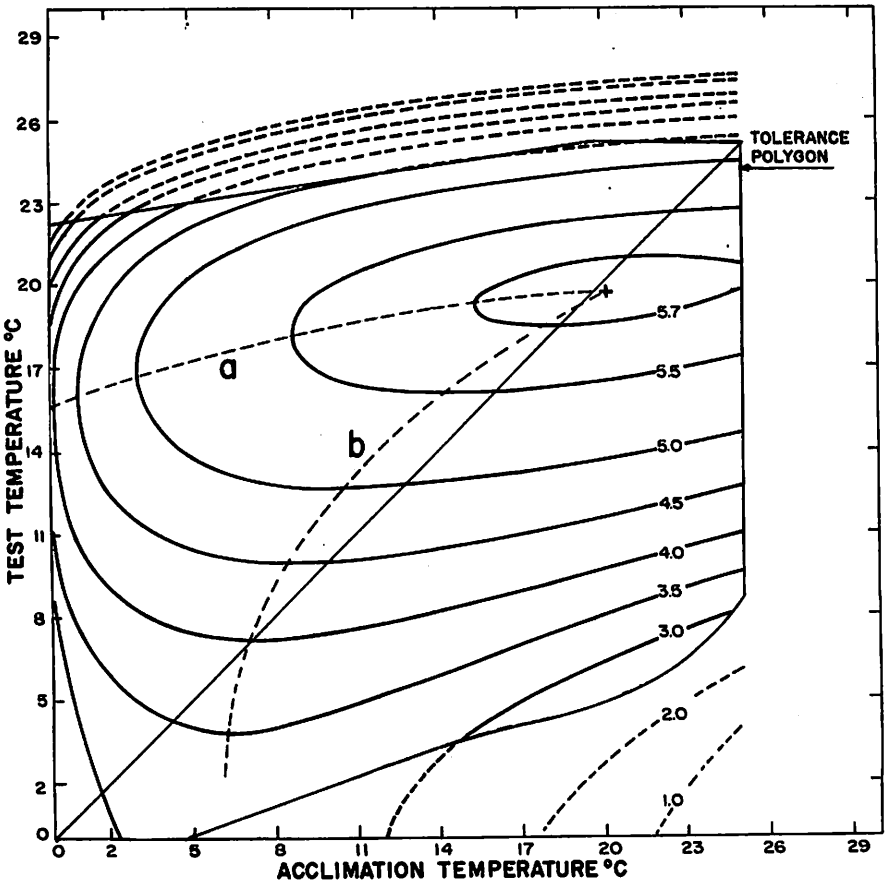


Fig. 4. Swimming speeds of juvenile coho salmon (lengths/second).

gives a reliable estimate of the absolute energy expended or heat produced (direct calorimetry).

The first of these involved exercising adult salmon by forced swimming (2 m.p.h. for approximately 14 days = 560 miles) and comparing the body composition. There was close agreement between the energy-expended calculations (derived from the decrease in body constituents) and from the swimming speed equivalents.

The second effort was conducted in the Mk I respirometer using young sockeye (19.5 cm; 74.5 g) which were forced to swim for 17.3 days (Feb. 16 to Mar. 5, 1965). An error in the way in which the proximate analyses were performed reduced the value of the results to such an extent that no final assessment was attempted.

A recent critical review by Krueger et al., 1968, on "Bioenergetics, exercise and fatty acids of fish", Am. Zool., 8: 119-129, has shown an apparently large discrepancy between energy expenditures derived from measures of O_2-consumption and changes in body constituents. Hence, another close examination of this problem was required. A repetition of the 1965 experiments with young salmon in the Mk I respirometer was performed with a view to comparing estimates of energy expenditures by (1) total oxygen consumption, (2) change in body composition, (3) decrease in calorific content, (4) defined equivalents from swimming speed requirements.

A sample of 50 highly uniform fish was selected. These were subsequently divided into 5 groups by random numbers immediately before the experiment started. One group of 10 was lightly anaesthetized, measured and weighed, and then put in the respirometer. Each of the other 4 groups of 10 was treated similarly for comparison, then killed and re-weighed after more careful drying, and stored in deepfreeze.

Results. The respirometer group was successfully exercised for 19 days. Five days elapsed before the first value for the O_2-consumption rate fell within the expected values from previous extensive studies. This prompted a subsequent experiment on the metabolic rate of the stock being tested. Confirmation for the 1964 published values was obtained.

The exercised fish lost 2.03 g wet weight per fish. From proximate analyses the energy expended from utilization of fat was 3.50 kcal/fish and that from protein was 2.35 kcal/fish, a total of 5.85 kcal/fish.

Final comparisons between the systems for determining energy expenditure have yet to be computed.

Feeding effect. By pooling all the data on metabolic rates of feeding sockeye (at 10 , 15 , 20 C) and applying the ratio of values obtained on non-feeding fish for 5 and 23 C, isopleths were constructed for metabolic rates accompanying any positive growth rate of yearling sockeye (maximum = 1.4% body wt/day) in relation to acclimation temperature. These form a provisionary

predictive model, the first such non-deductive model available. It provides the basis for an efficient 3 × 4 factorial experiment designed to establish the confidence limits.

19. Feeding Studies

Within the genetic potential of any species to grow there are many factors both abiotic and biotic which limit maximum growth. The daily rate at which food can be consumed is a prime factor. This in turn is related to the time to satiation, the development of appetite and the capacity of the stomach. A study of these biotic factors was performed on three sizes of sockeye (average of 1.9, 26 and 236 g) fed on Abernathy pellets at 15 C.

Satiation time. Voluntary food intake was determined by catching and weighing the uneaten food from pre-weighed samples introduced at 2-minute intervals. Mean satiation time was found to be 43 ± 8 minutes (S.D.), independent of size.

Appetite. Voluntary food intake increased in a sigmoid pattern with time, approaching a plateau (full appetite) in the region of 25 to 30 hours. When compared to the progress of gastric digestion there was an obvious delay in the development of appetite during the first 6 hours. The greatest increase occurred between 7 and 11 hours deprivation time when the stomach contents were respectively 75% and 90% digested.

Maximum food intake. The amount of food in a full stomach varied from 3 to 13% of body weight among the small fish, and 1 to 5% among the large fish. The relation between stomach contents and fish weight was found to be exponential. When Y = the contents as percent body weight and X = weight in grams, the relation was $Y = 14.1 - 4.95 \log_{10} X$. The predicted stomach capacity for a 1 g sockeye (early lake-resident fry) is approximately 14%.

It was apparent that the smaller fish have an enhanced ability to consume more food than the larger fish, not only at a single meal but to a greater extent as multiple daily meals.

20. Growth Studies

Food quality. Experiments on growth have been performed using prepared foods (Station wet mix, Abernathy moist pellet, Clark's dry pellet). It was of interest to know how some of these compare, and to what extent they match or exceed typical natural foods (zooplankton, fish) so that greater interpretative value might be applied to existing data.

The following diets were selected for feeding to yearling sockeye (25-30 g), using ration levels of 4% and 8% dry body weight/day: (1) frozen marine zooplankton, reinforced with vitamin pack, (2) fresh-killed sockeye fingerlings, made up into a mash, (3) Abernathy moist pellets, (4) Halver's test diet (casein, dextrin, gelatin, corn oil, vitamin and mineral mix), and (5) Clark's dry pellets.

Preliminary analysis indicates that greatest growth was obtained with Halver's test diet (rate = 1.97% per day). For the 6-week period of study no statistical difference occurred between the two pelleted feeds (Clark's = 1.79% and Abernathy = 1.67%). Growth on the sockeye mash was significantly less (1.39% per day) and the marine zooplankton distincly less (0.42% per day). The latter was partly due to a large moisture fraction which, together with indigestible chitin, presented bulk without corresponding calories. An increase in the amount of marine zooplankton presented, from 8% to 12% per day, induced a change in growth rate to 1.2% per day which was still quite significantly below the pelleted feeds.

It would appear that well-constituted artificial diets exceed natural diets when fed in equal proportions. There may be an appetite stimulating feature of natural diets which would result in improved growth when unlimited opportunity to feed was present. The question of applicability of the results with artificial foods is far from the case of lagging behind natural foods, but rather a reverse of this possibility.

Environmental manipulation. The discovery that there were unique combinations of ration and temperature which would produce either maximum growth or maximum conversion efficiency depending on appropriate definable levels prompted the development of multi-environmental controlled tanks. Although lacking supporting evidence on growth response for the optimum levels of the additional environmental factors chosen, judicious selection was possible from knowledge of metabolic rates and general growth phenomena.

The following factors and levels were selected for use in two tanks:

(1) Temperature - 14.5 C in A tank, and 11.5 C in B tank.

(2) Ration - excess in A tank, and 4% of body weight in B tank.

(3) Salinity - 10‰ (isotonic - equivalent to blood concentration).

(4) Photoperiod - 16-hr day (equivalent to long, spring days).

(5) Velocity - less than 0.5 ft/sec (lazy swimming rate).

(6) Numbers - 250 at start (uncrowded).

The levels selected for temperature and ration were from experiments conducted in fresh water, mostly on natural photoperiod in the fall season. They represent the combined conditions which result in maximum growth (A) and maximum food conversion efficiency (B).

These optimum environmental and dietary conditions induced rapid growth of yearling sockeye salmon which almost doubled their weight every month during a 2-1/2-month test period (22 to 110 g). By ration control, food conversion efficiencies of 25-30% were obtained, using a supplemented fish-meal diet.

The increase in maximum growth rate (1.4 to 2.4% per day) over the previous maximum demonstrates the potential inherent in environmental control as a means of enhancing production. If it were possible to maintain this high rate for approximately twice the test time, a weight of 1 lb would result (450 g by December 19, 21 weeks). Although growth rate must inevitably decrease with age, at a young stage it may well be possible to maintain such a growth stanza long enough to achieve this size in such a relatively short time.

ENVIRONMENTAL RESEARCH GROUP

T. R. Parsons

The Environmental Research Group was formed in August 1969. Since this was in the middle of the 1969-70 fiscal year, no attempt was made at that time to organize the internal structure of the group. Investigations which were put into the group consisted of 9 persons from Biological Oceanography and 13 from the Anadromous Fishes Group; the latter was subdivided into Lacustrine Ecology, Predator-Prey Relationships, Stream Ecology, Coho Biology, and Eggs and Alevins. While retaining certain aspects of these existing studies the overall structure of the group has now been formulated along lines which permit (1) a comprehensive coverage of the aquatic environment, and (2) flexibility in the assignment of personnel within the group. The 3 areas in which research will be carried out by the group are as follows:

Natural Environments

Environmental Enhancement

Environmental Deterioration

In order to meet contemporary research needs, the following research projects are included under the above headings for the purposes of this report:

Natural Environments:	1. Biological Oceanography
	2. Fisheries Oceanography
	3. Stream Ecology
	4. Ecology and Production of Freshwater Fishes
	5. Predator-Prey Relationships
	6. Burke Channel Studies
	7. Lacustrine Ecology
	8. Babine River Sports Fishing
Environmental Enhancement:	9. Eggs and Alevins
	10. Lake Fertilization
Environmental Deterioration:	11. Estuarine Pollution
	12. Logging and Stream Ecology

During 1969 the major project in biological oceanography was the trans-Pacific crossing on CNAV Endeavour, Esquimalt to Tokyo and Hakodate to Esquimalt, during the period March to May. Several reports have been published on the subject of this cruise and all data collected will appear in early 1970. As a follow-up to this project, data are being collected from American Mail Line vessels as part of a cooperative program between the University of Washington and the Fisheries Research Board, Nanaimo.

Further reporting on the results of the Strait of Georgia program was carried out through 1969. A summary is currently in preparation showing base line concentrations of nutrients, levels of particulate materials and plankton, together with the timing and occurrence of larval and juvenile fish in the study area.

A number of projects in Fisheries Oceanography are currently being terminated and reports submitted for publication. These include work on the distribution of larval herring in the vicinity of the Fraser River plume, food chains in the subarctic North Pacific and migration and distribution of fur seals. Work on assessing the oceanic environment from data on water transport has continued and a 2° grid of calculated water movements has been developed for coastal waters.

An extensive study on the diel drift of invertebrates in a small creek and its relation to the diet of coho fry is near completion. This study forms part of a larger program on stream ecology which includes observations on stream pollution. A study on the specific effects of logging in relation to salmon nursery streams has commenced as a new study. Another freshwater program has been concerned with species interaction between coho salmon and cutthroat trout. This study has shown that while the two species may live in the same environment they make different use of the food and space available.

Optimization of salmon hatchery conditions and field evaluation of these methods has continued through 1969; preliminary analyses of experiments carried out from 1968 to 1969 has indicated that, under test conditions, 90 to 95% survival from egg to fry can be obtained at egg densities of 2,000 per square foot.

A program in lake fertilization was started in 1969 with a study of the natural level of nutrients, plankton and the size of sockeye smolts in Great Central Lake, Vancouver Island. From a comparison of these data with data from other lakes it appears that Great Central Lake is ultra-oligotrophic and that there is a strong probability that sockeye smolts are limited in their size by the quantity of food available.

Reporting on factors governing the growth and mortality of pink salmon during early sea life as observed in Burke Channel has continued. Data on predator-prey relationships will continue to be collected as part of this program but all field data collections in the area of Burke Channel have terminated. Efforts previously employed in this program have been largely transferred to a new program on Estuarine Pollution which commenced in the latter part of the 1969 fiscal year. This program is centered in the Alberni Inlet and is primarily concerned with obtaining a definition, in biological terms, of a historically polluted inlet.

NATURAL ENVIRONMENTS

1. Biological Oceanography

T. R. Parsons, R. J. LeBrasseur, C. D. McAllister, W. P. Wickett and W. E. Barraclough

(a) North Pacific Ocean

During the past two years a cooperative program has been developed for the study of production processes in the subarctic North Pacific Ocean. The program is expected to last for an initial period of five years. The primary purpose is to examine components of oceanic variability which may affect commercial fisheries (e.g. high seas salmon mortality) and further to assess the productivity and diversity of organisms having potential value as a food resource for man. The principal agencies in this cooperative program are the Fisheries Research Board of Canada, Nanaimo, and the Department of Oceanography, University of Washington, Seattle.

In order to carry out this study, it was necessary to collect data over very large ocean areas. To this end, it was proposed that maximum use be made of observational platforms which regularly cover the North Pacific, such as weatherships (e.g. Station P), commercial vessels and satellites. In addition, however, it was considered necessary that a research vessel should be occasionally employed in this program in order to evaluate the large amount of data collected from established platforms. For this purpose a trans-Pacific cruise of CNAV Endeavour was carried out during March to May, 1969, with the primary purpose of investigating the waters of the subarctic Pacific, to examine plankton, small fish and other animals which form the primary food of secondary carnivores, including salmon, and to compare the results with theoretical predictions of biological productivity based on data collected from commercial vessels, weatherships and satellites.

The cruise track of the Endeavour (Fig. 5) was designed to follow the approximate route of American Mail Line vessels travelling on a great circle route, from Seattle to Yokohama. The cruise was timed to coincide with the onset of the spring plankton bloom in the subarctic Pacific. Surface sampling included continuous underway monitoring of nutrients, carbon dioxide, pH, chlorophyll, turbidity, temperature, salinity, zooplankton and solar radiation. In addition, depth profiles for plankton, nutrients and small fish were taken each day, for a total of 39 stations.

Data obtained from the continuous monitoring program, representing a coverage of approximately 8,000 miles of ocean surface, have shown the degree of both small- and large-scale variability in the nutrient structure of the subarctic Pacific. Long-term variations in these parameters, as measured from commercial vessels, will be used to assess time/space changes in the environment of the subarctic Pacific.

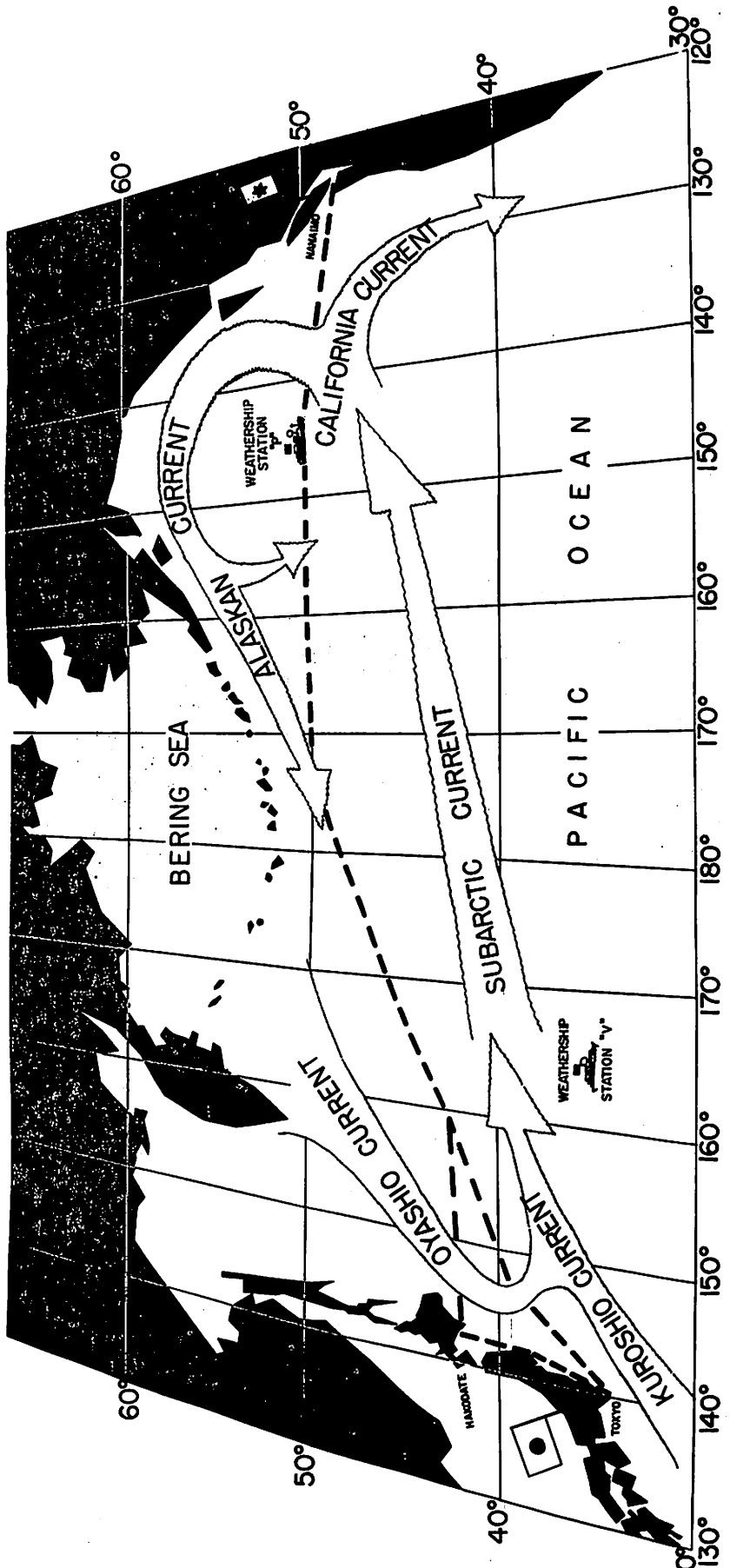


Fig. 5. Cruise track of CNAV Endeavour during trans-Pacific cruise, March to May, 1969.

Primary productivity measurements throughout the subarctic Pacific have been collected by commercial vessels and evaluated in the light of the more detailed studies conducted during the cruise of CNAV Endeavour. Data show that productivity in the spring is depressed in the vicinity of the Alaskan and Western Gyres, but that along the coast of North America, in the vicinity of the Aleutian Islands and off the coast of Japan, production increases steadily from February/March through June. Another significant aspect of the data is that the western subarctic Pacific is shown to be appreciably more productive than the eastern subarctic. Thus the average primary production for six months at longitudes east was 600 mg C/m^2/day compared with the average, throughout the same period for longitudes west, of 310 mg C/m^2/day.

Traces obtained from a 200 KHz (Furuno) echo sounder revealed the presence of an ocean-wide shallow scattering layer. This layer varied in intensity but was seldom absent. Detailed sampling using a Longhurst recorder showed that the layer was composed of a large marine copepod, Calanus cristatus at concentrations far exceeding any previously reported. This finding is both scientifically and economically significant. From a scientific point of view it is known that the amount of food a fish can acquire is related to the concentration of forage organisms and to their degree of aggregation or "patchiness". In previous studies of ocean environments, only prey concentrations have been measured, since patchiness is generally difficult to evaluate. With the use of the 200 KHz sounder, however, patchiness has been shown to be readily measurable, thus permitting a better interpretation of plankton data with respect to fisheries. Furthermore, the finding should stimulate a reappraisal of the possible direct utilization of plankton as a commercial source of protein and oil.

Food organisms of secondary carnivores (e.g. salmon) and plankton which were collected during the cruise of CNAV Endeavour are being identified by various agencies as follows: shrimp - Oregon State University; squid - University of Victoria; zooplankton - Fisheries Research Board, Nanaimo; phytoplankton - University of British Columbia; fish - National Museum, Ottawa, and Fisheries Research Board, Nanaimo.

In conclusion, the principal objective of the trans-Pacific cruise of CNAV Endeavour is being realized through analysis and comparison of the data with those collected by commercial vessels. The application of certain mathematical models to descriptions of production processes in the North Pacific has been found practical, and it is expected that some understanding of long-term changes in the oceanic environment of the subarctic Pacific will be achieved through the continuing program of observations from weatherships and commercial vessels. In addition, new information obtained on the trans-Pacific cruise will be utilized to modify mathematical representations of environmental processes. Finally, the cruise served to demonstrate that sophisticated experimental equipment could be operated under difficult conditions at sea, and this should encourage future wide-spread use of such instrumentation, especially in commercial vessels.

(b) Strait of Georgia Program

The collection of field data for the Strait of Georgia program was terminated in 1968, but work on writing up and interpreting the results was carried out through 1969 and will continue in 1970. To date, the principal findings of this program are:

(1) In the pelagic environment of the Strait, there are two basic food chains: the one is initiated by the growth of nanoplankton, which support the growth of microzooplankton and small fish, including larvae; the second is initiated by the growth of much larger phytoplankton, which support the growth of macrozooplankton and juvenile fish. Of these two food chains, the second generally predominates during the spring and summer due to the very high stability of the waters of the Strait.

(2) The annual input of terrigenous organic material from rivers entering the Strait is approximately equivalent to the primary production of organic carbon by phytoplankton. However, the utilization of this allochthonous material, through a bacterial cycle to the formation of particulate organic material capable of supporting animal growth, is only at the most 30% as efficient as the direct utilization of phytoplankton.

(3) The growth of young chum salmon was shown to be directly proportional to the quantity of food made available, and a positive selectivity of chum salmon towards large zooplankton prey was established.

(4) Biological base lines describing the pelagic environment of the Strait of Georgia in terms of nutrients, primary and secondary production, particulate material, transparency and variations by area and season in these and other parameters have been established. From these data it is apparent that beyond local effects, the Strait of Georgia is not a polluted environment when assessed in terms of the parameters given above.

(5) Miscellaneous discoveries which were made during the course of this program include descriptions of the infection of copepods by yeasts; the further identification of a common red-tide organism; the transport of terrigenous material into the marine environment and its role in the food chain of the sea; bacterial cycles in marine and estuarine environments.

(6) Scientific instruments, methods and taxonomic references were developed in connection with this program,

and a number of these have now found wide acceptance as research tools among aquatic scientists.

(7) Results from a 9 parameter model simulating plankton populations suggest that steady state mean ecological efficiencies cluster closely about a value of 12% and vary appreciably only with plant growth rate, zooplankton respiration and zooplankton mortality. However, very wide seasonal variations occur within simulated years.

(8) Seasonal distribution and abundance of the many different species of larval fish caught in net tows have been completed for 10 different stations in the Strait of Georgia for 1966-67. A more detailed study of the distribution and abundance of larval and juvenile fish from about 25 stations located in the waters associated with the Fraser River plume during spring and summer has been completed for the years 1966-68. The results are being reported in the Technical Report Series.

(9) A pelagic spawning area for anchovies has been discovered in the Strait of Georgia off Point Grey during the larval fish surveys. Small numbers of larval anchovies were first caught in association with herring larvae during the early summer of 1968. In 1969 significantly larger numbers were caught in this area to indicate a possible resurgence of the anchovy population in the Strait of Georgia.

Seventeen primary publications on the subject of this program have appeared or are in press. In addition, practically all original data have been tabulated in 10 data reports and 4 Technical Reports.

2. Fisheries Oceanography — W. P. Wickett, W. E. Barraclough, R. J. LeBrasseur and J. Manzer

The present methods of monitoring the effect of environmental changes on populations have been extended to the migration routes of Fraser River sockeye salmon with good results using ocean temperature and transport as parameters in a non-linear response analysis.

A 2° grid of calculated water movements has been developed for the study of coastal waters. Data for 1968 indicated the forces that developed the day previous to a 3 knot current, which damaged an oil-drilling rig in Hecate Strait on the 25th of September, 1968.

Twice daily computations of transport in the North Pacific Ocean have been made for the months of February, March and April, 1969 to indicate areas of intense vertical motion during the trans-Pacific cruise.

A relationship between the abundance of larval herring and one-year-old juvenile herring caught during three years of tow-netting indicates a possible useful index of year-class strength. The distribution and abundance of larval herring indicated that a late sub-tidal spawning probably occurs in Boundary Bay and the adjacent coastal waters of the State of Washington. Herring investigators confirmed the observations this spring. Joint publication of some of the data is being prepared.

A survey for larval lobsters was carried out in Fatty Basin from May through July. A total of only six larvae was caught. This very poor return may have been related to an extremely high predation of lobster larvae by a variety of fish. In this respect the lobster larvae would be very conspicuous prey among the low concentrations of very small zooplankton found in the inlet.

The analysis of existing data on pomfret gathered from 1956-65 will give the background for economic assessment of a substantial unexploited resource in the North Pacific Ocean. Pomfret distribution, abundance, growth and other aspects of the species' biology are to be reported on.

The results of several years' study of (a) food relationships in the North Pacific Ocean and (b) fur seal distributions, are reported below.

(a) Food Relationships of Terminal Predators in the Northeastern Pacific — R. J. LeBrasseur

The epipelagic zone of the northeastern Pacific Ocean is inhabited by three groups of marine animals which occupy the position of terminal predators. The latter are all migratory, apparently only feeding in the area. The groups are mainly represented by two species of baleen whales (Balaenoptera), three species of Pacific salmon (Oncorhynchus) and one species of pomfret (Brama). The annual mean biomass of the Pacific salmon is approximately twice that of the other two predator groups. Salmon live out their marine life of 2 to 4 years in the northern Pacific, while the pomfret and baleen whales are seasonal transients seldom being in the area more than 5-7 months before returning to southern waters.

The terminal predators nearly double their weight while feeding in the northeastern Pacific with the result that the annual yield is approximately equivalent to the mean standing stock, i.e. 0.03 g C/m^2. Examination of the stomach contents of the terminal predators revealed that a great variety of organisms are eaten but that there are some species preferences. In general, the prey could be grouped into three categories: herbivores, primary carnivores and forage animals. The herbivores were comprised of copepods, some pteropods and juvenile stages of other zooplankton. The primary carnivores

were mainly comprised of chaetognaths, amphipods and euphausiids. The latter were classed as carnivores since their oceanic environment, unlike the coastal environment, does not contain phytoplankton species which euphausiids are known to graze. The forage animals, squid and myctophid fish were only qualitatively sampled. The herbivores obtained 100% of their food requirements from primary producers, while the primary carnivores obtain their food from the herbivores and to a lesser extent from the phytoplankton. The food requirements of the forage animals were obtained in about equal proportions from the herbivores and primary carnivores (Fig. 6).

The biomass of the stock of herbivores increases at a mean rate of ca 5% per day during the spring. It is dominated by two species of copepods, C. plumchrus and C. cristatus. Both species attain their maximum weight by mid-May as Stage V copepodites. Having attained their maximum weight, approximately 4.5 and 12 mg respectively, both species descend from the epipelagic zone to depths in excess of 200 m. They remain at these depths where they live off their fat reserves, maturing in late winter and subsequently reproducing and then dying. Since the increase in biomass of terminal predators could not be attributed to direct predation upon the herbivores, it was postulated that euphausiids and, especially, squid and myctophids serve to store the energy consumed through predation on the herbivores. In turn, both groups are utilized throughout the year by the terminal predators. The forage animals appear to occupy a special role due to their size and to a life span of several years. A ration equivalent to 2,500-4,000 copepods or 500-1,000 euphausiids could be obtained by feeding upon one fish or squid weighing 10-15 g. The additional advantage of feeding on prey with a life span of two or more years is that they buffer short-term fluctuations in herbivore or primary production. The latter, plus the facts that salmon can expand or contract their feeding range and are comprised of several generations, increases the difficulties of predicting salmon yields from productivity data.

(b) Northern Fur Seal — J. I. Manzer

Additional evidence was obtained on the effect of surface transport on the distribution of fur seals in the northeast Pacific Ocean. This evidence is based on:

(1) Fur seal distribution and travel rates in relation to surface circulation and current velocities: In early winter when fur seals leave the Bering Sea and begin their migrations in the North Pacific, limited sighting data indicate that they are present in the central North Pacific north of 50°N except immediately south of the Alaska Peninsula. Surface currents in the latter area are westerly and approximately equal in velocity to calculated fur seal travel rates. These conditions of surface flow are believed sufficient to prevent significant net eastward migration of seals, and hence their absence in the area.

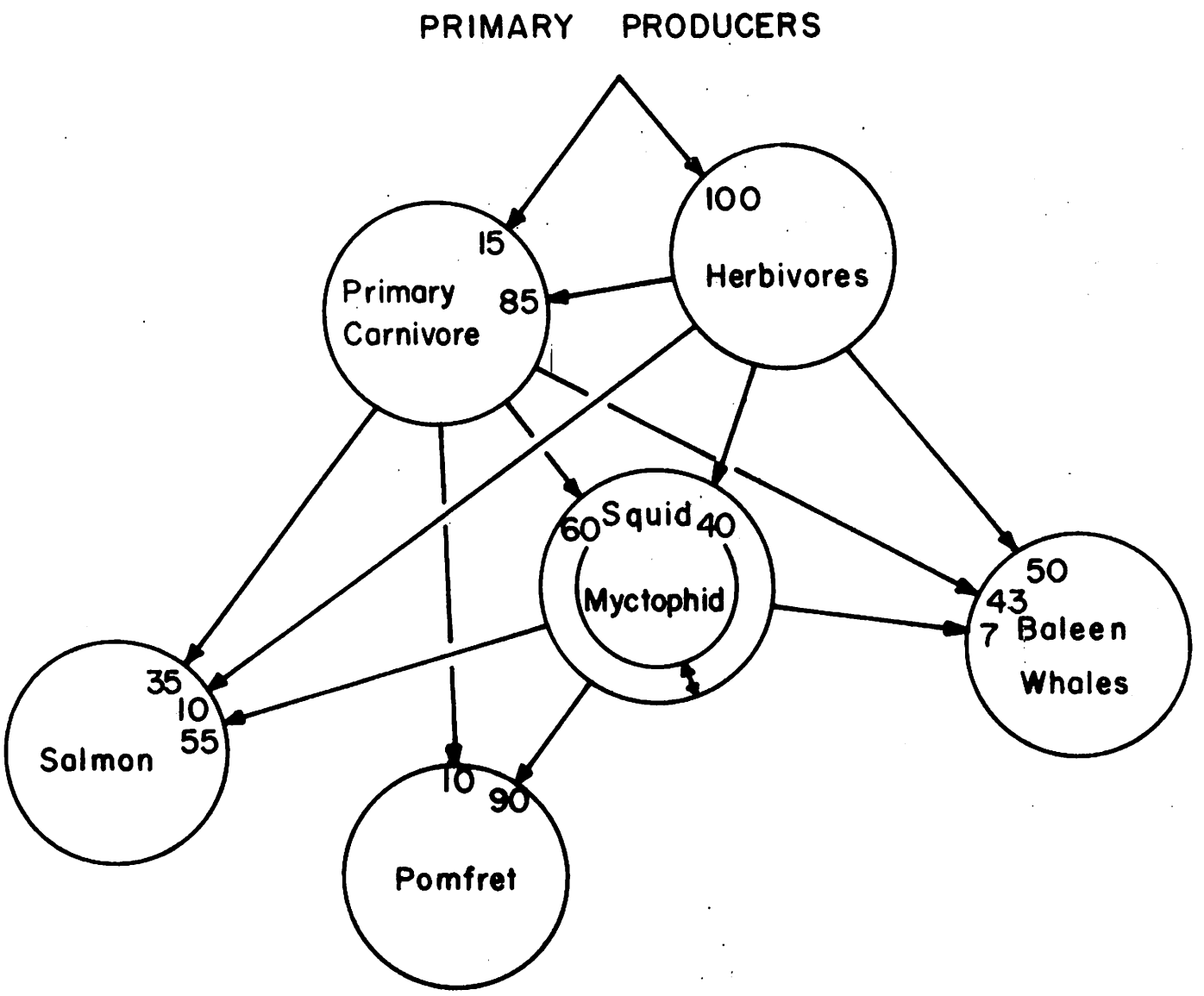


Fig. 6. Diagrammatic representation of a food web in the northeast subarctic Pacific Ocean (numbers indicate the percentage of food acquired from different sources).

(2) Comparison of surface transport and fur seal distribution in the early months of 1963 and 1965: Surface transport and fur seal distribution in the northeast Pacific Ocean were more northerly in 1963 than in 1965.

The above forms part of a major paper co-authored by J. I. Manzer, G. C. Pike and I. B. MacAskie, which reports on studies on the distribution and migration of fur seals in the northeast Pacific Ocean and which has been accepted by the Board's Journal for publication.

3. Stream Ecology — J. H. Mundie

As part of a study on invertebrate production utilizable by salmon in streams, a detailed analysis has been made at Robertson Creek, a controlled flow channel, of diel invertebrate drift in relation to diel feeding of resident coho fry. Of 50 different species of invertebrates found, 30 showed distinct diel periodicities in drifting. The relative numbers of species differed from their proportions in the benthos, demonstrating the varying propensities of species to drift. The diets of the fish over 24 hours contained 50 different kinds of food of which 7 made up 80% of the total. Of these, 4 were foods taken from the water surface and the remaining 3 were abundant in drift. Drifting material accounted, therefore, for the bulk of the diet and availability of food is probably dependent on the visibility of the items. Feeding activity of fry, as measured by the number of items in the fore-stomachs, showed bimodality with peaks at 0800 hr and 2000 hr, but the greatest intake of biomass was at 2200-2400 hr. Great variance was shown in weights of food expressed as a percentage of the weight of the fish so that analysis of large numbers of fish (360/24 hr) was necessary. Rates of digestion were established by counts of undigested discrete food items (chironomid larval head capsules) in different parts of the gut and by the passage of distinctive chironomid pupae which had presented themselves in the drift at one period of the day only. A daily mean rate of passage of food of about 5 hr was obtained. The actual daily ration was 16% of the body weight/day at 15 C. The study brings out the degree of selection of the food and the quantities eaten relative to the amounts of drift.

These findings have been obtained in a habitat which is influenced by domestic pollution. The best evidence of this is botanical, but zoologically it is indicated by an abundance of chironomids of the genus Cricotopus, and of naidid oligochaetes. The first, but not the second, are significant in the diet of the coho fry. Similar studies of invertebrate production in relation to coho diets are being carried out in a contrasting clean coastal creek.

4. Ecology and Production of Freshwater Fishes — J. C. Mason

The freshwater fish community of Lynn Creek is under study to gain better understanding of the process of coho smolt production. Emphasis is placed on species interaction within the community and on areas of possible competition. The community is a simple one dominated by coho salmon and cutthroat trout. Seasonal distribution, abundance, growth, food habits, and feeding behaviour of each fish species are being assessed. Growth and survival of coho and trout confined in stream pens reveal competitive interaction reflecting differences in feeding, territorial, and aggressive behaviours. Coho and trout given identical food and space resources use them dissimilarly. Coho expend far more energy in social behaviour at the expense of growth and survival than do trout. Trout appear to be more efficient foragers than coho in both riffle and pool habitats. A definitive analysis of food chain relations based on the dietaries of each fish species is underway.

5. Predator Prey Relationships — J. Walker and R. R. Parker

This investigation is carried out by James Walker, graduate student at the University of British Columbia, with guidance from Dr. R. R. Parker. It was begun in June, 1968 and is expected to terminate in late summer of 1970. Basically the study is concerned with the predation of juvenile coho salmon on different populations of prey species, notably chum salmon fry and the American sand launce. The work to date attempts to assess size selective predation by coho at consecutive time intervals on a prey population of decreasing density. At present, data indicates that mortality in such prey populations is biased with respect to smaller sizes. Individual size perception by the predator does not seem to be a factor. Measurement of dead, wounded and surviving prey at consecutive 5-day intervals suggests that all sizes are attacked randomly but only the smaller are ingested. This interpretation is reinforced by observations of individual predator-prey situations in which an attempt is made to analyze the components of attack as they affect size selection.

Future work will attempt to assess the effects of species populations on size selection by coho smolts.

6. Burke Channel Studies — R. R. Parker

(a) Material, primarily stomach analysis, is still being processed in the laboratory and is being reported in data summary form as MS reports.

(b) Predator-prey studies are in progress by J. Walker (UBC Graduate Student) as reported above.

(c) Reporting of oceanographic data for 1965-67 is in progress.

7. Lacustrine Ecology

D. W. Narver

1969-70 was spent working on data collected in the two previous years, writing reports, and using a new underwater light meter during a short field season. It has been reported earlier that during the day in Babine Lake the underyearling sockeye exist in two layers at about 22-30 m and 35-43 m. The light meter, used on August 20-21, revealed that the light intensity in the upper layer (25 m), where fish were feeding actively, was about 1×10^{-5} lux, while in the lower layer (40 m), where fish were not feeding, the light intensity was less than 1×10^{-7} lux. The latter is much below the visual threshold for feeding as has been shown experimentally. A manuscript entitled "Diel vertical movements and feeding habits of underyearling sockeye salmon in relation to the zooplankton of Babine Lake, B.C." has been accepted for publication in the FRB Journal about February 1970. A final paper, treating mainly the limnetic feeding biology of young sockeye, is in the early stages of preparation. A Manuscript Report entitled "Physical limnological measurements at Babine and Nilkitkwa Lakes in 1966-1968" is currently at the Printers.

8. Babine River Sports Fishery

D. W. Narver

Scales were collected from 121 adult summer steelhead trout taken in 1967 and 1968 in an increasingly important sport fishery on the Babine River. The sampling was done under our direction by a fishing lodge operator during September, October and November in both years. Virtually nothing is known about the life history of this stock, and consequently there is no sound basis for its management. Freshwater age ranged from 2. to 5. (3. and 4. were common) while ocean age ranged from .1 to .3. The most common total age was 3.2 (73% in 1967 and 60% in 1968), and the second most common age was 3.3. The males tended to remain a year longer in the ocean than did females before first maturation. Four of 121 (3.3%) scales, all from females, indicated the fish had spawned once previously. Three of these 4 fish did not mature the winter following the first spawning but instead returned two years later. The male to female ratio in the sport fishery was 1 : 1.33. Mean length at time of smolt out-migration as estimated from scales from 3.2 fish was 190 mm. A general decrease in estimated length with increasing smolt age was apparent in the first, second and third year in the stream, thus supporting other workers who have suggested that size is important in determining the age at smoltification.

ENVIRONMENTAL ENHANCEMENT

9. Eggs and Alevins

R. A. Bams

The Salmon Egg and Alevin project is concerned with increased understanding of the biological requirements of larval salmonids, with an aim to develop effective artificial propagation methods for various species of Pacific salmon. An important part of the acquired biological information was published in 1969 in the "Symposium on salmon and trout in streams, H. R. MacMillan Lectures in Fisheries, U.B.C. 1968", under the title "Adaptations of sockeye salmon associated with incubation in stream gravels". At present the main effort is directed toward optimizing the hatchery method so far developed and evaluating this method in the field. Preliminary analyses of experiments carried out from 1968 to 1969 indicate that, under the test conditions, very high survivals (from 90 to 95% from egg to fry) can be obtained with the present method; that egg (alevin) density of 2,000 per sq. ft of gravel is not excessive and can possibly be increased; that burying eyed eggs in gravel up to a depth of 3 feet has no measurable effect on survival and time of emergence; and that average growth rate is positvely correlated with both water velocity and egg density. Further tests are in progress to clarify the established correlations and define optimal ranges.

The hatchery evaluation program, which was initiated in 1968 on the Tsolum River pink stock, suffered a severe setback when the 1969 adult run to the system failed. Instead of the expected minimum of some 3,000 fish, only about one-tenth that number entered the river. This event prevented the execution of a test on this year-class and, probably, at least the next few cycle years. Operations on the 1968 brood were concluded satisfactorily. The hatchery produced a total of 200,000 pink fry, the creek an estimated 127,000. Of these, 77,600 hatchery fry and 75,800 creek fry were differentially marked by the removal of one ventral and the adipose fin. The remainder was released unmarked. These fish are due to return in 1970 and, if an adequate number of marked fish can be recovered, the degree of success achieved during this hatchery operation can be measured by the relative survival of the two sources.

At migration, the fry of both sources compared as follows: average weights and average lengths differed by only a few percent, the hatchery fry being the smaller; average stage of development, as expressed by a condition factor, differed by 0.035; and average time of migration differed by 4 days, the hatchery fry being the earlier.

A previous operation at Hooknose Creek, King Island, B.C., on the 1967 runs of local pink and chum salmon, was terminated at the fry stage without the execution of a marking program, due to an insufficient number of pink fry. Evaluation of the hatchery method at the fry stage on fish lengths, weights, stage of development and timing of the fry runs has been concluded, and a paper, "A revised hatchery method evaluated on pink and chum salmon fry", has been submitted for publication.

It is shown that during this operation the average developmental rate of both pink and chum was not significantly affected by factors other than temperature. This conclusion is important because it indicates a lack of density-related stressing factors, such as micro-environmental deviations in O_2 and other metabolite concentrations, which could have affected growth rate adversely. Migration occurred prematurely in both species. The cause for this premature emergence behaviour is unknown. Analysis showed that about 70% of the hatchery population migrated at a stage of development similar to the wild fish, the remaining 30% were immature. Growth during incubation was not adversely affected; the method utilized the available yolk, and an average growth rate was retained virtually identical to that experienced by the naturally propagated brood. This result is a significant improvement over a previous attempt elsewhere when potential size was consistently reduced by some 20% at completion of the incubational period. High mortalities were experienced, particularly during the pre-eyed stages. The average estimated survival in the incubational units (gravel boxes) was, at 78%, below expectation. The presence of silt and periods of reduced flows, due to inadequacies of the water supply, are considered to have been responsible. In the creek, chum post-emergence growth in fresh water was demonstrated.

10. Lake Fertilization

T. R. Parsons, R. J. LeBrasseur, C. D. McAllister, W. E. Barraclough, W. P. Wickett and J. Manzer

During 1969 a program was initiated to collect data on the limnology of Great Central Lake. These data, together with some historical data on sockeye salmon escapement and smolt size, have been accumulated in a report describing the general form of the natural production cycle in the lake. The principal findings of this report are that the primary productivity of the lake is very low (ca 5 $gC/m^2/yr$) and that this is in part due to the low nutrient level and the high degree of stratification maintained throughout the summer and autumn. Zooplankton biomass shows a maximum during September/October, and this coincides with the maximum growth rate of young sockeye salmon in the lake. The mean size of the latter at time of seaward migration is ca 63 mm for one-year-old smolts and ca 80 mm for two-year-olds smolts. All these data are considerably lower than similar data obtained during 1963, 1966 and 1969 from Babine Lake. In the latter system the winter level of nutrients (N and P) is approximately three times that found in Great Central Lake while one-year-old Babine Lake smolts are approximately twice as large (by weight) compared with Great Central Lake smolts. From these and other data a general assessment of productivity in Great Central Lake has led us to the conclusion that small but sustained additions of nutrients to Great Central Lake should be attempted in order to increase the production of young sockeye salmon. In experiments conducted in the laboratory, various nutrients were tested for their ability to increase phytoplankton growth, and from these results it appeared that nitrogen and phosphorus additions produced the most consistent results in increasing phytoplankton growth. A commercial grade of fertilizer (27-14-0) containing these elements was found to produce similar

results and to be highly soluble (96%). In addition, the material was found to be biologically inert to young salmon when added at a concentration one hundred times that suggested for use in the fertilization experiments.

Reports on the planning of this program have been prepared as follows:

Anon. 1969. Lake fertilization (a proposal to enrich, with commercial fertilizer, the waters of a large sockeye-producing lake). Report to File 1969-3, 8 p.

Anon. 1969. Lake fertilization - Report II (a proposal to enrich, with commercial fertilizer, the waters of a large sockeye-producing lake). Report to File 1969-6, 17 p.

ENVIRONMENTAL DETERIORATION

11. Estuarine Pollution — R. R. Parker

In response to Headquarters' request for the orientation of certain research programs towards aquatic pollution, the following program is currently being developed.

This program is called Estuarine Pollution. It is essentially ecological in nature, dealing with biological populations and their interactions among themselves and with the physical-chemical environment. The aim is to maintain or increase the potential for useful biological production in estuaries. The long-term objective is to provide units of measure with which changes in productivity of important food and recreational fishes caused by pollution in the estuary may be measured. Implicit in this objective is a depth of understanding which allows prediction of a biological result from a man-made alteration to the physical or chemical environment. The study area is Alberni Harbour and Canal. Field sampling commenced in January and will continue for 5 years.

12. Logging and Stream Ecology — D. W. Narver

Under our present system of logging and watershed management in British Columbia, severe short-term (at least) damage to small salmonid streams is unavoidable and will continue. Thus the most meaningful research is in the area of stream recovery after logging. The underlying hypothesis of this research is that the "productivity" of a small salmonid stream

decreases drastically immediately after logging, recovers rapidly and actually reaches a level "X" years after logging that is higher than before logging. A preliminary study of these problems commenced in 1969 in the south fork of the Nanaimo River watershed; this watershed has forest cover ranging from virgin hemlock-cedar stands, to clear cut, to 30-year-old alder-Douglas fir stands.

PACIFIC OCEANOGRAPHIC GROUP

A. J. Dodimead

The Pacific Oceanographic Group has, in the last year, been supplemented by secondees from the Marine Sciences Branch, Department of Energy, Mines and Resources. The research programs of the Group include studies (a) in physical and chemical oceanography, and (b) on pollution problems, primarily in association with the discharge of pulpmill effluents, sewage and wood solids, into the marine environment. Most of the programs are carried out in cooperation with other government agencies and with universities. Programs in 1969 were essentially a continuation of those carried out in 1968.

Physical oceanographic studies in the Strait of Georgia consisted mainly of continuous current observations from moored buoys, analysis of drift observations for surface circulation in the Fraser River plume area, and completion of a study of a one-dimensional hydrodynamical-numerical model of the Strait of Georgia-Juan de Fuca Strait system. The results of the analysis of the current velocity data obtained at 200 m depth during the latter part of 1968 indicate that oceanographic events in the Strait of Georgia have time scales from a few hours to several days and, therefore, demonstrate the effectiveness of a relatively long series of observation. The semi-diurnal and diurnal components of the tide have by far the greatest influence on the currents in the Strait.

Results of studies of the surface circulation in the vicinity of the Fraser River plume show that, in the absence of significant wind drift, Fraser River water inflowing during the later stages of the ebb or at high-water slack usually maintains its entrant direction until about the next low-water slack, suggesting a basic balance between Coriolis and ebb-tidal forces during the ebb tide. The surface water can subsequently undergo a variety of motions: (a) persistent northward movement (during ebb as well as flood tides) to near the mainland shore west of Howe Sound; (b) flow northward and eastward towards the mainland shore between Burrard Inlet and the South Arm; (c) motion generally westward to the offing of the Canadian Gulf Islands. Fraser River water entering the Strait at low-water slack appears to turn northward immediately. The largest surface speeds occur at or near the mouth of the River during the "freshet-and-strong-ebb" conditions. Values from 3 to 5 knots are common. The speeds in the "open" Strait are generally between 1 and 2 knots in the absence of significant winds; they can be greater during strong winds. The smallest value recorded was about 0.2 knots.

A study of a one-dimensional hydrodynamical-numerical model of the Strait of Georgia-Juan de Fuca Strait system has been completed and a report prepared. The model offers considerable insight into the semidiurnal and diurnal tidal phenomena within the system. The values of the depth-mean velocities agree well with such current observations as are available.

Studies of the seasonal and annual variability of the waters

extending to about 200 miles off the British Columbia coast were continued. Three cruises were completed in 1969. It appears that off the west coast of Vancouver Island the prime factor limiting the depth of surface mixing during late winter and early spring is the salinity of the surface waters. Temperature of the bottom waters overlying the continental shelf off Vancouver Island were everywhere about 1.0 C higher in April 1969 than in September 1967, and October and April 1968.

The Weathership program was expanded to two ships in early 1969. During the May-June patrol of CCGS Quadra, the collection and analysis of physical oceanographic data were facilitated by the use of a salinity-temperature-depth (STD) system, a STD digitizer and a data acquisition system. Satellite navigation equipment was also successfully operated on this cruise. For the first time bottom currents were measured for several days using a free-fall current meter system. A buoy program to include current measurements at several depths was begun in cooperation with the Institute of Oceanography, University of British Columbia. A program of studies on air-sea exchange of CO_2 is also being initiated.

Considerable progress in the analyses both of data collected the past year, and of selected data gathered in past years, has been made. The frequency distribution for observed surface temperature and salinity data obtained daily since 1956 at Ocean Station P is trimodal, with a primary mode at 32.60‰, 6.0 C, and secondary modes at 32.80‰, 5.5 C, and 32.60‰, 13.0 C. The surface waters had lowest temperature and highest salinity in March, were least saline in October, and had highest temperature in August. Bottom currents were measured at Ocean Station P using a free-fall current meter system. Preliminary analysis of the velocity records indicates that the mean bottom velocity for the period 29-31 May was 0.015 kt, 073°; for the period 4-7 June was 0.002 kt, 277°. Comparison of data from Nansen bottle and STD casts has shown that data obtained from a recently laboratory-calibrated STD approximates hydrographic data within the specifications provided by the manufacturer. However, if used over a prolonged time, it is necessary to check the STD calibration at a minimum of two depths for each cast.

Statistical analyses of sea level data for Tofino, Tasu Sound, Prince Rupert and Bella Bella for May 1962 to May 1964 were undertaken. Results show that phase values at most frequencies indicate that the lag between Tasu Sound and Prince Rupert sea-level fluctuations was least and that the lag between Tasu Sound and Tofino sea-level fluctuations was greatest.

Daily seawater observations were continued at 17 shore stations. During 1969, the collection of seawater samples for the laboratory analysis of salinity was discontinued at all but one station; instead, measurements of seawater density by hydrometer are being made. This procedure gives an accuracy of 0.5‰ in salinity. Seawater temperatures at most stations were below normal during January, February, August and September. Near-normal temperatures prevailed in spring and early summer until June, when 8 of the stations reported above-normal temperatures. Normal temperature conditions were generally prevalent in October and November, except in Hecate Strait, where above-normal temperatures were observed.

Oceanographic support to the Station's lobster studies was provided in Fatty Basin and adjacent waters, and involved a series of current measurements during May-June. The surface tidal circulation is modified by meteorological conditions in Barkley Sound. Drift cards released on the ebb tide in the channel connecting Fatty Basin and Useless Inlet moved out into Barkley Sound. Some were recovered within the Sound, while others moved out of the Sound and northward toward Amphitrite and Long Beach. Two were picked up on the Washington-Oregon coast. One card, recovered at sea, indicated a drift of about 12 miles per day.

Oceanographic observations from the drill rig SEDCO-135F were continued until May 1969, at which time Shell Oil concluded drilling operations on the continental shelf off the coast of British Columbia.

Oceanographic studies in the waters receiving pulpmill wastes along the east coast of Vancouver Island, and in the northern passages and inlets in existing and potential pulpmill areas, were continued. Data collected during two cruises in 1969 are being processed for publication.

The study of the effect of winds on flushing in Departure Bay is being pursued with collaboration from Dr. T. S. Murty of DEMR, Ottawa. From early numerical analysis, there is agreement of theory and observations on upwelling by strong sustained westerly winds. The effect of offshore winds in such areas may prove to be an important factor in flushing out wastes received at the surface.

Laboratory experiments on pollution by water-borne wood solids were continued. Hydraulically-active diameters of 15 types of wood particles were measured by 3 different methods. Preliminary trials of the sedimentation trough were restricted to wood particles of intermediate to large particle sizes (125-500 microns). The trough was modified to extend its capacity to handle smaller particles and to make more accurate measurements.

A conductivity-temperature-depth system, designed to POG specifications, has been built at the National Research Council in Ottawa. It is designed both for rapid vertical lowerings and for surface towing at high speeds. The instrument has been tested from both a research vessel and a hovercraft. It has performed well at all speeds up to 30 knots.

1. Strait of Georgia - Physical Oceanography — S. Tabata, P.B. Crean, L.F. Giovando & J.A. Stickland

(a) Current Velocity Measurements from Moored Buoys — S. Tabata and J.A. Stickland; S. Huggett (MSB, Victoria)

The current-velocity measurements from moored buoys in the Strait of Georgia constitute the main field program of physical oceanography for the area. The program is carried out in conjunction with that of the Tidal and Current Surveys Division of the Canadian Hydrographic Service who are making

similar observations in the same general area with emphasis, however, on tidal information.

The main purpose of the present program is to examine the current velocities in one area of the Strait for much longer duration than has hitherto been done so that accurate knowledge on the non-tidal current velocities can be obtained. In order to achieve this, a line of 3 stations, spaced 10 km apart, between Valdes Island and Iona Jetty has been established, and current velocities are measured continuously at depths of 4, 50 and 200 m depth from each of the 3 stations (Fig. 7). The observations commenced in mid-April 1969 (mooring from one station was snagged by some unknown vessel soon after mooring was established. This station was re-established in mid-July). It is planned to continue the present series of observations for one year from each of the stations. Observations at 4 m depth were discontinued due to difficulties in making reliable measurements at this depth. Survey details are summarized in Table 8.

The Aanderaa recording current meters are capable of making temperature measurements as well as current velocities. To date their performances have been very good, and current velocity and temperature data have been recorded at 10-minute intervals successfully for up to one-half of the year. The percentage data retrieval is 94%. Only a few minor difficulties were noted. The Plessey recording current meters placed at 4 m depth have not produced satisfactory data as yet.

The data obtained from the Aanderaa current meters are stored on 1/4-inch magnetic tapes. They are sent to Bergen, Norway for initial translation. Computer programs are being written to further process the data so that they will be in analyzable form.

The buoys, moorings and instruments are serviced at approximately monthly intervals. CGS Parizeau is used for this task. Weekly inspection of buoys and surface moorings are made, availability of vessels permitting.

(b) Preliminary Examination of Current Velocities Measured at 200 m Depth from Moored Buoys during 1968 — S. Tabata

During the latter part of 1968, current velocity measurements were made at two locations, one at Station F-11 (Lat. 49°03.12'N, Long. 123°25.88'W, depth 300 m) between Porlier Pass and Sand Heads and another at Station M-10 (Lat. 49°17.32'N, Long. 123°44.46'W, depth 295 m) between Entrance Island and Halibut Bank. The measurements were made, in part, to examine the current velocities at depths relatively free from surface disturbances and, in part, to obtain information upon the performance of two types of magnetic tape recording current meters, two Geodyne and two Plessey, that were recently acquired. The Geodyne meters were placed at 200 m and the Plessey at 50 m depth.

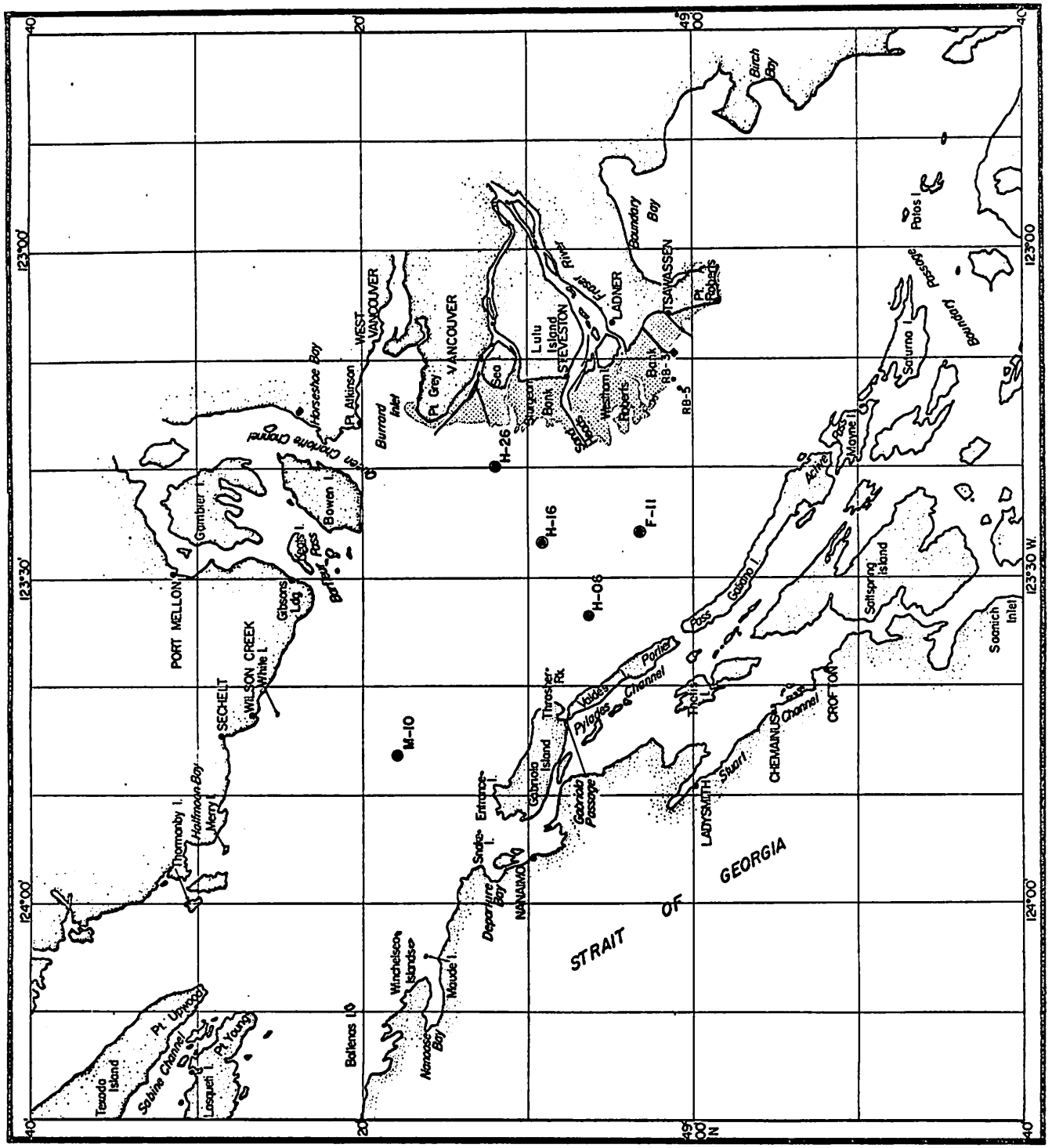


Fig. 7. Chart showing location of stations occupied during 1969. The large circles denote moored current meter stations.

TABLE 8. SUMMARY OF CURRENT MEASUREMENTS.

Station number	Latitude (N)	Longitude (W)	Depth (m)	Instrument	depth (m)	Dates	Remarks
H-06	49°06.22'	123°33.74'	250	Plessey*	4	+16-27 Apr.	*Fins damaged, as discovered on Apr. 18. +Buoy mooring presumably cut by tow line; surface float found drifting on Apr. 17; recovered on Apr. 18.
						++17-28 Jul.	++Fins again noted to be damaged.
				Aanderaa	50	+++16-21 Apr. 10 Jul. -	+++Subsurface buoy in position until Apr. 21 when it was retrieved. Surface float: Geodyne toroidal type.
				Aanderaa	200	+++16-21 Apr. 10 Jul. -	
H-16	49°09.04'	123°19.80'	290	Aanderaa	50	16 Apr. -	Surface float:- D.O.T. river navigational buoy - on loan from Dept. of Transport.
				Aanderaa	200	16 Apr. -	
H-26	49°11.93'	123°19.80'	170	Plessey*	4	16-24 Apr.	*Fins damaged, and leakage noted on Apr. 23.
				Aanderaa	50	+16 Apr. - 24 Jul. 28 Aug.-	+Surface buoy reported adrift on Jul. 25, whole buoy assembly dragged 5 miles to north. Examination of data showed accident occurred at about 2045 (PST) Jul. 24.
				Aanderaa	140	+16 Apr. - 24 Jul. 28 Aug. -	Surface float:- Geodyne toroidal type.

One Geodyne meter recorded successfully for 49 days at 15-minute intervals in "burst sampling" of 15 samples every 5 seconds for 75 seconds. The other sampled for 40 days, after which it became inoperative due to battery corrosion.

One Plessey meter recorded data for 26 days, but due to a fault in the instrument the information is difficult to examine systematically. The other did not yield any useful information.

At Station F-11 where the measurement commenced in mid-August a considerable down-strait flow (ebb) was noted at 200 m depth, the rate being approximately 3 km/day. The energy of the currents associated with the semi-diurnal component was more than 3 times that of the diurnal component. At Station M-10 where the measurement commenced in mid-October a more variable net flow was indicated. During the first week, a down-strait flow of 6 km/day occurred; this was followed by 3 weeks of up-strait flow of 2 km/day. Then followed one week when no net flow occurred (just the reversing tidal flow being present). During the last week of observations an up-strait flow of 2 km/day occurred again. Here the energy of the current associated with the semidiurnal component was again more than 4 times that associated with the diurnal component. A comparison of spectral energies in the major tidal frequencies indicates that Station F-11 contained a peak at the inertial frequency, while M-10 did not. Significant peaks occurred at both stations at periods of about 8, 6, 5 and 4 hours. Spectral energy densities for both stations decreased at the rate in the range of - 5/3 or - 4/3 power in the frequency range between 1/10 and 1.0 cycles per hour, suggesting a cascading of "turbulent" energy toward higher frequencies.

The results from these two stations indicate that oceanographic events having time scales from 4 hours to several days are present and therefore demonstrate the effectiveness of a relatively long series of observation.

(c) Short Term Current Velocity Profile Measurements — S. Tabata, L.F. Giovando and J. Wong

Two short cruises were made in the Strait of Georgia to make current velocity profile measurements.

The first series of measurements were made at Station H-16 (one of the 3 stations from which continuous measurements of current velocity at two depths are made) from CNAV Laymore in May. The data obtained will complement those taken from moored instruments. Observations were made at hourly intervals for 4 days from a lifeboat provided by the ship and moored to an anchored surface buoy.

The second series of measurements were made at Stations RB-3 and RB-5 off Roberts Bank. It was a cooperative survey between POG and the Tidal and Current Surveys Division of the Canadian Hydrographic Service. Current

profile measurements in the upper 100 m depth were obtained from MV A.P. Knight at hourly intervals for 5 days at RB-5, while only surface current measurements were made at hourly intervals for 4 days from CNAV Laymore. The latter ship also provided support for the operations of two hydrographic launches of the CHS conducting drift studies in the area.

(d) Hydrodynamical-Numerical Study of the Tidal Circulation in the Georgia-Juan de Fuca System — P. B. Crean

A study of a one dimensional hydrodynamical-numerical tidal model of the Georgia-Fuca system has been completed and a report has been prepared. The model offers considerable insight into the semidiurnal and diurnal tidal phenomena within the system. The values of the depth-mean velocities agree well with such current observations as are available. The frictional resistance in the system is considerably higher than that encountered in other coastal areas.

Mr. Crean left the Station at the end of July to commence educational leave at the University of Liverpool. There he plans to work on a more complicated model of the system.

(e) Surface Circulation in the Vicinity of the Fraser River Plume — L. F. Giovando

Data on the surface circulation in the vicinity of Fraser River plume in the Strait of Georgia were obtained during 1966 and 1967 by means of free-floating current followers. A total of 16 follower-tracking "sessions", involving 52 followers, was undertaken; the duration of the sessions ranged from 2 to 33 hours. Analysis of the data has generated the following conclusions:

1. Oceanographic and meteorological conditions at the onset of wind-induced surface drift significantly affecting the monitored flow could not be determined. However, it appeared that 25-knot winds acting on a very thin (1- to 2-meter) surface layer resulted in noticeable drift, whereas 10- to 15-knot winds acting in a layer about 4 meters thick did not.

2. The water from the South Arm enters the Strait as a (surface) jet. The bulk of this jet apparently does not undergo marked spreading.

3. In the absence of significant wind drift, water inflowing either during the later stages of the ebb or at high-water slack usually maintains its entrant direction until about the next low water, suggesting a basic balance between Coriolis and ebb-tidal forces during the ebb tide. The (modified) surface water can subsequently undergo a variety of motions:

(a) Persistent northward movement (during ebb as well as flood tides) to (near) the mainland shore west of Howe Sound. It can subsequently flow westward to mid-strait and then northwestward, rather than immediately northwestward along the mainland shore.

(b) Flow northward and eastward towards the mainland shore between Burrard Inlet and the South Arm. This movement can be manifest within one flood tide, and results perhaps from both residual and flood-tidal effects.

(c) Motion generally westward to the offing of the Canadian Gulf Islands.

4. Water entering the Strait at high-water slack possesses significantly smaller speeds than does that entering during the ebb. These lesser values are believed generally to result from dynamical restraint of the Fraser River outflow by the flood tide.

5. Water entering the Strait at low-water slack appears to turn northward immediately. It too can undergo either "persistent" northerly, or easterly movement.

6. In the absence of wind effects, water entrant during the earlier stages of the ebb can sometimes be moved southward, apparently by the combined action of residual and of ebb-tidal flow.

7. The bulk of the (modified) South Arm water attaining the shore of the Fraser River delta north of the Arm is not advected parallel to that shore.

8. The largest surface speeds apparently occur at the mouth of the Arm itself during "freshet-and-strong-ebb" conditions. Values from 3 to 5 knots are common. The speeds in the "open" Strait are generally between 1 and 2 knots, in the absence of significant winds; they can be greater during strong winds. The smallest value recorded was about 0.2 knots.

9. Other factors being equal, markedly different entrant speeds at the South Arm can apparently occur during similar conditions of Fraser River runoff as recorded at Hope, B.C. Such differences may be associated at least partly with variability in the flow of rivers entering the Fraser River west of Hope.

10. In the absence of significant winds, South Arm water might be considered generally to contribute both to the formation of, and the extension of, the portion of a "plume" north of the Arm. Wind drift would modify such a plume, and could also be the predominant reason for the extension of the plume south of the Arm.

(f) Processing of Current Velocity Data Obtained from Anchored Vessels — S. Tabata, L.F. Giovando, J.A. Stickland and J. Wong

The current velocity data obtained from a number of stations in the Strait of Georgia from anchored vessels during 1967 through 1969 have been processed and outputted on computer print-outs. The computer program was written by Mr. J. Wong. It is anticipated that these print-outs will be made generally available in 1970 in form of data records.

(g) Trials of Towed Salinity-Temperature-Depth Recorder — S. Tabata; & T.M. Dauphinee (NRC, Ottawa)

A towed salinity-temperature-depth recorder designed to POG specifications is being built at the National Research Council in Ottawa under the direction of Dr. T. M. Dauphinee of the Applied Physics Division. It is designed for high speed measurements and at present is suited to measurements down to 200 m depth. Initial trials for its performance were conducted for 3 days in the Strait of Georgia. During the first day, towing trials were made from the CGS Parizeau. The instrument performed very well in speeds up to a maximum of 16 knots. During the following 2 days, trials were conducted aboard the Canadian Coast Guard hovercraft, 021 SRN. Again, the instrument performed very well when towed at a constant depth at all speeds to a maximum of 30 knots. The large amount of information acquired during a run between Entrance Island-Sand Heads-Active Pass-Trincomali Channel within an hour or so indicated that the instrument has great potential for conducting high-speed surveys in a short time. It also appears to be an ideal instrument for making observations on high-frequency oceanographic events.

(h) Howe Sound Investigation — S. Tabata

During the winter of 1968-69, the areas in the vicinity of Vancouver experienced a period of record-breaking cold weather. As polar air was prevalent over the large portion of British Columbia, cold, strong down-inlet winds occurred in the B.C. inlets, and particularly Howe Sound. It was believed that such a meteorological event might leave recognizable changes in the water of the Sound. On the shores of Howe Sound are located: two pulp mills, at Woodfibre and Port Mellon; one mining plant, at Britannia Beach; and one chemical plant, at Squamish. The possibility of pollution by effluent from these plants must be considered and, therefore, it is important

to know the flushing characteristics of the inlet. If the down-inlet winds are strong enough it might result in significant flushing of the inlet. With this as a background, a quick survey into the inlet was made, first on 8 January 1969 aboard a hovercraft 021 (SRN-5) supplied by the Canadian Coast Guard, and again on 22 January aboard the CGS Parizeau. A further observation was made on 28 January aboard the CGS Parizeau and another on 2 May aboard the CNAV Laymore. Comparison of data from 8 and 22 January, 1969, indicated that during a 2-week period the temperature of the upper 100 m layer of the water in the inlet had risen by about 2 C, despite the presence of a cold spell during which daily heat loss greater than about 500 g-cal/cm^2 must have occurred. The warming is almost certainly due to the inflow of the Georgia Strait water at intermediate depth. It appears unlikely that the effluent discharges from plants at Squamish and Woodfibre contributed to this warming.

2. Isentropic Analysis of Water of Northeast Pacific Ocean — S. Tabata

The examination of the circulation of water in the northeast Pacific Ocean, using isentropic analysis, is being continued whenever opportunity permits. In addition to data from 12 cruises made by the Pacific Oceanographic Group, others taken during 1949, 1954 and 1956 by United States sources are being examined. Acceleration potentials at 7 σ_t surfaces for these cruises have been computed by the Marine Sciences Branch of DEMR (Ottawa) and have been plotted on a polar-stereographic projection chart using computer facilities available locally. To date, data from all cruises mentioned above for σ_t = 26.0 through 27.2 have been plotted and contoured. It is anticipated that an atlas containing these charts will be produced and outputted as joint FRB-MSB report within a few years.

3. Oceanic - Coastal Program — A. J. Dodimead and R. H. Bigham

Studies primarily to define the seasonal and year-to-year variations in the physical and chemical properties of the waters extending to approximately 200 miles off the coasts of British Columbia and Washington were continued. The study is partly designed in support of investigations on development of strong and weak groundfish year-classes during some years. In 1969, the field program consisted of 3 cruises. The first was a short but intensive survey of a small area overlying the continental shelf north of Barkley Sound, undertaken in early March, and consisted of 3 sections extending from the coast to the continental slope. The second and third cruises were approximately 3-week cruises in April and October, similar in extent to those undertaken in 1967 and 1968.

(a) Depth of Mixed Layer - April 1968

In April 1968, the thickness of the surface mixed layer varied between 0 and 90 meters, with the shallowest depths occurring near the coast of Vancouver Island. These depths are considered to be representative of mid-winter and early-spring conditions. There is a marked similarity in the distribution of these isopleths and of the surface isohalines, particularly seaward of Vancouver Island. The main features of the gradients are nearly coincident, and the shallowest mixed-layer depths are associated with the lowest surface-salinity values.

The formation of the mixed layer is considered to be due to wind mixing and to convective overturn resulting from cooling and evaporation. The depth to which these processes extend will depend on the stability within the water column. It would appear that, off the coast of Vancouver Island, the prime factor limiting the depth of mixing during late winter and early spring is the salinity of the surface waters.

(b) Surface Salinity, April 1969

The surface salinity distribution reflects the winter convergent situation that usually exists at this time of the year, with low-salinity water confined near the coast, and relatively high-salinity water lying near the continental slope.

Off the coast of Vancouver Island, the convergent situation was more fully developed in April 1969 than in April 1968, as indicated by the strength of the near-shore gradient.

In Queen Charlotte Sound, surface salinities in April 1969 were slightly higher (by about 0.5‰) than those observed in April 1968.

(c) Vertical Distribution of Temperature

Temperatures in two sections (one section extends seaward from Estevan Point at about mid-Vancouver Island; the other extends seaward from McInnes Island in Queen Charlotte Sound) are representative of the general thermal features seaward and northward of Vancouver Island. A feature common to all sections is the presence of temperature inversions in the depth interval between 75 and 175 m. The temperature inversions were more pronounced in the Estevan Point section than in the McInnes Island section.

In April 1968, between 250 and 800 m depth, the isotherms tended to slope upward, while in the deep water (below about 800 m) the isotherms tended to slope downward on approaching the continental slope. In April 1969 all the isotherms tended to a downward slope on approaching the continental shelf. The change is probably associated with a redistribution of mass and a change in the circulation of the waters seaward of the continental slope.

There were significant differences in the temperatures of the bottom waters overlying the continental shelf. Off Vancouver Island and in Queen Charlotte Sound, bottom or near-bottom temperatures in April 1969 were from 1.0 to 1.5 C greater than those observed in April 1968.

A review of the data from cruises in 1967-69 indicates that bottom or near-bottom temperatures off Vancouver Island were similar in September 1967, April 1968 and October 1968, ranging from approximately 6.0 C at the edge of the shelf to 7.2 C about 5 miles from the coast; however, they were about 1.0 C higher in April 1969. In the McInnes Island section to the north, shelf bottom temperatures ranged from 5.5 C at the edge of the shelf to 6.2 C in the eastern sector of Queen Charlotte Sound in September 1967 and October 1968. In April 1968, temperatures ranged from about 4.3 C to 6.8 C, and in April 1969, from 5.5 C to 7.3 C.

4. Ocean Station P - Line P

(a) Program, 1969

C.A. Collins, D.A. Healey & C. DeJong

The regular program of oceanographic observations from the weather-ships CCGS Vancouver and CCGS Quadra was continued during 1969. Oceanographers were present on the 9 patrols in 1969. The program included one Nansen bottle cast per week at Station P to 4,200 m to determine vertical profiles of temperature, salinity and dissolved oxygen. A continuous recording salinity-temperature-pressure (STP) system was used to a maximum pressure of 1,500 db except on cruise 3 for which no instrument was available. STP casts were scheduled daily for cruises 4, 5 and 6, twice-weekly for cruises 2, 7, 8 and 9, and for each station en route to and from Station P (Line P). A survey of 8 stations around Station P was reinstituted during cruise 2 and the STP was also used for these stations. Observations have been graphically summarized in Table 9.

Biological observations were scheduled as follows:

(i) Zooplankton observations:

a) daily, a 150 m vertical plankton haul;

b) twice during a cruise, a 1,200 m vertical plankton haul;

c) nine times during a cruise, a 10-minute horizontal plankton haul;

d) weekly, a Van Dorn bottle cast for micro-zooplankton.

TABLE 9. STATION P AND LINE P OBSERVATIONS FOR 1969

4200 M - NANSEN BOTTLE CAST

Cruise number	1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week	Grid P
1	x	x					
2	x	x	x	x	x	x	x
3	x	x	x		x	x	x
4	*	x	x	x	x	x	x
5	x	x			x	x	x
6	x	x	x	x	x	x	x
7	x	x	x	x	x	x	
8	*	*	*	*	*	*	
9	Not yet available						

Note: * = asterisk indicates STP data available to 1500 m

LINE P STATIONS

Cruise number		1	2	3	4	5	6	7	8	9	10	11	12
1	out							x					
	in	x	x	x	x		x	x	x	x	x		
2	out	x	x	x	x	x	x	x	x	x	x	x	x
	in		x	x	x	x	x		x	x	x		x
3	out									x			
	in		x	x	x	x	x	x	x	x	x	x	x
4	out	x	x	x	x	x							x
	in	x	x	x	x	x	x	x	x	x	x	x	x
5	out	x	x	x	x	x	x	x	x	x	x	x	x
	in												
6	out	x	x	x	x	x							
	in			x				x					
7	out	x	x	x	x	x	x			x	x		x
	in												
8	out												
	in												
9	out						x				x	x	

x - indicates a completed station.

(ii) Productivity observations:

a) every second day, surface measurements of photosynthesis and of plant pigment;

b) three times during a cruise, a Van Dorn bottle cast for photosynthesis, plant pigment and nitrate measurement;

c) surface nitrate samples at each Line P station.

Biological data are processed by the Environmental Research Group, Biological Station, Nanaimo.

When weather permitted, the crews of both ships made bathythermograph observations every three hours to coincide with routine meteorological observations. Daily samples of surface water for salinity determinations were also collected by the crew.

The following were collected for other institutions:

(i) Surface samples on each patrol for analysis by the Inland Waters Branch, DEMR.

(ii) During cruises 2 and 4, ten 15-gal samples between 50 and 3,000 meters were obtained and treated for C^{14} analysis by Dr. Fairhall, University of Washington; some samples for chlorophyll measurements along Line P were obtained for Dr. Anderson, University of Washington.

(iii) Surface and rainwater samples were obtained for Scripps Institution of Oceanography.

Observations for the U.S. Atomic Energy Commission and the U.S. Naval Radiological Laboratory were discontinued during 1969.

During Cruise 6, additional biological data were obtained by personnel from the National Museum of Natural Sciences, the University of Ottawa, and the University of Victoria. Eleven midwater trawls were made to depths of 950 m. Depths of 600-800 m seemed most productive for mesopelagic fishes. Several of the specimens obtained were rare, and at least one was probably an undescribed species. Seven trawls were made with a surface Neuston net, and sauries and blue lantern fish were obtained; experimental work was carried out on the bio-luminescence of the lantern fish. Other samples were obtained to study the effects of diurnal light changes on phytoplankton.

During Cruises 2, 4 and 6, additional physical oceanographic data were obtained. Water samples were gathered near the ocean bottom with Nansen bottles and vertical STP profiles were obtained to study internal tidal waves as well as higher-frequency internal waves. A near-bottom current meter was also used on Cruise 4.

Collection and analysis of physical oceanographic data was facilitated by a Hewlett-Packard data acquisition system on Cruise 4 and an STP digitizer on Cruises 4 and 6. Satellite navigation equipment was also successfully operated on Cruise 4.

(b) Studies of Data C. A. Collins

In addition to the analysis of data collected during the past year, preliminary analysis of selected sets of data gathered in past years has begun. Data include surface temperature and salinity observations, seasonally-averaged Line P data, deep data at Station P, and Station P bathythermograph data for 1960-69.

A frequency distribution for observed surface temperature and salinity is given in Fig. 8. Samples were obtained daily since 1956. The frequency distribution is trimodal; secondary modes occurred at 32.80‰, 5.5 C and 32.60‰, 13.0 C. The most frequently observed T-S pair (primary mode) was 32.60‰, 6.0 C. Mean values for each month, as well as a total mean are also indicated in Fig. 8, and an annual oscillation of salinity as well as temperature can be observed. The surface waters had lowest temperature and highest salinity in March, were least saline in October, and had the highest temperature in August. The range of the monthly mean salinity values was 0.12‰ and the range of the monthly mean temperature values was 7.8 C. The total mean for the population, 8.3 C, 32.65‰, was not "representative" of the distribution. Preliminary analysis indicates the secondary mode at low temperatures was due to lower salinities in the years 1959-61 and 1964-65.

When data at standard depths were grouped by season and averaged; and each seasonal average then weighted equally to produce an overall average, features easily noted in the temperature section are: the steady, upward rise of the 3.9-7.0 C isotherms to the west; the fact that the 8-10 C isotherms are deepest at 127°W and slope upward both to the east and west.

In contrast to the westward-rising isotherms, most isohalines varied little in depth from 126°W to 145°W. At depths below 450 m, maximum salinity values at a given depth were found at 129°W and at 145°W; the longitude of the maximum depth of an isohaline increased with increasing salinity, from 133°W for the 34.10‰ isohaline to 137°W for the 34.35‰ isohaline. Isohalines at the bottom of the halocline, 33.90‰ and 33.80‰, slope downward to the west while those at the top of the halocline, 32.60-31.50‰, slope upward to the west; the result is a steady decrease in the intensity of the halocline to the west, a well-documented feature of the northeastern Pacific Ocean.

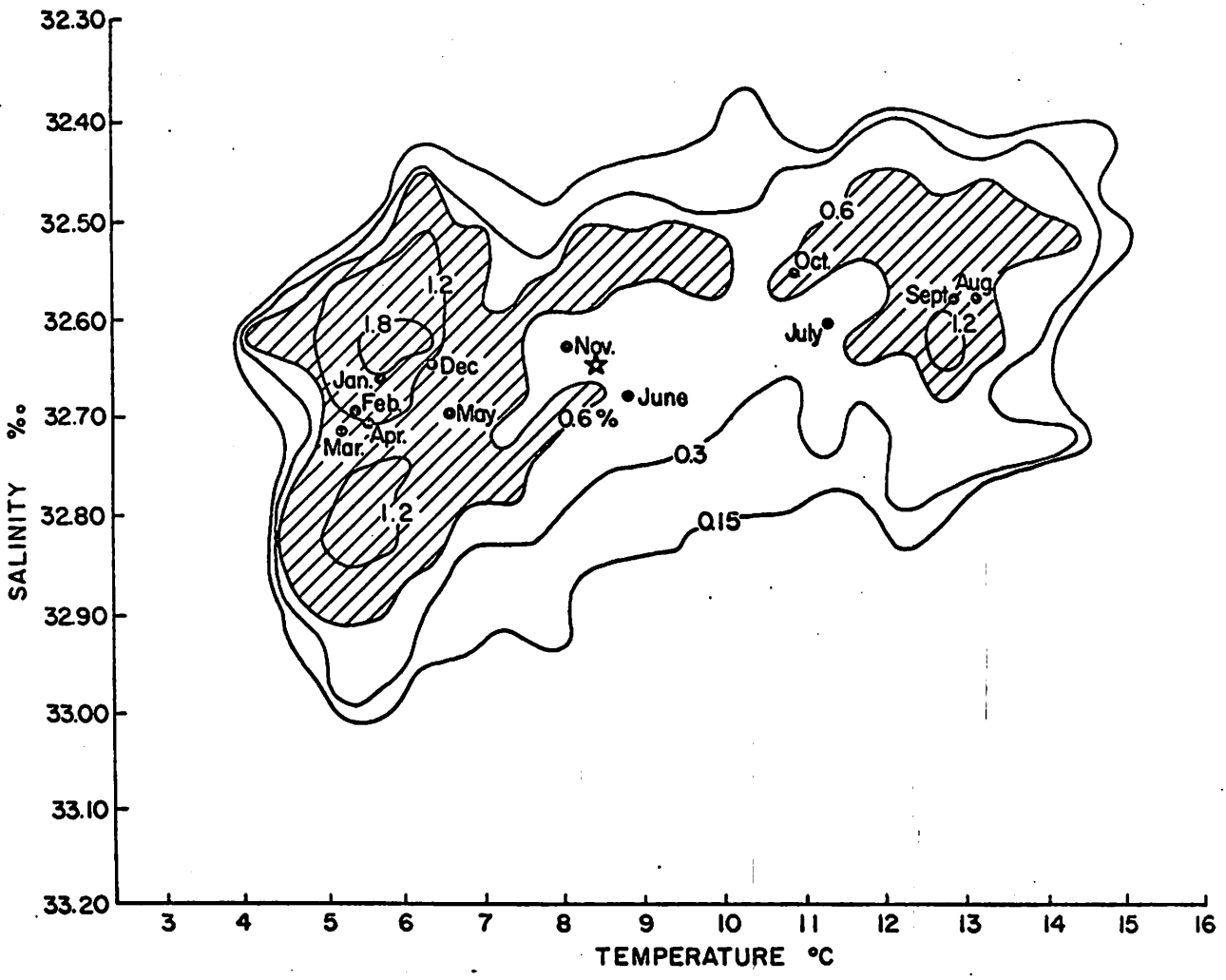


Fig. 8. Frequency distribution for Station P surface temperature and salinity observations. Numbers on isolines represent the percentage of the total number of observations. Data were obtained in years 1956-1969. Monthly means and the mean of all data (a star) are also indicated.

The specific volume anomaly section illustrates the effects of temperature and salinity on the field of mass. Isosteres equal to or less than 140 rise to the west. A decrease in the rate at which isosteres 80 to 140 rise to the west occurs at 129°W. For isosteres 100-75 a similar point occurred at 141°W. The depth of isostere 180 was nearly constant while isosteres 200-300 rose both west and east of 131°W. Isosteres 325, 350 and 375 appeared only close to shore.

Analysis of 125 surface-bottom profiles of salinity, oxygen and temperature for Ocean Station P is also progressing. This work has benefited from analysis of the same data set by Mr. Stewart Rupp, who concluded that average properties near the bottom were 1.50 C, 34.69‰, and 3.30 ml/l, and that the uncertainties of published salinity and oxygen values were 0.012‰ and 0.10 ml/l. Collection of additional deep data is continuing, and thermometers have been recalibrated to give results to thousandths of a degree; on patrol 4 the deep temperature minimum, 1.50 C, was observed between 3,800 m and 3,900 m.

Bathythermograph data for Station P for 1960-67 have been digitized by the National Oceanographic Data Center of the United States and listings have been obtained. Current bathythermograph data are being digitized by Scripps Institution of Oceanography. These data are being statistically summarized by Mr. K. Abbott-Smith using computer facilities at the University of Victoria.

Analysis of data collected from the grid surveys around Ocean Station P was undertaken by Miss A. Huyer.

(c) Deep-Sea Instrumentation — C. A. Collins

During Cruise 4, a free-fall current meter system was twice launched and recorded. The system consisted of a buoy on which was mounted 2.5 Mhz and 27 Mhz radio beacons and a flashing light, and from which was suspended a current meter and a release device (Fig. 9). A corrosive link was also placed in the line in case the release device failed. The system was designed to sink to the bottom, record current velocity, and to return to the surface at a preset time. The rate of fall and ascent of the instrument was about 0.8 m/sec; this meant that it took the buoy about 1.3 hours to reach the bottom.

The system was first launched on 29 May and was preset to surface at 0900 on 31 May. The system was detected on the surface at 0910, 31 May, with the 27 Mhz beacon (the delay in receiving the 2.5 Mhz signal was due to the fact that the hollow fiberglass antenna must drain completely). Recovery was made using the ship's RDF (2.5 Mhz); it took about one hour of searching to find the buoy in foggy weather. The system was on the bottom a total of 40 hours and was recovered (despite southerly winds) 3 miles south-southwest of the launch point.

The system was again launched on 4 June and was set to be on the ocean

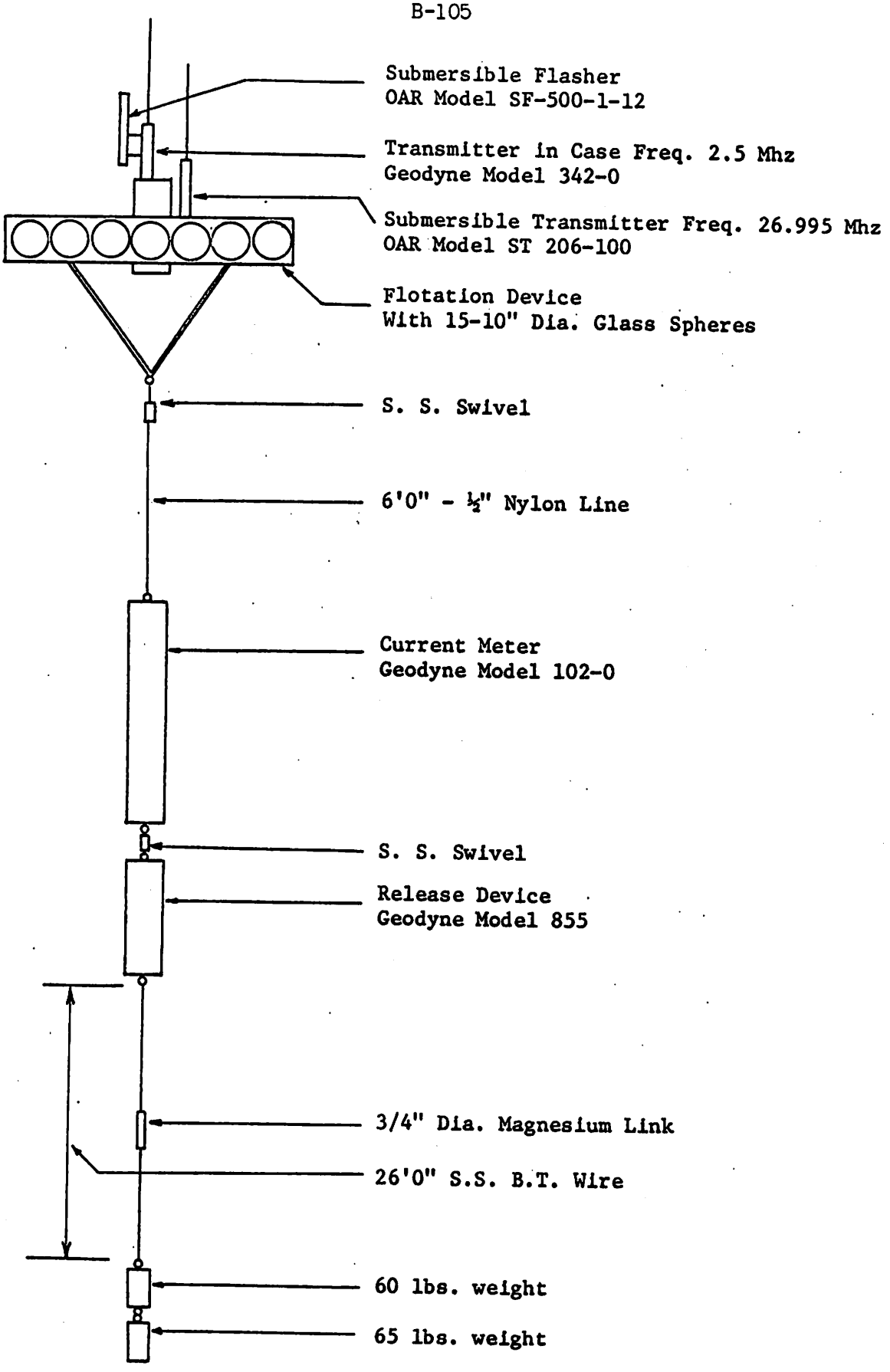


Fig. 9. Schematic diagram of deep-sea free-fall current meter system.

bottom for 92 hr. After approximately 62 hr a signal was noted by the watch officer (who was checking twice during the 4-hr watch) on 2.5 Mhz; we checked at this time and also noted a signal at 27 Mhz. Again recovery was made using the ship's RDF. Radar detected the surface buoy at 6 mi (it was nearly calm) and it was spotted visually at a distance of 2 mi. After transmitting for approximately 3 hr, the 2.5 Mhz transmitter stopped and later smeared across a rather wide frequency band; the cause of the transmitter failure was a faulty transistor. The fact that the buoy surfaced early was the result of the failure of the corrosive magnesium link. (The link was a flamed magnesium rod of 11/16-inch diameter; 5/16-inch diameter holes were drilled 1/2-inch from each end and through these passed an unthimbled eye of stainless steel BT wire.) The buoy was recovered one mile to the north of its launch point. All instruments were in excellent condition after surfacing.

The current meters recorded in the "continuous mode" so that speed direction and instrument tilt were recorded every 7 sec. Each deployment event - launching, recovery, settling and rising from the bottom - was clearly indicated in the resulting record. As the meter sank to, or rose from, the bottom, the direction vane rotated through 360° about once every 500 m and indicated speeds were 0.1 knot. On the bottom, direction values became steady and speeds dropped to 0.05 knots or less. At the surface, indicated speeds increased to 0.5 knot or more, tilts occurred, and the direction stopped its steady rotation and became more variable.

Preliminary analysis of the velocity records indicates that the mean bottom velocity for the first period, 29-31 May, was 0.015 knot, 073°; the mean velocity for the second period, 4-7 June, was 0.002 knot, 277°. The measured velocity should be an indication of barotropic transport and so the data confirm that the barotropic transport is time dependent. Other features of the velocity data were that flow to the southwest seldom occurred during 29-31 May and that flow to the northeast seldom occurred during 4-7 June. A semidiurnal oscillation occurred in the data and the amplitude of the associated speed variation was 0.005 knots.

Future experiments will measure horizontal and vertical coherence as well as obtain longer time series which will include other parameters.

(d) Compatability of STD and Hydrographic Cast Data — D. A. Healey

During use in the field, the calibration of the Bissett-Berman model 9006 and model 9040 salinity-temperature-depth instruments must be continually checked. As these instruments are being used to replace Nansen bottle casts, it is important that the two sampling methods yield compatible results. Nansen bottles are placed immediately above the STD and tripped when the STD is at its maximum depth. In addition a surface sample is obtained while the STD is at the surface, so that two values of temperature and salinity are available for checking each STD cast. During each survey, a number of hydrographic casts are made immediately before or after STD casts, giving vertical profiles of temperature and salinity for comparison.

Immediately following laboratory calibration, it has been found that STD data approximate hydrographic data within the specifications provided by the manufacturer (salinity accuracy ±0.03‰, temperature accuracy ±0.05 C). By comparing the two types of data and applying a correction factor to the STD data, the two data sets may be made to agree more closely. However, surface and maximum depth comparisons are of value only when the STD error is constant, or linear with depth.

Comparison of data collected during June 1969 from CCGS Quadra showed a somewhat poor agreement between STD and hydrographic data. The 300 m STD and surface Nansen bottle casts were taken every 1-1/2 hr for over 100 hr. Of 27 pairs of observations, 5 pairs differed by more than 0.05 C. The 3-m separation of the STD and Nansen bottle, and the presence of a vertical temperature gradient close to the surface, can account for reversing thermometer temperatures higher than corresponding STD temperatures, but higher STD temperatures cannot be explained. The salinity samples obtained from Nansen bottles are all within ±0.02‰ of 32.51‰, but the STD salinities fluctuate wildly, with an extreme value of 33.15‰. These salinity errors are normally constant with depth to 300 m, but in a significant number of casts the error is non-constant.

A salinity shift has been observed on previous cruises in about 5 per cent of stations. Its occurrence has been intermittent, and has never occurred in two consecutive casts. These results have made it necessary to check STD calibrations with at least two points for each cast. The calibrations deteriorate with prolonged instrument use.

(e) Intercomparison of In-Situ Salinity-Temperature-Depth Instruments — D.A. Healey and C. DeJong

A 2-week intercomparison cruise was carried out in cooperation with Dr. R. Trites of the Bedford Institute. A Bissett-Berman model 9040 STD, an NRC STD and a German-manufactured Bathysonde were compared in the western North Atlantic from CSS Dawson, September 2-12. Each of the instruments was lowered before and after hydrographic casts. The Bissett-Berman and NRC units were lowered in conjunction with the tripping of bottle casts with close spacing of bottles through detailed temperature and salinity structures. An attempt was also made to compare the instruments in uniform temperature and salinity conditions. All data were logged with a digital data logging system, except when two of the STD units were used simultaneously.

Preliminary results indicate that each instrument measured temperature rather well (when compared to reversing thermometer temperatures). The Bathysonde measures temperature and conductivity independently, but has no facility (internal) to determine salinity from the two. The NRC unit measures temperature and conductivity and converts the two to temperature-compensated salinity. It remains to compensate salinity for pressure. The Bissett-Berman STD has a direct output of both temperature and salinity, making its analogue traces the easiest to interpret. In regions of strong temperature gradient, the NRC STD seems to compensate for the temperature changes much better than

the Bissett-Berman, which may give errors as large as 0.40‰ salinity in temperature gradients of 2 C/m. As a survey tool, the Bathysonde has little use, as the conductivity output is dominated by temperature, so that salinity changes are not obvious from the analogue traces. The Bissett-Berman unit is the easiest to operate, but the NRC underwater unit is the only one which can be handled easily by one man.

5. Statistical Analysis of Time Series — C. A. Collins

During 1969, analysis of sea level data for Tofino, Tasu Sound, Prince Rupert and Bella Bella for May 1962 to May 1964 was undertaken. Data were numerically tapered to remove tides and then decimated to one observation per day; autospectra, phase and coherence square were calculated. The slope of the autospectra (log energy density vs. log frequency) was between 4/3 and 5/3. At no single frequency did the energy density dominate the autospectra; values of energy density which were statistically greater than the spectral continuum occurred at 0.06, 0.135 and 0.20 cpd for most stations. A statistically significant peak also occurred at 0.33 cpd for Tofino, Tasu Sound and Bella Bella sea level series and at 0.38 cpd for Prince Rupert sea level.

Phase values at most frequencies indicated that the lag between Tasu Sound and Prince Rupert sea level fluctuations was least and that the lag between Tasu Sound and Tofino sea level fluctuations was greatest. This relationship was true at 1.34 and 0.20 cpd, and is the sort of phase relationship one would expect associated with atmospheric fronts moving to the east from the northeastern Pacific Ocean. At 0.06 and 0.33 cpd, the relationship was reversed, i.e., the sea level fluctuations proceeded from south to north.

Coherence square values indicated that, in general, sea level fluctuations at Tasu Sound were most coherent with those at Prince Rupert and least coherent with those at Tofino (coherence square values are significantly greater than zero at the 90% level if they exceeded 0.25). Peaks in the coherence square vs. frequency curves occurred at 0.06, 0.135 and 0.20, and for the 0.33 to 0.38 cpd band, i.e., at the same frequencies as autospectral peaks.

This study is proceeding; the next step is to utilize atmospheric pressure data and compute cross spectra for the pressure-sea level time series.

Another time-series analysis study concerned numerical demodulation of current velocity time-series to see how the kinetic energy at the inertial frequency varied with time. Data were obtained at Oregon State University and were partially described in my Ph.D. dissertation. One hundred to 240 erg peaks in the time variation of kinetic energy were detected at the inertial frequency. These peaks were superimposed on a noise level of about ten ergs although values as low as three ergs were obtained. These peak values were obtained only in the velocity time-series obtained above the pycnocline. A statistic for the coherence between the two hodographs did not seem very useful.

The demodulation technique and results are given fully in a report submitted to file.

Spectral analysis of 6-week averaged hydrological variables observed at Ocean Station P have been commenced; it is hoped that a preliminary report describing first results can be submitted to file early next year.

6. Support Oceanography

R. H. Herlinveaux and others

(a) Seamount Investigation

During 1969 a joint project with Defence Research Establishment Pacific was undertaken to determine the feasibility of using those seamounts situated off the British Columbia and Washington coasts as observation platforms. Four trips were made to Bowie Seamount to carry out a bathymetric study and to collect rock samples and bottom organisms. Canadian Forces divers were used on two occasions to obtain photographs and to collect samples. Fish were caught by the crew of CSS Parizeau and were brought back for analysis. Oceanographic observations were made over, and in the vicinity of, the seamount. A current meter was operated for 11 hr at 20 m depth while the ship was at anchor over the seamount.

The fish on Bowie Seamount were so numerous (Fig. 10) that the divers had to push them out of the way in order to take photographs. It is possible that these fish make up a resident and isolated population. The bottom organisms at 100 ft are also unique in that they are usually found in shallow intertidal coastal areas.

Defence Research Establishment Pacific installed recording instrument packages on Cobb, Union and Bowie Seamounts. It is planned to retrieve these in late summer, 1970.

(b) Fatty Basin - Lobster Transplant

A program to monitor surface currents (upper 2 m) in Fatty Basin and in the adjacent waters was carried out from March to June, 1969. Continuous current meter observations were made in Junction Passage and in the channel between Fatty Basin and Useless Inlet. Drift cards were also released.

The current observations taken in the channel leading to Useless Inlet from Fatty Basin show that during calm periods surface velocities are proportional to the rate of change of tidal height. However, during periods of relatively strong westerly winds the flood current is approximately twice the predicted flow and the ebb current about one-half the predicted flow. During the easterly winds the ebb flow was greater than the flood flow.

Fig. 10. Concentration of fishes near the Bowie Seamount (100-110 ft), August 14, 1969.

Drift cards released on the ebb tide in the channel between Fatty Basin and Useless Inlet moved out into Barkley Sound and were recovered in Sechelt Channel, Imperial Eagle Channel and Alberni Inlet. Some moved out of Barkley Sound northward toward Amphitrite Point and Long Beach. Two were retrieved on the Washington-Oregon coast. One card recovered at sea indicated a drift of about 12 mi per day.

(c) Observations from the Drill Rig SEDCO-135F

Oceanographic observations (continuous current and temperature data) were continued until May 1969, at which time Shell Oil concluded drilling operations on the continental shelf off the coast of British Columbia. Preliminary analysis of the data shows that off the west coast of Vancouver Island the net flow at 100 m depth was at a rate of 3.0 nautical miles per day during the period February 12-20, 1969. The maximum velocity recorded was 1.08 knots. There was a suggestion of a weak clockwise tidal component.

Further analysis of the data from the drill rig will be carried out as a cooperative program with Dr. C. Collins, M.S.B.

7. Daily Seawater Observations

H. J. Hollister

During 1969 surface sea temperature and salinity observations were made daily at 17 shore stations, the majority being located at Department of Transport lightstations. Starting in July, the collection of seawater samples for the laboratory analysis of salinity has been replaced at all but one station by the use of *in situ* measurement of seawater density by hydrometer. This changes the accuracy of the salinity data from 0.05‰ by analysis to 0.5‰ by hydrometer. It brings to an end, in a number of cases, 35 years of salinity determinations of seawater samples. Most of the stations were visited in the summer and fall months to deliver the hydrometer equipment and explain its use. The Canadian Coast Guard helicopter services were used extensively for these journeys; visits by land transportation were also involved.

Seawater temperatures at most stations were below normal during the winter months of January and February. This is a continuation of the cooler trend first noted in the December 1968 records. A period of near-normal temperatures followed in the spring and early summer months until June, when eight of the stations reported above-normal temperatures. In August and September most stations had below-normal temperatures. Normal temperature conditions were generally prevalent in October and November, except at the three stations in Hecate Strait and the one at Cape St. James, all four of which reported above-normal temperatures. Salinities were most often near normal in the first 5 months of the year, with the exception of scattered occurrences of below-normal conditions at the stations on the Vancouver Island shores and in the Strait of Georgia during the 3-month period April to June.

At Langara Island, in the entrance to Dixon Entrance, monthly mean sea temperatures ranged from a minimum of 4.9 C in January and February to a maximum of 11.5 C in September. During the first 3 months of the year, temperatures were 1.1 C below normal. For the remaining 8 months the temperatures were never more than ±0.4 C from normal values. At the stations in the Hecate Strait region, sea temperatures ranged from a minimum of 4.4 C in February at Bonilla Island to a maximum of 12.9 C in July at McInnes Island. Temperatures were about 1.5 C below normal during the first 2 months, but in June they were 1.0 C above normal. A brief period of normal temperatures in July preceded a change to temperatures 0.7 C below normal in August and September. This cooler trend was reversed in October and November; at these times temperatures were 0.7 C above normal. Pine Island temperatures have a smaller seasonal range, from 6.1 C in February to only 9.9 C in July. Here also, winter temperatures were below normal; the spring and summer temperatures were in general normal, below-normal conditions being experienced only in August.

Along the exposed open coast from Cape St. James to Amphitrite Point, the average winter temperature of 6.1 C in February was 1.1 C below normal. The average summer temperature was 12.5 C. June temperatures were 1.0 C above normal. Below-normal temperatures occurred variously in August and September, followed by near-normal temperatures at Kains Island and Amphitrite Point during October and November. At Cape St. James during these latter 2 months, temperatures were above normal. At Race Rocks, in Juan de Fuca Strait, the sea temperatures ranged from a minimum of 6.4 C in February to a maximum of 10.5 C in August, just slightly higher than the temperatures recorded at Pine Island, at the extreme northern end of Vancouver Island. Significant below-normal temperatures were recorded at Race Rocks during the winter months of January and February, and during the fall months of September and October. Summer temperatures at Sheringham Point, 15 miles further westward in the Strait, were 0.7 C higher than at Race Rocks.

In the Strait of Georgia, temperatures at the shore stations ranged from a minimum of 5.1 C in January at Sisters Island to a maximum of 18.2 C in July at Departure Bay. Temperatures averaging 1.2 C below normal were observed at stations in the central strait region during the first 4 months of the year. At Entrance Island the deficiency was as much as 1.6 C in January. Above-normal temperatures were reported at several stations for various months during the period May to July. Temperatures about 1.5 C below normal were observed in August and September in the central region, while at Cape Mudge in the northern region, below-normal conditions prevailed in July and September. Summer temperatures at Porlier Pass and Active Pass were 1 to 2 C lower than at Entrance Island.

Salinity data are available from most stations until May, and from a few until July. The patterns of monthly variations in salinity conditions change from region to region, but there was no clearcut, overall trend away from normal levels along the whole coast. There was only one occurrence of above-normal salinity, in January at Kains Island. Salinities for the most part were near normal, except for 1 or 2 months in the April to June period,

when below-normal conditions were reported from stations along the coast of Vancouver Island south of Pine Island and in the Strait of Georgia. This was probably caused by excessive rainfall and river discharges that prevailed both on Vancouver Island and on the mainland coast during these 3 months.

8. POLLUTION STUDIES — M. Waldichuk

(a) Pollution - Oceanography — M. Waldichuk and J. Meikle

Two 10-day cruises were made in August and September, 1969. Oceanographic stations were taken in waters receiving pulpmill wastes along the east coast of Vancouver Island and in the northern passages and inlets in existing and potential pulpmill areas. The data are being processed for publication.

The study of the effect of winds on flushing Departure Bay, for which field work was carried out during July-August 1968, is being pursued in collaboration with Dr. T. S. Murty of DEMR, Ottawa. From early numerical analysis, there is agreement of theory and observations on upwelling by strong sustained westerly winds. The effect of offshore winds in such areas may prove to be an important factor in flushing out wastes received at the surface.

(b) Effects of Water-borne Solids — A. E. Werner

Setting of wood particles. The apparatus for measuring "active" diameters was tested with 5 mm glass beads and 1/8-inch stainless steel balls and found to function satisfactorily. It was then applied to fifteen kinds of wood particles, made of fir, cedar and hemlock woods in five particle sizes (63, 80, 125, 250 and 500 microns).

Methods of operation:

(i) The basic "fixed bed" method was refined to a "compressed bed" system in which (a) the initial column length is varied with the particle size in such a way that reasonable pressure differences are obtained at all flow rates used; (b) the water velocities are so adjusted that all measurements fall into the same flow range (laminar, intermediate); (c) the actual, not the nominal, column length is recorded together with flow and pressure difference. This method was particularly suitable for medium and large particles.

(ii) In the "expanded bed" method the expansion of an unconfined bed is measured as a function of water velocity.

Experience showed that increasing the latter caused the upper bed limit to become increasingly diffuse even with repeatedly screened particles. Particles

graded by elutriation gave slightly sharper boundaries. The "expanded bed" method was developed mainly for small particles. Data from both improved methods have been used to calculate "active" diameters. The calculations were based on formulae incorporating published empirical constants not necessarily applicable to wood. Consequently, the results bear little relation to the nominal particle sizes obtained by screening or, indeed, to one another. Therefore, these literature constants are now being re-evaluated for wood particles on the basis of our own data. Ultimately the "active" diameters will be related to the results of forthcoming experiments with the sedimentation trough.

Preliminary trials of the sedimentation trough were restricted to wood particles of intermediate to large particle sizes (125-500 microns). The particles behaved as expected in that even homogeneous-size groups settled in a pile not characterized by a Gaussian distribution. The following modifications were made to the equipment:

(i) The middle section was lengthened from 1 m to 3 m.

(ii) Larger flow meters were installed.

(iii) A larger reservoir was inserted between circulating pump and trough.

(iv) The return flow system was enlarged.

(v) The orifices of the weirs were enlarged.

(vi) The particle feed system was moved forward.

(vii) Drains and feed inlets were provided.

These modifications extend the capacity of the trough to handle smaller particles and to make more accurate measurements.

Microbiology. Bacteriological surface and bottom samples were taken at 12 stations off Port Alice on June 2, 1969. The organisms in these samples were subjected to standard bacteriological techniques in order to culture and isolate cellulose-degrading microbes. The surface water of all stations was free from cellulo-clastic organisms and so were 2-3 of the bottom samples. The latter came from marginal stations (at which gas had not been observed in 1966). All other bottom samples contained an abundance of cellulose degraders.

All surface and about half the bottom samples contained Gram-positive organisms although there were many more Gram-negative vilvios, rods, tetrads and thread-like aggregates. Malodoriferous gas was produced in nearly all cases, suggesting not only H_2S but also skatole. The attack on cellulose (Whatman filter paper No. 1) consisted in perforating the paper wherever colonies had settled, forming a viscous suspension of the decaying fibres. The cellulose degraders grew at 15 C but not at 25 C and in anaerobic conditions only. The accompanying organisms were not so selective.

Similar samples were taken at 12 stations off Port Alberni in October. In addition to treating them like those from Port Alice, they are also being tested for ligno-clastic organisms. Fir, cedar, and hemlock woods are used. Growth and gas production was observed in nearly all samples, but attack on wood and cellulose is not yet apparent. This is normal in view of the 134-day incubation period which the Port Alice samples required.

Bio-assay of wood-extractives. The toxicity to Arternia salina was tested of seawater extracts of fir, cedar and hemlock woods. Animals exposed at 23 C for 24 hr to various concentrations of these extracts were so highly resistant as to render this species unsuitable as a test-organism. Search for a test-organism continues.

Leaching rates. The installation was modified and the water handling and filtration system enlarged. The first few batches of leaching data were produced.

SCIENTIFIC SERVICES

S C I E N T I F I C S E R V I C E S G R O U P G.L. Robins

1969 was an important year for Scientific Services in that they finally emerged as a cohesive and effective group encompassing not only the "traditional" service departments, but also Station facilities previously annexed to individual investigations or Research Groups. The Scientific Services Group, as of December 31, 1969, was comprised of the following departments:

Chemistry Stores and Bulk Stores

Engineering Research and Development

Fish Culture (Facilities at Nanaimo and Rosewall Creek)

Histology

Library

Publications and Information Unit

Statistics and Computations

The collection of these departments under one administrative "umbrella" will ease operational problems and, hopefully, generate an esprit-de-corps which is always evident in the Research Groups, but is not an obvious factor in Administration or in Service Groups.

1. ENGINEERING RESEARCH AND DEVELOPMENT GROUP W.H. Bell

During the year, the activities of the Group were concentrated in three areas:

(1) Major instrumentation projects involving various fields of engineering, but particularly electronics.

(2) Minor instrumentation projects; assistance to investigations in the solution of minor engineering problems; routine maintenance of research equipment.

(3) Monitoring new advances in instrument technology and briefing scientists on new items or techniques which may be relevant to their fields of research.

Major projects included an opto-electronic plankton size distribution counter for plankton having lengths greater than 0.5 mm. This was completed about mid-year and turned over to the Environmental Research Group for final sample sizing tests. A data acquisition system was completed for the Genetics Investigation, to interface certain measuring apparatus outputs to computer-compatible paper tape. Development of a photo-electric salmon scale reader for the Salmon Stock Assessment Investigation neared completion, together with a data acquisition system. Other projects completed during the year included an infra-red activity monitor, an X-Y coordinate reader, an air drying and sampling system, and modifications to several existing items of scientific equipment.

Assistance on the engineering aspects of the Great Central Lake fertilization scheme was provided to the Environmental Research Group. The feasibility of magnetic tag detection on steel vessels was examined in connection with the proposed herring tag and recovery program. Field and laboratory support was provided to the lobster transplant program, particularly in connection with sonic tags. In addition, technical assistance and consulting services were provided to various investigations in connection with low light level measuring and observing systems, data acquisition and processing equipment, underwater towed vehicles, fish tank systems, etc.

The group has been consulted on the purchase, construction and operation of various types of apparatus. Considerable repair, maintenance, and machining services have been provided in connection with Station equipment. New advances in commercial equipment have been examined and brought to the attention of Station scientists, where appropriate. In some instances, demonstrations have been arranged for research personnel.

2. FISH CULTURE — R. M. Humphreys

The Fish Culture services were again in great demand in 1969 with 75 tanks of various sizes in use for most of the year. Approximately 40,000 salmon, of all species, were reared for experiments conducted by 9 investigations, and for stocks which will be held into 1970. The Fish Culture service provided facilities for studies on salmon hybridization, salmon scale development, diet-induced parasitic infection and diet-induced internal tagging, as well as space for a "production tank" sockeye experiment carried out by the Physiology Investigation. Ten tanks of sablefish were reared throughout the year as part of a continuing study. Two tanks of adult herring were held to provide spawn for larval studies, and lobsters were reared for experimental purposes.

Recent growth of the Fish Culture facility resulted in an unsightly sprawl of tanks around the outer perimeter of the building. In 1969, to consolidate these in one area and also to provide better control over their contents, a 30-ft by 60-ft addition was built on the landward side of the

former building. This provided space for seventeen 6- and 8-ft diameter tanks. In addition, a light-proof room was constructed in the building to provide a facility for the scale development experiment previously mentioned. A small heat exchanger was built and tested. This was used in conjunction with a "Min-O-Cool" portable refrigeration unit to provide water at a constant temperature for experimental purposes.

Rosewall Creek

The Rosewall Creek freshwater facility was transferred to Fish Culture in August of 1969. The facility has continued to be mainly used by the salmon egg and alevin, and salmon genetic investigations. However, many other investigations have showed great interest in the excellent facilities at the Rosewall station and plan to utilize them in 1970. During the year, an incubation room and dark room were built in the laboratory building, a fire pump house constructed and a diesel-driven pump installed to provide more fire protection for the facility.

Other improvements carried out were the installation of a rock dike to prevent erosion of the river bank near the pump house, installation of a smaller third diesel generator to provide additional electric power, and the installation of a gauge line in the groundwater well to provide a measure of pump drawdown.

The demonstrated suitability of the ground and surface waters for fish culture purposes provides the Station with additional experimental and culture facilities of a high quality.

3. HISTOLOGY — J. W. Bagshaw

During the course of the past year this department has functioned within three main spheres of activity. These are:

(1) Provision of an histological service by preparing, for microscopic examination, various samples of animal tissue as required by the investigations.

(2) Execution of interpretive work on prepared tissues as requested.

(3) Development of new techniques or modification of existing methods in order to meet the requirements of certain projects.

The major part of the year's work was devoted to the first of the three categories. Among the projects undertaken have been the sectioning of

invertebrate gonadal material to ascertain spawning condition, the gonads of herring, two local species of shrimp (P. hypsinotus and P. jordani), and the ovaries and testes of hybrid salmon to determine fertility. Several types of parasitic copepods have been sectioned for anatomical studies. Some interpretive work was carried out on the gonads of the herring whereby the histologist was requested to compare the gross findings of the investigators with the microanatomical detail and classify them according to an international scale. The scales of young sockeye salmon have been sectioned using a technique developed by this department, whereby the scales (the smallest measuring 0.2 mm) are sectioned perpendicularly to the horizontal plane and almost exactly through the nucleus of the scale, giving a section roughly 1 μ in thickness. This work is being done at the request of an investigator concerned with the growth characteristics of scales.

There was, in 1969, a marked increase in the number of requests received from investigations and it would seem likely that this upward trend will continue through 1970, especially in the interpretive field.

In December, Histology joined the Scientific Services Group and became a separate department directed by the Scientific Assistant to the Director.

4. STATISTICS AND COMPUTATIONS — J. A. C. Thomson

During 1969 the Station's IBM 1130 computer logged over 1,895 computing hours, a 10% increase over 1968. The addition, early in January, of a further 8 K of core not only had a significant effect on the efficiency of many existing programs but also allowed for larger and more sophisticated programs. Later in the year the addition of an 8 channel paper tape reader allowed users to enter data into the computer directly from a wide assortment of laboratory and field measuring devices. Almost all of the Station's investigations made use of the service during 1969. The following table gives the percentage used by the major groups:

Group/Investigation	% of total	Hours
Computer Service	12	227.5
Fisheries Biology Group - total	23.6	446.8
Population Dynamics	7.3	139.1
Marine Mammal Models	4.4	83.1
Experimental Biology and Pathology Group	32.6	618.2
Genetics	11.8	223.2
Physiological Ecology	20.2	382.2
Environmental Research Group	5.5	103.8
Pacific Oceanographic Group	15.8	300.1
Department of Energy, Mines & Resources	10.5	198.6

The additional core permitted significant advances and extensions to major statistical analysis programs, notably the response surface package and the discriminant function analysis. A series of growth and yield programs were either converted or developed. Specialized programs for X-ray spectrum analysis and activity analysis were also developed to use directly produced data on paper tape. As in the past, a fair percentage of the output from the computer was used directly in both Manuscript and Technical Reports.

During the year the computer centre staff gave a series of 3-day courses on Fortran programming, a series of lectures on likelihood estimates in statistics, and a seminar on multivariate analysis. Over 45 staff members attended one or more of these courses. There has been an increase in the number of investigators writing their own programs with varying amounts of assistance from the staff of the centre. This in itself is an additional measure of the value of the service.

STAFF LIST

S T A F F L I S T

All employees are listed who were on strength during any part of the period Jan. 1, 1969 to Dec. 31, 1969. The arrangement of investigations and services applies to the major portion of the year.

Director	K.R. Allen, M.A., F.R.S.N.Z.
Assistant Director	K.S. Ketchen, Ph.D.
Scientific Assistant to Director	G.L. Robins, Ph.D.
Executive Assistant	I.J. Strong, B.A.
Senior Scientist (H.Q. Staff)	W.E. Ricker, Ph.D., F.R.S.C.
Anadromous Fishes Group	R.R. Parker, Ph.D. (Group Head)
ST 5	Frances C. Helsing (Group Secretary)
Coho Biology	
Scientist 2 in charge	J.C. Mason, Ph.D.
Technician 3	D.W. Rimmer, B.Sc.
Experimental Hatchery and Genetics	
Scientist 3 in charge	J.R. Calaprice, Ph.D.
EG 5	R. Hungar
EG 4	A.J. Solmie (from 1 Apr)
GL 7	G.E. Johnston (to 21 Aug)
GL 7	E.W.H. Moore (to 21 Aug)
Technician 1	R. Angotti (10 Feb to 30 Aug)
Assistant Technician 3	R.B. Hobbs (14 Jul to 25 Aug)
Salmon Eggs & Alevins	
Scientist 2 in charge	R.A. Bams, Phil. Drs.
Technician 6	R.C. Wilson
EG 4	D.G. Crabtree
Assistant Technician 3	D.G. Andrew (20 Jun to 21 Aug)
Student Assistant	Nadine F. Bentley (26 May to 30 Aug)

Salmon Stock Assessment	
Scientist 2 in charge	H.T. Bilton, B.A.
EG 6	D.W. Jenkinson
EG 3	M.M. Aarts (to 25 Oct)
Assistant Technician 3	D.E. Wilson (30 Jun to 29 Aug)
Assistant Technician 3	W.J. Wyllie (23 Jun to 30 Aug)
Chinook and Coho Hatchery Evaluation	
Scientist 3 in charge	H. Godfrey, M.A.
EG 6	E.A.R. Ball
Technician 2	T. Leetma (28 Apr to 6 Sep)
Assistant Technician 3	R.M.T. Chiang (28 Apr to 6 Sep)
Assistant Technician 3	B.C. Jones (1 May to 30 Aug)
Assistant Technician 3	P.F. McIntosh (28 Apr to 16 Aug)
Assistant Technician 3	G. Tong (23 Jun to 6 Sep)
Assistant Technician 3	B. Wong (23 Jun to 6 Sep)
Babine Development Research	
Scientist 3 in charge	J. McDonald, M.A.
EG 6	A.S. Coburn
EG 5	J.R. Scarsbrook
Lacustrine Ecology	
Scientist 3 in charge	D.W. Narver, Ph.D.
EG 6	B.C. Andersen, B.Sc.
Student Assistant	Penelope L. Brown (12 May to 6 Sep)
Student Assistant	Wendy A. Lake (18 Jun to 30 Aug)
Babine Sockeye Production	
Scientist 2 in charge	H.W.D. Smith, M.Sc.
EG 7	F.P. Jordan
EG 6	I. Miki
EG 5	J. Martell
Assistant Technician 3	R.G. Aaronson (20 Jun to 21 Aug)
Assistant Technician 3	H.H. Klassen (20 Jun to 21 Aug)
Assistant Technician 3	C.D.L. MacKenzie (14 Jul to 3 Sep)
Assistant Technician 3	N.J. McLean (20 Jun to 3 Sep)
Assistant Technician 3	M.J. Rawlins (14 Jul to 30 Aug)
Assistant Technician 3	C. Slade (14 Jul to 3 Sep)
Assistant Technician 3	P.A. Truelove (14 Jul to 3 Sep)
Salmon Stream Ecology	
Scientist 3 in charge	J.H. Mundie, Ph.D.
EG 5	D.E. Mounce, B.Sc.
Student Assistant	Catherine L. Farmer (7 May to 16 Aug)

Special Salmon Projects	
Scientist 4 in charge	F.C. Withler, M.A.
EG 6	R.B. Morley, B.Sc.
Ethology	
Scientist 3 in charge	C. Groot, Ph.D.
Technician 6	C.E. Turner
Graduate Student Assistant	K.S. Simpson (1 May to 6 Dec)
Marine Ecology of Salmon	
Scientist 4 in charge	R.R. Parker, Ph.D.
EG 4	Beverley A. Bravender, B.Sc.
Marine Ecology	
Scientist 3 in charge	J.I. Manzer, M.A.
Studies of Salmon on the High Seas	
Scientist 4 in charge	M.P. Shepard, Ph.D. (seconded to Dept. Fisheries and Forestry)
Scientist 2	K.V. Aro, B.A.
CR 5	Dorothy P. Giovando
Marine Fisheries Group	K.S. Ketchen, Ph.D. (Group Head)
ST 5	Eleanor E. Kehler (Group Secretary)
Groundfish	
Scientist 5 in charge	K.S. Ketchen, Ph.D. (returned from secondment to Ottawa 6 Aug)
Scientist 4	S.J. Westrheim, M.Sc.
Scientist 4	W.A. Kennedy, Ph.D.
Technician 8	C.R. Forrester
Technician 6	R.M. Wilson
EG 7	W.R. Harling
EG 6	D. Davenport
EG 5	R.M. Wowchuk
EG 4	M.S. Smith
EG 3	Doris E. Chilton
CR 4	Janice E. Smith

Herring and other Pelagic Fishes	
Scientist 4 in charge	F.H.C. Taylor, Ph.D.
Scientist 3	A.S. Hourston, Ph.D.
Scientist 2	D.N. Outram, B.A.
EG 6	R.S.K. Isaacson
EG 6	J.S. Rees
EG 6	L.W. Barner
EG 5	C.W. Haegele, B.Sc.
EG 4	A. Rigby
EG 4	E.W. Stolzenberg
Assistant Technician 3	M. Sawyer (2 Jun to 1 Nov)
Student Assistant	Beverley J. Davies (25 Jun to 30 Aug)
Student Assistant	S. Jane Donnelly (5 May to 14 Aug)
Student Assistant	Kathi R. Hogan (3 Jul to 30 Aug)
Molluscs	
Scientist 4 in charge	D.B. Quayle, Ph.D.
Scientist 3	N. Bourne, Ph.D.
Scientist 2	M.J. Tynen, Ph.D. (to 16 Jan)
EG 7	F.R. Bernard
EG 6	D.W. Smith, B.Sc.
EG 5	P.A. Fraser
Student Assistant	D.M. Bianchin (28 Apr to 30 Aug)
Shrimp and Crab	
Scientist 3 in charge	T.H. Butler, M.A.
EG 7	A.N. Yates
Student Assistant	R.H. Hiltz (26 Jun to 29 Aug)
Lobster	
Scientist 3 in charge	R.J. Ghelardi, Ph.D.
EG 7	C.T. Shoop
Assistant Technician 3	F.C. Lazuk (9 Jun to 10 Sep)
Assistant Technician 2	C.R. Hill (to 1 Nov)
Caretaker 2	Ann J. Hill (to 1 Nov)
Pacific Oceanographic Group	M. Waldichuk, Ph.D. (Group Head)
ST 5	Sandra B. Bowers (Group Secretary) (to 30 Oct)
Pollution	
Scientist 5 in charge	M. Waldichuk, Ph.D.
Technician 7	A.E. Werner
Technician 3	W.F. Hyslop, B.Sc. (to 9 Jul)

Oceanic Coastal Program	
Scientist 3 in charge	A.J. Dodimead, M.Sc.
Student Assistant	T.E. Bohart (30 Jun to 30 Aug)
Student Assistant	L.A. Spearing (2 Jun to 30 Aug)
Physical Oceanography	
Scientist 3 in charge	S. Tabata, Ph.D.
Scientist 3	L.F. Giovando, Ph.D.
Scientist 2	P.B. Crean, M.A.
EG 7	A.J. Stickland
EG 6	J.H. Meikle
GL 9	R.E.O. Forbes
Assistant Technician 3	B. de Lange Boom (2 May to 3 Sep)
Student Assistant	Taina M. Tuominen (1 May to 30 Aug)
Biological Oceanography	
Scientist 4 in charge	T.R. Parsons, Ph.D.
Scientist 3	C.D. McAllister, M.A.
Scientist 3	R.J. LeBrasseur, M.A.
Scientist 2	W.E. Barraclough, M.A.
EG 7	J.D. Fulton
EG 6	O.D. Kennedy
EG 5	R.G. Robinson, B.Sc.
Assistant Technician 3	M.J. Hardon (1 May to 6 Sep)
Assistant Technician 3	H.R. Newman (1 May to 30 Aug)
Assistant Technician 3	S.W. Sheehan (1 May to 30 Aug)
Student Assistant	Carole Stanley (5 May to 30 Aug)
Fishery Ecology	
Scientist 3 in charge	W.P. Wickett, M.A.
Student Assistant	Lesley E. Smith (17 Jun to 30 Aug)
Support Oceanography	
Technician 7	R.H. Herlinveaux
Daily Seawater Observations	
Technician 7	H. Hollister
Weathership (Line P) Program	
EG 5	K.A. Gantzer
EG 5	J. Wong, B.Sc. (to 1 Nov)
EG 5	R.H. Bigham
Technician 2	O.H. Joergensen, B.Sc. (to 1 Aug)

Pathology and Physiology Group	L. Margolis, Ph.D. (Group Head)
ST 5	L. Mavis Colclough (Group Secretary)
Parasitology	
Scientist 5 in charge	L. Margolis, Ph.D.
Scientist 4	Z. Kabata, D.Sc.
Scientist 2	N.P. Boyce, M.Sc.
EG 5	T.E. McDonald, B.Sc.
Student Assistant	J.H. Yearsley (1 May to 13 Sep)
Physiology	
Scientist 5 in charge	J.R. Brett, Ph.D., F.R.S.C.
Scientist 2	J.E. Shelbourn, M.Sc. (educational leave from 20 Sep 68)
EG 7	D.B. Sutherland
EG 5	G.D. Heritage, B.Sc.
Student Assistant	C.A. Zala (9 Jun to 5 Sep)
Microbiology	
Scientist 3 in charge	G.R. Bell, Ph.D. (returned from Sabbatical leave 18 Aug)
Scientist 3	T.P.T. Evelyn, Ph.D.
EG 6	G.E. Hoskins, B.Sc.
Physiological Ecology	
Scientist 3 in charge	D.F. Alderdice, Ph.D.
EG 6	F.P.J. Velsen
Graduate Assistant	J.S. Griffiths (1 May to 23 Sep)
Scientific Services	G.L. Robins, Ph.D. (Group Head)
Photography and Illustrating	
PY 6	C.J. Morley
DD 5	A.A. Denbigh
Library	
Librarian 3	Emily A. Young
CR 2	Shirley M. Dixon

Computations & Theoretical Population Studies	(Supervised by the Director)
Scientist 2	J.A.C. Thomson, M.Sc.
Scientist 2	L.V. Pienaar, Ph.D. (to 10 Mar)
CS 1	Arlene M. Sandnes
DA 2	Gloria G. Fedechko
DA 2	Kathleen Mitchell
Graduate Assistant	E.A. Price (2 Jun to 5 Sep)
Fish Culture	
Technician 6	R.M. Humphreys
EG 5	W. Griffioen
GL 7	D. Pozar
GL 7	G.E. Johnston (from 22 Aug)
GL 7	E.W.H. Moore (from 22 Aug)
Student Assistant	R.L. Cootes (2 Jul to 30 Aug)
Chemical Laboratory Services	
Technician 6	K.V.C. Stephens
Development & Instrumentation Research	
Scientist 2 in charge	W.H. Bell, M.Sc.
Scientist 2	J.S. Ford, B.A.Sc.
Technician 7	L.D.B. Terhune
EL 5	M.C. Armstrong
EL 4	R.A. Cook
GL 10	G.T. Atkinson
DD 4	D.J. Redman
Graduate Assistant	R.W. Niessen (16 Jun to 5 Sep)
Histology Laboratory Services	
EG 7	J.W. Bagshaw
Secretarial and Registry Services	
CR 5 (Supervising Clerk in charge of Publications; & Director's Secretary)	Ethel E. Robinson
CR 5 (Secretary to Dr. Ricker)	Dorothy Gailus
CR 4 (Files)	Margaret K. Philp
CR 4 (Supervising Clerk, Steno Pool)	Ruth Cote
CR 2 (Assistant Files)	Lois B. Endel
OE 1 (Multilith Operator)	Gloria D. Melluish
ST 3	Terezia Beg
ST 3	Audrey K. Clements
ST 3	Josephine M. Bain
Student Assistant	Lynda M. Kaip (26 May to 30 Aug)

Administrative & Technical Services — I.J. Strong, B.A.

Purchasing, Accounts and Personnel

PG 3 (Purchasing)	O.O. Morgan
PE 3 (Personnel)	J.F. Griffin
FI 1 (Accounts)	L.A. Noon
PG 1 (Purchasing)	J.R. Hancock
GS 5 (Stores)	J. Lucop
CR 4	S.C. Grando
CR 3	R.R.D. Curry (to 15 Jul)
CR 3	Chris M. Gorton
CR 3	Mary Arbanas
ST 5	Doris Luvisotto
ST 2	I. Linda Riddell
GL 4	J.G. Naysmith
Student Assistant	Joyce A. Hurford (13 May to 30 Aug)

Buildings and Grounds

HP 5	H.G. Reinstein (from 17 Feb)
GL 11	M.S. Wilson
GL 7	A.G. Paul
GL 4	J.R. Jardine
GL 4	J.M. McArthur
GL 2	W.W. Thompson
Assistant Technician 3	R.M. Hadley (23 Jun to 16 Aug)

Vessels, Shops and Services

EG 9	J.H. Brennan
GL 10	K. Sutherland (to 14 Jan)
GL 10	A.P. Kirkwood (from 17 Feb)
GL 9	A. Brown
GL 9	M. Ilich

Research Vessels

CGS G.B. Reed

SO 8	J. Liston
SO 7	R. May
SO 4	J. Swindell
SO 4	E.R. Pollard
SO 3	W. Colp
SO 3	W.S. Sutherland
SO 2	D.M. Clerke
SO 2	W. Van Beest (to 4 Nov)
SO 2	W.H. Craigie
SO 2	C. Stewart

SC 5	D.W. Addison
SC 5	A.J. Fletcher
SC 4	M.A. MacLean
SC 4	W.J.E. Hewitt
SC 3	E.C. Ryan
SC 3	G.A. Wiseman
SC 3	A.E. Bailey
SC 3	R.A. Dean
SC 3	J.D.A. MacKay
SC 3	R.H. McLaughlin
SC 3	W.E. Wolden
SC 3	M.G. Frobisher (from 10 Jan)
SC 3	R.N. Ostle (to 12 Jun)
SC 3	R.P. Coulton (from 16 Jun)
SC 3	A. Gow (from 8 Jan)
SC 2	F. Kreger
SC 2	J.M. Mitchell
SC 2	R.H. Slasor
SC 2	R.I. Edwards
SC 1	J.J. Backmann
SC 1	J.W. Johnson (to 30 Aug)

MV A.P. Knight

SO 6	C. Watson
SO 3	W.P. Winstanley
SO 2	L.V.M. Soper
SO 2	W. Ryles
SC 3	W.H. Lutz
SC 3	S.O. Gibson

MV Investigator No. 1

SO 5	J.T. Ferguson
SO 3	R. Page
SO 2	W.D. Nichol
SC 3	L. Stennes

Small Craft

GL 7	R.E. Hirst
GL 7	D.B. Donnelly
GL 5	H. Neate

Personnel from the Marine Sciences Branch of DEMR seconded to the Nanaimo Station

C.A. Collins, Ph.D.	Research Scientist 1	Physical Oceanography (Ocean Station P)
C.S. Wong, Ph.D.	Research Scientist 1	Chemical Oceanography (Ocean Station P)
D.A. Healey, M.Sc.	Scientific Officer 2	Physical Oceanography (Ocean Station P)
A. Huyer (Miss)	Scientific Officer 2	Ocean Station P (from 5 Jan to 25 Sep)
L. Boilard (Miss)	Scientific Officer 2	Ocean Station P (from 12 May to 4 Jul)
K.B. Abbott-Smith	EG 3	Ocean Station P
C. DeJong	EG 4	Ocean Station P
B.G. Minkley	EG 4	Ocean Station P
R.L.K. Tripe	EG 4	Ocean Station P (to 30 Oct)
R. Bellegay	EG 4	Ocean Station P (from 1 Apr)

NON-STAFF RESEARCH WORKERS

C.J. Berkley, F.C.I.C.	Honorary Research Associate
R.E. Foerster, Ph.D.	Honorary Research Associate
F. Neave, Ph.D.	Honorary Research Associate
H. Seki, Ph.D.	NRC Post-doctorate Fellowship (to 25 Aug)
S. Morita, Ph.D.	Exchange Scientist (14 Jan to 15 Apr)
M.C. Healey, Ph.D.	NRC Fellowship (from 15 Oct)
G. Hewitt, Ph.D.	NRC Fellowship (from 22 Dec)

PUBLICATIONS

1. Primary Publications

Allen, K. Radway. 1969. Limitations on production in salmonid populations in streams. University of British Columbia Institute of Fisheries, H. R. MacMillan Lectures in Fisheries, Symposium on Salmon and Trout in Streams 1968. p. 3-18.

1969. An application of computers to the estimation of exploited populations. J. Fish. Res. Bd. Canada 26(1): 179-189.

1969. Distinctive aspects of the ecology of stream fishes: a review. J. Fish. Res. Bd. Canada 26(6): 1429-1438.

1969. Application of the Bertalanffy growth equation to problems of fisheries management: a review. J. Fish. Res. Bd. Canada 26(9): 2267-2281.

Anderson, G. C., T. R. Parsons and K. Stephens. 1969. Nitrate distribution in the subarctic Northeast Pacific Ocean. Deep-Sea Research 16: 329-334.

Bams, R. A. 1969. Adaptations of sockeye salmon associated with incubation in stream gravels. University of British Columbia Institute of Fisheries, H. R. MacMillan Lectures in Fisheries, Symposium on Salmon and Trout in Streams 1968. p. 71-87.

Arai, Hisao P. 1969. A new trematode of the genus Lipidophyllum (Digenea : Steganodermatidae) from a cotid fish, Hemilepidotus hemilepidotus. J. Fish. Res. Bd. Canada 26(4): 799-803.

1969. Preliminary report on the parasites of certain marine fishes of British Columbia. J. Fish. Res. Bd. Canada 26(9): 2319-2337.

Barraclough, W. E., R. J. LeBrasseur and O. D. Kennedy. 1969. Shallow scattering layer in the subarctic Pacific Ocean: detection by high-frequency echo sounder. Science 166: 611-613.

Bell, Gordon R., Gary E. Hoskins and John W. Bagshaw. 1969. On the structure and enzymatic degradation of the external membrane of the salmon egg. Canadian J. Zool. 47(1): 146-148.

Bernard, F. R. 1969. The parasitic copepod Mytilicola orientalis in British Columbia bivalves. J. Fish. Res. Bd. Canada 26(1): 190-191.

1969. Preliminary diagnoses of new septibranch species from the eastern Pacific (Bivalvia, Anomalodesmata). J. Fish. Res. Bd. Canada 26(8): 2230-2234.

Bernard, F. R., and J. W. Bagshaw. 1969. Histology and fine structure of the accessory boring organ of Polinices lewisi (Gastropoda, Prosobranchiata). J. Fish. Res. Bd. Canada 26(6): 1451-1457.

Bilton, H. T., and D. W. Jenkinson. 1969. Age determination of sockeye (Oncorhynchus nerka) and chum (O. keta) salmon from examination of pectoral fin rays. J. Fish. Res. Bd. Canada 26(5): 1199-1203.

Boyce, Norbert P. J. 1969. Parasite fauna of pink salmon (Oncorhynchus gorbuscha) of the Bella Coola River, Central British Columbia, during their early sea life. J. Fish. Res. Bd. Canada 26(4): 813-820.

Bourne, Neil, and D. E. McAllister. 1969. The black hagfish, Eptatretus deani, from British Columbia. J. Fish. Res. Bd. Canada 26(12): 3246-3248.

Bourne, Neil, and M. A. Pope. 1969. Deep-sea line fishing off British Columbia. J. Fish. Res. Bd. Canada 26(9): 2527-2531.

Brett, J. R. 1969. Temperature and fish. Chesapeake Sci. 19(3&4): 275-276.

Brett, J. R., J. E. Shelbourn and C. T. Shoop. 1969. Growth rate and body composition of fingerling sockeye salmon, Oncorhynchus nerka, in relation to temperature and ration size. J. Fish. Res. Bd. Canada 26(9): 2363-2394.

Butler, T. H., and R. W. Sheldon. 1969. Trawl-board sediment sampler. J. Fish. Res. Bd. Canada 26(10): 2751-2753.

Calaprice, J. R. 1969. Production and genetic factors in managed salmonid populations. University of British Columbia Institute of Fisheries, H. R. MacMillan Lectures in Fisheries, Symposium on Salmon and Trout in Streams 1968. p. 377-388.

Evelyn, T. P. T. 1968. Tissue levels of chloramphenicol attained in sockeye (Oncorhynchus nerka) and coho (O. kisutch) salmon by feeding. Bull. Off. Int. Epiz. 69(9-10): 1453-1463.

Forrester, C. R. 1969. Results of English sole tagging in British Columbia waters. Pacific Marine Fisheries Commission Bull. 7: 1-10.

1969. Sinistrality in Platichthys stellatus off British Columbia. J. Fish. Res. Bd. Canada 26(1): 191-196.

Kabata, Z. 1969. Four Lernaeopodidae (Copepoda) parasitic on fishes from Newfoundland and West Greenland. J. Fish. Res. Bd. Canada 26(2): 311-324.

1969. Phrixocephalus cincinnatus Wilson, 1908 (Copepoda : Lernaeoceridae): morphology, metamorphosis, and host-parasite relationship. J. Fish. Res. Bd. Canada 26(4): 921-934.

1969. Tanypleuridae fam. nov. (Copepoda : Caligoida), parasitic on fishes in the Canadian Atlantic. J. Fish. Res. Bd. Canada 26(6): 1407-1414.

1969. Revision of the genus Salmincola Wilson, 1915 (Copepoda : Lernaeopodidae). J. Fish. Res. Bd. Canada 26(11): 2987-3041.

1969. Chondracanthus narium sp. n. (Copepoda : Chondracanthidae), a parasite of nasal cavities of Ophiodon elongatus (Pisces : Teleostei) in British Columbia. J. Fish. Res. Bd. Canada 26(11): 3043-3047.

1969. Copepoda parasitic on Australian fishes. IX. Family Chondracanthidae. J. nat. Hist. 3: 497-507.

LeBrasseur, R. J. 1969. Growth of juvenile chum salmon (Oncorhynchus keta) under different feeding regimes. J. Fish. Res. Bd. Canada 26(6): 1631-1645.

LeBrasseur, R. J., W. E. Barraclough, O. D. Kennedy and T. R. Parsons. 1969. Production studies in the Strait of Georgia. Part. III. Observations on the food of larval and juvenile fish in the Fraser River plume, February to May, 1967. J. exp. mar. Biol. Ecol. 3(1): 55-61.

Levings, C. D. 1969. The zoarcid Lycodopsis pacifica in outer Burrard Inlet, British Columbia. J. Fish. Res. Bd. Canada 26(9): 2403-2412.

McAllister, C. D. 1969. Aspects of estimating zooplankton production from phytoplankton production. J. Fish. Res. Bd. Canada 26(2): 199-220.

McDonald, J. G. 1969. Distribution, growth, and survival of sockeye fry (Oncorhynchus nerka) produced in natural and artificial stream environments. J. Fish. Res. Bd. Canada 26(2): 229-267.

Manzer, J. I. 1969. Stomach contents of juvenile Pacific salmon in Chatham Sound and adjacent waters. J. Fish. Res. Bd. Canada 26(8): 2219-2223.

Margolis, L., and N. P. Boyce. 1969. Life span, maturation, and growth of two hemiurid trematodes, Tubulovesicula lindbergi and Lecithaster gibbosus, in Pacific salmon (genus Oncorhynchus). J. Fish. Res. Bd. Canada 24(6): 893-907.

Mason, J. C. 1969. Hypoxial stress prior to emergence and competition among coho salmon fry. J. Fish. Res. Bd. Canada 26(1): 63-91.

Mundie, J. H. 1969. Ecological implications of the diet of juvenile coho in streams. University of British Columbia Institute of Fisheries, H. R. MacMillan Lectures in Fisheries, Symposium on Salmon and Trout in Streams 1968. p. 135-152.

Narver, David W. 1969. Productivity of Owikeno Lake, British Columbia. J. Fish. Res. Bd. Canada 26(5): 1363-1368.

1969. Age and size of steelhead trout in the Babine River, British Columbia. J. Fish. Res. Bd. Canada 26(10): 2754-2760.

Parker, Robert R. 1969. Validity of the binomen Caligus elongatus for a common parasitic copepod formerly misidentified with Caligus rapax. J. Fish. Res. Bd. Canada 26(4): 1013-1035.

Parsons, T. R. 1969. The use of particle size spectra in determining the structure of a plankton community. J. Oceanogr. Soc. Japan 25(4): 172-181.

Parsons, T. R., R. J. LeBrasseur, J. D. Fulton and O. D. Kennedy. 1969. Production studies in the Strait of Georgia. Part. II. Secondary production under the Fraser River plume, February to May, 1967. J. exp. mar. Biol. Ecol. 3(1): 39-50.

Parsons, T. R., and H. Seki. 1969. A short review of some automated techniques for the detection and characterization of particles in sea water. Bull. Japan. Soc. Fisheries Oceanog., Special Number (Prof. Uda's Commemorative Papers). p. 173-177.

Parsons, T. R., K. Stephens and R. J. LeBrasseur. 1969. Production studies in the Strait of Georgia. Part I. Primary production under the Fraser River plume, February to May, 1967. J. exp. mar. Biol. Ecol. 3(1): 27-38.

Pienaar, L. V., and J. A. Thomson. 1969. Allometric weight-length regression model. J. Fish. Res. Bd. Canada 26(1): 123-131.

Pike, G. C., and I. B. MacAskie. 1969. Marine mammals of British Columbia. Bull. Fish. Res. Bd. Canada 171. 54 p.

Quayle, D. B. 1969. Paralytic shellfish poisoning in British Columbia. Bull. Fish. Res. Bd. Canada 168. 68 p.

1969. Pacific oyster culture in British Columbia. Bull. Fish. Res. Bd. Canada 169. 192 p.

Rausch, R. L., and L. Margolis. 1969. Plicobothrium globicephalae gen. et sp. nov. (Cestoda : Diphyllobothriidae) from the pilot whale, Globicephala melaena Traill, in Newfoundland waters. Can. J. Zool. 47(5): 745-750.

Ricker, W. E. 1969. Effects of size-selective mortality and sampling bias on estimates of growth, mortality, production, and yield. J. Fish. Res. Bd. Canada 26(3): 479-541.

Ricker, W. E., and H. H. Ross. 1969. The genus Zealeuctra and its position in the family Leuctridae (Plecoptera, Insecta). Can. J. Zool. 47(6): 1113-1127.

Seki, Humitake. 1969. Marine microorganisms associated with the food of young salmon. Appl. Microbiol. 17(2): 252-255.

Seki, H., and J. Fulton. 1969. Infection of marine copepods by Metschnikowia sp. Mycopathol. Mycol. Appl. 38, Fasc. 1-2, p. 61-70.

Seki, H., and Owen D. Kennedy. 1969. Marine bacteria and other heterotrophs as food for zooplankton in the Strait of Georgia during the winter. J. Fish. Res. Bd. Canada 26(12): 3165-3173.

Seki, Humitake, and Douglas G. Robinson. 1969. Effect of decompression on activity of microorganisms in seawater. Int. Revue ges. Hydrobiol. 54(2): 201-205.

Seki, H., K. V. Stephens and T. R. Parsons. 1969. The contribution of allochthonous bacteria and organic materials from a small river into a semi-enclosed sea. Arch. Hydrobiol. 66(1): 37-47.

Tanaka, S., M. P. Shepard and H. T. Bilton. 1969. Origin of chum salmon (Oncorhynchus keta) in offshore waters of the North Pacific in 1956-1958 as determined from scale studies. Intern. North Pacific Fish. Comm. Bull. 26. 57-155.

Tautz, Arthur, P. A. Larkin and W. E. Ricker. 1969. Some effects of simulated long-term environmental fluctuations on maximum sustained yield. J. Fish. Res. Bd. Canada 26(10): 2715-2726.

Waldichuk, Michael. 1969. Eutrophication studies in a shallow inlet on Vancouver Island. J. Water Pollution Control Fed., Part 1, 41(5): 745-764.

2. Interpretive Publications

Outram, D., and C. Haegele. 1969. The time and extent of herring spawning along the British Columbia coast in 1969. Fish. Res. Bd. Canada, Nanaimo Biol. Sta. Circ. 88. 15 p. [Also appeared in Western Fisheries 79(6): 17-18, 20, 22, 52-54.]

Waldichuk, Michael. 1969. Effects of pollutants on marine organisms, improving methodology of evaluation - a review of the literature. J. Water Pollution Control Fed. 41(9): 1586-1601.

3. Sub-Publications

Allen, K. Radway. MS, 1969. A re-examination of recruitment in Antarctic fin whale stocks. Fish. Res. Bd. Canada MS Rept. 1044. 8 p.

Anon. MS, 1969. Ocean weather station "P", North Pacific Ocean, September 15 to December 7, 1967. Canadian Oceanog. Data Centre, 1969 Data Record Ser. 3. 118 p.

MS, 1969. Ocean weather station "P", North Pacific Ocean, December 3, 1967 to February 28, 1968. Canadian Oceanog. Data Centre, 1969 Data Record Ser. 6. 116 p.

MS, 1969. Ocean weather station "P", North Pacific Ocean, February 23 to May 23, 1968. Canadian Oceanog. Data Centre, 1969 Data Record Ser. 10. 149 p.

MS, 1969. Ocean weather station "P", North Pacific Ocean, May 17 to August 15, 1968. Canadian Oceanog. Data Centre, 1969 Data Record Ser. 12. 163 p.

Ball, E. A. R., and H. Godfrey. MS, 1969. Lengths and ages of chinook salmon taken in the British Columbia troll fishery in 1968. Fish. Res. Bd. Canada MS Rept. 1073. 53 p.

Barraclough, W. E. MS, 1969. The need for measurements of acoustical characteristics of underwater sound scatterers in fisheries research. In Abstracts, Symposium on North Pacific Oceanography and Biology, Hakodate, Japan. p. 13.

Bilton, H. T. MS, 1969. Evaluation of the sampling of British Columbia catches of sockeye, chum and pink salmon. Fish. Res. Bd. Canada MS Rept. 1036. 22 p.

MS, 1969. Evaluation of the sampling of the Skeena River 1968 sockeye catch. Fish. Res. Bd. Canada MS Rept. 1057. 6 p.

Bilton, H. T., and H. D. Smith. MS, 1969. Scale characteristics of sockeye salmon (Oncorhynchus nerka) originating from small nursery areas of the Skeena River system. Fish. Res. Bd. Canada Tech. Rept. 133. 33 p.

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MS, 1969. Population studies on the razor clam at Masset, British Columbia. Fish. Res. Bd. Canada Tech. Rept. 118. 24 p.

Butler, T. H. MS, 1969. Catch and effort statistics of the Canadian shrimp fishery on the Pacific Coast in 1967. Fish. Res. Bd. Canada MS Rept. 1031. 4 p. [Also appeared as INPFC Doc. No. 1166, 4 p.]

Calaprice, J. R., and J. S. Ford. MS, 1969. Digital calipers - an inexpensive electronic measuring and recording device. Fish. Res. Bd. Canada Tech. Rept. 141. 6 p.

Collins, C. A., R. L. Tripe, D. A. Healey and O. Joergensen. MS, 1969. The time distribution of serial oceanographic data from the Ocean Station P program. Fish. Res. Bd. Canada Tech. Rept. 106. 39 p. [Also appeared as INPFC Doc. No. 1161, 39 p.]

Collins, C. A., R. L. K. Tripe and S. K. Wong. MS, 1969. Programs for processing hydrographic data on an IBM 1130 computer. Fish. Res. Bd. Canada MS Rept. 1071. 128 p.

Cooper, Edwin L. MS, 1969. Scale characteristics of cutthroat trout from Chef Creek, Vancouver Island, B. C. Fish. Res. Bd. Canada MS Rept. 1025. 85 p.

Crean, P. B. MS, 1969. A one-dimensional hydrodynamical numerical tidal model of the Georgia-Juan de Fuca Strait system. Fish. Res. Bd. Canada Tech. Rept. 156. 32 p.

Dodimead, A. J. MS, 1970. Canadian oceanographic research in the Subarctic Pacific Region during 1969. Intern. North Pacific Fish. Comm. Doc. 1235. 16 p.

Forrester, C. R. MS, 1969. Summary of Canadian groundfish fisheries in the northeastern Pacific Ocean, 1968. Intern. North Pacific Fish. Comm. Doc. 1241. 1 p.

MS, 1969. Life history information on some groundfish species. Fish. Res. Bd. Canada Tech. Rept. 105. 17 p.

MS, 1969. Estimated annual catches of Pacific ocean perch, by nation, 1959-1968. Fish. Res. Bd. Canada MS Rept. 1069. 2 p. [Also appeared as INPFC Doc. No. 1231, 2 p.]

Forrester, C. R., and J. E. Smith. MS, 1969. A summary report of the British Columbia trawl fishery in 1968 and some aspects of its investigation. Fish. Res. Bd. Canada Tech. Rept. 131. 41 p.

Forrester, C. R., and J. A. Thomson. MS, 1969. Population studies on the rock sole (Lepidopsetta bilineata) of northern Hecate Strait, British Columbia. Fish. Res. Bd. Canada Tech. Rept. 108. 104 p.

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