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FISHERIES RESEARCH BOARD OF CANADA

BIOLOGICAL STATION
NANAIMO, B.C.

ANNUAL REPORT

and

INVESTIGATORS' SUMMARIES

1968

K. Radway Allen, Director

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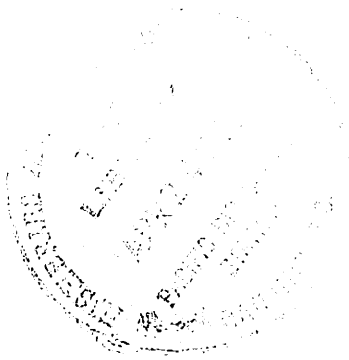

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INTRODUCTION

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

K. Radway Allen

During 1968 the Nanaimo Biological Station continued to be responsible for research on a wide range of topics concerned, directly or indirectly, with the management and development of the fisheries resources of the Canadian Pacific coast. As in the past, a balance has been maintained between projects aimed at the solution of problems of immediate importance to the fisheries, and research on more basic biological phenomena and principles which may be expected to lead ultimately to new developments and techniques in fisheries management.

During the year gradually increasing financial stringency prevented the continued expansion of the Station's activities at the rate which had prevailed over the previous few years. It was not possible to make any new appointments to the scientific staff and opportunities to enter upon major new fields of research were severely limited. Despite this, the research programme remained extremely active, and important developments were made in a number of fields.

During the year the staff and the work of the Station has continued to be organized in four major groups, each group being as homogeneous as possible in either the disciplines or the kinds of animals with which it is concerned.

The Anadromous Fishes Group is responsible for most of the research on the five species of salmon (Oncorhynchus) which, together, form the largest component of the fisheries of British Columbia. At present most of the work of this Group is directed towards increasing the size of salmon stocks, particularly by augmenting the numbers of young fish entering the sea. The work ranges from studies aimed directly at the development of improved hatchery techniques to basic studies on the genetics, ecology and behaviour of salmon. The work related to hatcheries includes both cooperative studies with United States scientists on the contribution made by U.S. coho and chinook hatcheries to the catches in both Canadian and U.S. fisheries in various areas, and the development of techniques for producing stronger and more viable pink salmon fry. The latter project, which was located temporarily at Port John in 1967, was in 1968 transferred on a more permanent basis to Headquarters Creek on the Tsolum River near Courtenay, Vancouver Island. Here the marine survival of wild pink salmon fry will be compared with that produced by the new technique of hatching the eggs in gravel-filled boxes. At Babine Lake, work has continued in close cooperation with the Department of Fisheries on monitoring the results of the spawning channels and on testing the basic hypotheses. Ecological work in the freshwater environment has included studies on factors affecting the production of young coho salmon in streams, and on the ecology and utilization by fish of the stream bottom fauna. The genetics investigation was expanded at a new site on Rosewall Creek during the year. A new study on salmon behaviour is aimed at examining some of the factors controlling the migration of salmon, including their influence on both the activity and the orientation of the fish.

The Marine Fisheries Group tends to be concerned with immediate management problems more completely than any of the other groups. Studies include most of the commercially important species of fish other than salmon, and of invertebrates. The groundfish studies are concerned with both the inshore species and the offshore rockfish. The work on the latter species gained increased importance during the year as a result of a decision by the International North Pacific Fisheries Commission to undertake joint studies by the member nations in the Northeast Pacific. The herring work continued to be influenced by the extremely low abundance of this species which led to an almost complete closure of the reduction fishery in 1968. In an attempt to investigate the possible existence of additional unexploited herring stocks further offshore, a survey was undertaken during the summer, in cooperation with the Department of Fisheries. The results gave little encouragement to the belief that additional resources would be found in these waters. The studies on the possibility of introducing the Atlantic lobster to the British Columbia coast have continued successfully and a large population is now established in Fatty Basin in Barkley Sound. So far, no factors have been disclosed which would suggest that, with proper planning, a large-scale introduction would not be likely to succeed. Other work on invertebrates has included the development and testing of improved prawn traps, the continued oyster spatfall forecasting at Pendrell Sound, and the assessment of clam populations.

The Pacific Oceanographic Group has been concerned with both physical and biological oceanography. The physical studies have included detailed analysis of some aspects of water movements within the Strait of Georgia and somewhat more generalized studies of the outer coast. The routine collection of temperature and salinity data at a number of established stations has also been continued. Much of this work provides a valuable background to the understanding of problems arising from fluctuations in the stocks of commercial fishes. The biological studies have concentrated on the analysis of productive processes in the marine environment extending from primary production through to the utilization of zooplankton by young fish. During the year much of this work was carried out either in the vicinity of the Fraser River Plume or in Saanich Inlet.

The Pathology and Physiology Group included investigations in microbiology, parasitology, physiology and physiological ecology. The work in microbiology included studies on the bacteria occurring on salmon eggs in streams and on the effects of Gaffkaemia, a disease of Atlantic lobsters, on British Columbia crabs and shrimps. It also includes studies on several diseases affecting salmon in hatcheries. The parasitological studies are largely concerned with the use of parasites as indicators of fish stocks and with the effects of parasites on their hosts. Work has largely been concentrated on copepod and trematode parasites. In physiological ecology, new and improved techniques of data analysis, using response surface techniques, have been applied in the studies of the effects of environmental factors on the early development of various marine species. The physiological work, mainly on sockeye salmon, has examined the bioenergetics of growth and food utilization at various temperatures and salinity and for different ration compositions.

The Station's Annual Report is presented in the format adopted in 1967: it includes summaries by the investigators of the projects in progress at the Station in 1968 arranged within the four major Groups outlined above. The work of each Group is preceded by a more general statement of its activities. The staff list is appended to this report.

As in the past, the Station's work has been reported in a large number of publications, and at a variety of levels. Primary publications numbered 51, of which 30 were published by the Board and the remainder in other journals, many of which were produced outside North America.

During 1968 the Station has welcomed a great number of visiting scientists and fishery workers from both Canada and many other countries. The staff has derived great benefit from such visits through the media of personal consultations, informal discussion groups and formal seminars.

The cooperation with the Department of Fisheries, which is essential for the success of many aspects of this Station's work and for the proper application of the results, has continued to be maintained, both through a number of specialist committees and by less formal exchanges between members of the staffs. Station personnel also participate in the work of consultative committees, established by the Department, for various fisheries. Relations with the industry have also been successfully maintained by numerous personal contacts. The valuable association with the Provincial fisheries authorities has continued, both through the Director's membership in the Federal-Provincial (B.C.) Fisheries Committee and through numerous personal contacts. In the oceanographic field, close ties with kindred organizations are maintained through the Canadian Committee on Oceanography for which the Station obtains valuable help in the provision of vessel time for oceanographic work from arrangements made with other organizations through the Committee's West Coast Working Party.

In the academic field, the Station has continued to have many contacts with appropriate departments of the British Columbia universities, and several members of the staff hold honorary appointments at the University of British Columbia or at the University of Victoria.

Station staff have continued to be active in the international field, particularly as advisers to the Canadian Commissioners on international commissions. The principal activity has been in the International North Pacific Fisheries Commission but work has also been done in connection with the International Pacific Halibut Commission and the International Whaling Commission. The Station has also participated in the work of the Informal Committee on Chinook and Coho in which both Canada and the United States participate.

The demands on the Station's scientific services continued to grow in 1968. Although these were met, the need for the expansion of these facilities with respect to both equipment and personnel is becoming ever more acute as the research becomes more sophisticated. The growing demand for scientific

support is evident throughout the services but is especially noticeable in the Statistics and Theoretical Populations section where computer time more than doubled in 1968 as compared to 1967.

Early in 1968, construction was started on a new laboratory building. This addition, comprising 42,000 square feet of floor space, will make available 27 research laboratories, a seminar room, a large library and additional office space. We expect to occupy the new building sometime in the latter half of 1969. A new culture facility was constructed at Rosewall Creek approximately 45 miles from Nanaimo for the use of the genetics, and eggs and alevins investigations. The new site is ideal for extensive fish culture operations because large volumes of both creek and ground water are readily obtainable. The ground water is especially suitable due to its nearly constant temperature over a 12-month period.

INVESTIGATORS' SUMMARIES

ANADROMOUS FISHES GROUP R.R. Parker

Research projects of scientists comprising the Anadromous Fishes Group were mainly oriented toward biological problems associated with "increasing the resource base". Factors which presently limit the size of the populations are incompletely known, let alone understood, and these are the initial objectives.

If a population is presently self-limiting through density-dependent sources of natural mortality, then an increase in the amount of environment used during the limiting phase is required. If, on the other hand, the stock is over-fished, then a larger escapement is required as a first remedy. Apart from maintaining or enhancing existing stocks, successful introduction of salmon into new, unused environments can lead to increasing the resource base. A parallel problem is that of preserving the present resource in the face of multiple water use demands, i.e. pollution, recreation, energy, etc.

Increasing the yield by increasing the resource necessitates understanding of the animal's biology and the population's needs from the environment.

Initially, the extent and variation of present levels of production must be documented. H.T. Bilton is documenting the relative contribution of specific brood years of sockeye and chums to the catch and to the escapement. Past research has led to the hypothesis that the main basin of Babine Lake can support many more young sockeye than can be produced from adjacent natural spawning grounds. This hypothesis is being tested by the creation of artificial spawning grounds by the Resource Development Branch of the Canada Department of Fisheries. J. McDonald is continuing research on this question by (1) determining the distribution, growth and survival of sockeye produced from the Fulton River artificial spawning channel using fish naturally produced in the Fulton River as a control, and (2) monitoring production of smolts and adults of these test populations. Also working at Babine, D.W. Narver is studying the ecological significance of the diel vertical movement of underyearling sockeye, their feeding biology, and food production rates. H.D. Smith is studying (1) the relationship between age of parents and age of progeny in sub-stocks, (2) the post-lacustrine mortality rates associated with smolts of various sizes, and (3) the effects of the cestode parasite Eubothrium salvelini on the production of Babine Lake sockeye. Very little is presently known about this parasite.

The use of hatcheries has long been proposed as a means of increasing production of salmon. Historically, tests by F.R.B. in British Columbia disclosed that sockeye hatcheries were not fulfilling their purpose. They were, therefore, abandoned. H. Godfrey has worked cooperatively with a United States evaluation of Columbia River and Puget Sound chinook and coho hatcheries, and preliminary results indicate that some hatcheries are indeed making worthwhile contributions to the coho and chinook fisheries. Several

years' work by R. Bams on the physiology and behaviour of salmon larvae has led to a new concept of hatchery design currently being tested on pink salmon. Other experiments by F. Withler have led, in some instances, to improved methods and knowledge necessary for interbreeding and storing sex-products.

Productivity of flowing waters is being studied by H. Mundie. Kinds and quantities of insect foods of coho fry are being studied both seasonally and diurnally. Diets are being compared with samples of organic drift, and the influence of water velocity and depth on benthic production is becoming known. Studies by J. Mason on interactions of coho with other species of fish in streams are leading to concepts of coho production.

The separation of stock characteristics, such as growth rate, fecundity, age at maturation, mortality rate, etc., into components environmentally induced and those reflecting genetic inheritance, has not been previously attempted. A new investigation by J. Calaprice began to study these components of Babine Lake sockeye populations in 1967 and extended its studies to 1968 to include pinks, chums and cohos.

Much of the natural environment now being used for reproduction and juvenile rearing of salmon faces alteration or deterioration from the demands of growing industrial and urban use. These changes have caused a tendency in the United States toward domestication of salmonid stocks which are reared to the stage where they can use the part of the environment which remains unaltered. As in animal husbandry, fish domestication can often be enhanced by controlled breeding for special characteristics. F. Withler is documenting several characteristics of inter-species hybrids. One aspect of natural mortality is an interaction between coho smolts preying on pink fry in the early marine period. This problem is currently being studied by R. Parker and J. Walker.

Field work on salmon distribution in the Gulf of Alaska has been terminated, but the analysis of data and writing is being continued by M.P. Shepard and V. Aro. J. Manzer is studying the food and feeding conditions of juvenile pink and chum salmon in northern B.C.

Migrations of Pacific salmon are a well-known phenomenon; however, the mechanics of migration are little known. Transplanting salmon to new environments or even maintaining them in their present state will be considerably enhanced with an understanding of the means by which these fish are able to navigate over long distances and through a variety of environments. C. Groot will be studying the migration of adult Skeena sockeye in cooperation with University of Wisconsin scientists and with the Research & Development Branch of Fisheries Service.

More detailed accounts of these investigations follow.

1. Salmon Stock Assessment

H.T. Bilton, D.W. Jenkinson, and M.M. Aarts

Sampling of the British Columbia commercial catches of sockeye, pink and chum salmon was continued in 1968. 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.

Estimates of ages of sockeye and chum salmon from pectoral fin rays were compared with ages as estimated from their scales or otoliths. For both sockeye and chums the scale or otolith and pectoral fin ray methods generally provided the same estimates of either ocean or total age. Freshwater age of sockeye could not be determined from the fin ray. For samples of both sockeye and chums, the percent agreement ranged from 73.8 to 97.2.

Analyses of Skeena system sockeye scale patterns. Relatively small samples of scales obtained from age 1. and 2. adult spawning sockeye salmon of various sub-stocks of the Skeena River system in central British Columbia during the period 1945-1966 were examined in detail. These were studied with a view to possible use in both sub-stock identification and the study of growth patterns in relation to the geographical location and the environment of the nursery area. The study suggests there is some possibility of providing a general separation of stocks spawning at a low elevation relatively near the sea from those spawning at a relatively high elevation far inland. Scale patterns seem to provide insight into the physical conditions of the nursery areas where the juveniles are reared. Turbidity, mean depth, and maximum surface temperatures were compared with the freshwater growth on the scales of age 1. and 2. fish. For the conditions tested, scale growth in the first freshwater year of age 1. and 2. sockeye appeared to be positively correlated only with the maximum surface temperature. The amount of scale growth during the first year in the ocean of various sub-stocks of age 1. sockeye was inversely correlated with the distance of their nursery areas from the Skeena River estuary. Sub-stocks closest to the estuary had the most ocean growth and those from the upper reaches of the system the least.

The scale service for various investigations was continued. This involved aging of coho and chinook salmon, scale measurements of Babine Lake sockeye spawners, migrant yearlings, underyearlings and kokanee. A number of other projects of a more minor nature were also completed.

2. Lacustrine Ecology of Salmonids

J. McDonald

This division of the Anadromous Fishes Group was formed in April of this year. It was given the objective of increasing our understanding of factors influencing production of salmonids in lake systems. Presently our attention is centered on the capacity of Babine Lake to produce sockeye salmon. Current studies all contribute to this objective and to the joint F.R.B. Fisheries Service, Babine Lake Sockeye Development Program.

3. Babine Sockeye Development Evaluation — J. McDonald, J.R. Scarsbrook and A.S. Coburn

Research was designed in 1966 to meet the dual objectives of (1) comparing the distribution, growth and survival of sockeye fry produced from the natural spawning grounds of the Fulton River and from the Fulton River artificial spawning channel, and (2) defining the parts of the lake used as a nursery area by this major stock of salmon. This last objective is considered a first step toward examining the broader question of the lake's capacity to produce sockeye. A mark by fin amputation and recovery technique was employed.

Recoveries of marked fish in the lake have provided a description of lacustrine distribution in time for 3 brood years (1966-1968), and comparative data on the distribution, growth and survival to the seaward migrant stage of "river" and "channel" fish for 2 years (1966-67, 1967-68). Analysis of 1966-67 data is completed (McDonald, 1969, J. Fish. Res. Bd. Canada). Analysis of more recent data is not completed, but the following generalizations appear warranted.

(1) During the 3 brood years studied, sockeye fry from the Fulton River and Fulton Channel dispersed rapidly and mainly southward into Babine's mainlake basin.

(2) Their distribution was neither uniform nor static; rather, the marked young sockeye were found to be concentrated in different parts of the main lake at different times of their first growing season.

(3) Channel and river fry differed little in size at time of lake entry. However, subsequently, channel fry were consistently smaller on the average. This was considered due to their later date of lake entry and slower rate of growth during the first few weeks in the lake. Thereafter, their growth rate was comparable to that of river fish.

(4) Differences in survival to the seaward migrant stage were small and not considered to be significant. The survival rate of marked 1965 brood year fry to age 1 seaward migrant was about 13% in 1966-67. Preliminary analysis of 1967-68 data indicates that survival of the marked 1966 brood year fry was about twice that rate.

Analysis of data describing the diel vertical movements and feeding activities of underyearling sockeye continued. Additional information was obtained on the distribution, age composition and growth of kokanee - probably the most serious competitor with sockeye in Babine Lake.

4. Babine Sockeye Production

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

The objectives of this investigation are to improve understanding of certain phenomena related to natural production of sockeye and to record annually vital statistics of the escapement and smolt production necessary for management of the stock and evaluation of the Babine Development Program.

(a) Parent-progeny age relationships and size and growth of sockeye in Babine Lake sub-stocks

Annually from 1962, measurements have been made of age, size and growth patterns in Babine sockeye sub-stocks. These will be used to assess the significance of correlation between ages of parents and progeny within sub-stocks and to assess differences in size and growth rate among the sub-stocks and brood years.

Generally there is a greater variability in age composition of sub-stocks between, than within years, but sub-stocks in the North Arm and Morrison systems frequently differ in both size and age composition from those in the more southerly main lake basin.

(b) Post-lacustrine mortality

Efforts to obtain a more efficient utilization of lake nursery areas and the forecasting of adult returns will be aided by an understanding of the relation between smolt size, time of migration and ocean survival.

Smolts in several size categories were marked with Bergman-Jefferts coded magnetic wire tags in a pilot operation in 1966 and on an expanded scale in 1967 and 1968. In 1968 a few recoveries were obtained from the return of adults tagged as smolts in 1966, and 4 tags of the 1967 smolt tagging were recovered from a sample of 600 jacks examined on the Fulton River. The latter suggests that a substantial recovery of tags may be possible in 1969. This investigation is a cooperative study with J. McDonald.

(c) Studies of Eubothrium salvelini in sockeye smolts

Survival of smolts may be influenced by parasitism. The tapeworm E. salvelini is associated primarily with smolts of less than average size. As part of the program to measure the effect of the parasite upon the sockeye host, parasitised and unparasitised smolts were tested together in a stamina tunnel. Smolts were starved for 24 hr and then forced to swim for 30 min

in each of a series of velocity increments of 0.2 ft per sec until exhausted. Unparasitised smolts swam an average of 1.7 times as far as heavily infected smolts of similar size.

Apparently E. salvelini can remain in the host for an appreciable time after reaching the sea. Smolts were transferred to Nanaimo in May and placed in salt-water tanks. There has been no change in infection rate after 6 months of this treatment.

The copepod Cyclops bicuspidatus occurs in Babine Lake and is viewed as a likely intermediate host of the parasite. Samples have been brought to Nanaimo, and efforts are being made to cycle them in the laboratory.

(d) Operation of the Babine counting fence

The counting fence was installed in 1946 and has been used to obtain complete counts in 21 of 23 years of operation. The 1968 counts were as follows:

Sockeye:	3-year-old jacks	54,000
	4- and 5-year-olds	552,000
Chinook:	small (<75 cm fork length)	2,050
	large (>75 cm fork length)	1,300
Coho:		6,600
Chum:		3
Steelhead:		100

The 1968 sockeye escapement was sampled extensively at the fence in cooperation with personnel of the Resource Development Branch. Age, length and weight measurements, and scale samples were obtained.

(e) Babine smolt estimates

Estimates of daily smolt output have been made using mark and recovery procedures. The 1968 total was 30 million and represents a survival of about 4.9% from potential egg deposition.

5. Lacustrine Ecology

D.W. Narver and B.C. Andersen

The diel vertical movements and feeding habits of underyearling sockeye salmon, along with the diel vertical distribution of zooplankton, were described in 1967 and will be the subject of a scientific paper. The objective of the work in 1968 was to enlarge our understanding of these diel activities. The major technique was periodic 24-hr series of samples and observations taken with a 1-m Isaacs Kidd midwater trawl, Miller zooplankton samplers, and a 175-kc Honeywell echosounder.

Underyearling sockeye were first found in the pelagial zone about July 9 at which time they were in a single layer at about 10 m during the day but ascended to the surface at dusk. By July 16 the fish during the day were in two distinct layers, one at about 27 m and the other at 35 m. Fish of both layers performed diel vertical movements in which they ascended to the surface at dusk, dispersed below the thermocline after dark, ascended to the surface at dawn, and then again formed two layers at mid-day. This general pattern of behaviour continued through the summer until mid-October when only fish in the upper layer approached the surface in the evening. In mid-November fish during the day were found at a depth (about 28 m) analogous to that of the upper layer during the previous months; at dusk the fish tended to disperse vertically to occupy the midwater, but none came to the surface.

As in 1967, the Calanoid copepod Heterocope appeared to play an important role in the daytime vertical distribution of underyearling sockeye. Heterocope is an annual species that displays a pronounced diel vertical movement. It is fed upon extensively by the young sockeye. In June the nauplii and early copepodids occur in the top 5 m for the 24-hr period, but starting in early June the mid-day depth of the early copepodid stages increased rapidly. On July 9, during the day, Heterocope was most abundant at 10 m as were the young sockeye. By mid-July Heterocope had taken up a deeper daytime distribution that peaked at about 25 m - the depth of the upper layer of fish. From mid-July to October underyearling sockeye in the upper layer were feeding at a rather low intensity on Heterocope while those in the lower layer were not feeding. Feeding was most intensive in the epilimnion at dusk and dawn.

Use of an underwater light meter indicated the range of light intensities (approximately 10^{-2} lux for the upper layer and 3×10^{-6} for the lower layer - the latter obtained from extinction coefficient) at the depth of the fish during the day. It appears that fish occupying the lower layer during the day are found in an increasingly higher light intensity as they ascend in the evening (i.e. they are not following a specific light intensity), since feeding near the surface at dusk occurred at a light intensity above 2×10^{-2} lux. When light intensity at the surface dropped below about 10^{-2} lux, virtually all fish settled down to the thermocline or below.

In areas of Babine Lake where the depth is about 20 m, underyearling

sockeye were found to be on the bottom during the day, where they were available to a bottom trawl but not a midwater trawl. These, too, ascend to the surface in the evening.

6. Hatchery Evaluation — H. Godfrey and E.A.R. Ball

(a) Studies of hatchery production of chinook and coho salmon

The cooperative United States-Canadian investigations to evaluate the production of chinook and coho salmon by United States hatcheries were continued during 1968. The studies were initiated to determine the hatchery production from four brood year stocks (1961-1964) of Columbia River "fall" chinook salmon, two brood year stocks (1965, 1966) of Columbia River coho salmon, and three brood year stocks (1964-1966) of Puget Sound-Washington coast coho salmon.

In British Columbia in 1968 approximately 165,000 chinook salmon and 431,000 coho salmon (mainly from the troll fisheries) were examined for marks. These amounted to 28% and 16% respectively of the total troll catch of chinook and coho salmon in Statistical Areas 6-29. (In 1968 catches from Statistical Areas 1-5 were not examined for marks, as sampling was eliminated at Prince Rupert because of the paucity of marks from those areas in earlier years.)

In addition, approximately 9,500 chinook salmon and 5,600 coho salmon were sampled for needed age, size and other biological data.

In 1968 only two age classes (4- and 5-year-old fish) of chinook salmon of the evaluation study were present in the ocean; coho salmon were in their second and third years. Marked salmon (of these programs) found in British Columbia totalled 758 complete plus 292 partial chinooks, 928 Columbia River coho salmon and 4,244 Puget Sound-Washington coast coho salmon. The marked coho salmon included a few 2-year-old fish. In the case of the Columbia River coho salmon, it appears probable that recoveries of fish with the single adipose fin mark included numbers of fish whose adipose fins have been lost from natural causes.

Most of the catch of Columbia River hatchery chinook salmon in British Columbia is made in the west coast of Vancouver Island troll fishery. A preliminary estimate of the Canadian catch there in 1968 of hatchery evaluation chinooks is 19,758 or 4.9% of the total Canadian troll catch in the area. Similar estimates cannot yet be made for catches of the two groups of hatchery coho salmon.

In 1968, data became available on the coastwide catches (sport and commercial) of Columbia River hatchery evaluation chinook salmon in 1966. The estimated total Canadian-United States catch of these fish was 174,401

(6.5% of the total coastwide catch in fisheries sampled of 2,681,507), of which British Columbia took 65,826 or 37.7%, mainly in the troll fisheries. These estimates have not been adjusted for marking mortality, and in the case of the 1961 brood a preliminary estimate has been made that the survival of the marked fish was about 70% that of the unmarked fish.

Similar estimates cannot yet be made for coastwide catches in 1967, but it has been estimated that in British Columbia in that year the total catch of the hatchery chinook salmon was 78,000 (about 7% of the total British Columbia catch) and 46,000 in the west coast of Vancouver Island troll fishery (about 12% of that catch). Neither of these estimates has been adjusted for marking mortality.

In the case of chinook salmon, the studies have shown that the survival rate can vary greatly both among broods and hatcheries. For example, the survival of the first brood was about twice that of the second, and that of the third rather similar to the first; and survival of the 1961 brood released from Elokomin and Oxbow hatcheries was only between one-tenth to one-half that of the Kalama and Spring Creek hatcheries. It has also become evident that fish from different hatcheries exhibit differences in their ocean migrations. This, among other things, would subject them to different fishery pressures. For example, marked Kalama River fish of the 1961 brood showed a more northerly distribution than did marked Spring Creek fish. In a general way, it would seem that the ocean distributions of marked and unmarked fish from a given hatchery were similar, but it still is not known whether and to what extent the actual movements (i.e. rate and distance travelled) of the two groups might have differed. A significant difference could be important, since the determination of production by a hatchery employs the marked-to-unmarked ratio at release to compute the estimated catch of marked and unmarked hatchery fish in a fishery.

A preliminary estimate has been made (United States Bureau of Commercial Fisheries) of the benefit:cost ratio achieved with the 1961 brood of Columbia River hatchery chinook salmon. It was estimated that the total catch (sport and commercial) of these fish was worth $1,900,000 and that they cost $831,000 to produce, so that the estimated benefit:cost ratio was 2.3:1. This, of course, is an average value for the 12 hatcheries involved in the program.

(b) Ocean migrations of North American chinook and coho salmon

In preparing the Canadian report for the Informal Committee on Chinook and Coho, a review was made of Canadian and United States tagging and marking experiments carried out prior to 1965. The review makes it evident that in the sea chinook and coho salmon are both ubiquitous and restricted in their ocean distributions. Individuals of particular stocks may be present during much of the year over a wide area and in all possible directions from their points of entry into the sea. Yet both species also exhibit a high degree of chronological regularity in their appearance in large numbers at locations along well-defined routes. There is variation between the species, and

among populations of each, in the predominant direction in which they initiate their migration - that is, northwards or southwards and possibly also offshore. As a result of their ocean migrations, United States and Canadian chinook and coho salmon intermingle over a wide area, in inside passages as well as in outside coastal waters. Yet the degree of regularity in their ocean migrating behaviour ensures that extensive intermingling occurs only in certain areas. It is in these waters where some of the major fisheries have developed and where the magnitude of the catch depends on fish originating in both countries.

(c) Ages and sizes of chinook salmon taken in British Columbia commercial fisheries in 1967

Sampling data were weighted to commercial catches to describe the 1967 age and fork length composition of catches by area, 2-week periods, age and flesh colour. The data for the years 1964-1967 are now available in the Station's Manuscript Report Series, Nos. 947, 952, 954 and 998.

(d) Informal Committee on Chinook and Coho

The Canadian report of the Committee was completed by the Technical Working Group and submitted to the Canadian Section of the Committee. The report reviews the present (up to 1964) status of North American chinook and coho salmon and summarizes what is known at this time of the intermingling between stocks of the two countries and the extent to which one country intercepts fish of the other. General recommendations were made on future research needs for improving knowledge on intermingling.

7. Eggs and Alevins

R. Bams, R.C. Wilson and D.G. Crabtree

The Salmon Eggs and Alevins project is presently strongly oriented toward optimising and testing of a hatchery method that incorporates changes in design as suggested by results of previous research into the requirements and behaviour of larval salmon.

The methodical changes concern preservation of energy in the developing larvae and aim at maintaining conditions conducive to high survival, maximal growth and appropriate timing of emergence. The fry produced by this new method compare favourably with naturally propagated fish in terms of length, weight, condition, timing, swimming performance, vulnerability to predation and general behaviour. The outstanding discrepancies in fish size, performance and timing, typical of older hatchery methods, are greatly reduced, and a substantial increase in survival potential at the fry stage is expected.

To test the surmised improvement in fry quality, a program was initiated in 1968 that will compare survival to the adult stage of naturally and artificially propagated pink salmon of a common stock. The program calls for continuing tests on both cycles of the Tsolum River (near Courtenay, Vancouver Island, B.C.) pink stock until a satisfactory assessment has been obtained. The procedure is to obtain brood stock from a consistent percentage of the available escapement throughout the run, incubation in vertical stack incubators to the eyed stage, planting of these eggs in special, gravel-filled incubation boxes, and capture of the resulting fry upon self-release the following spring. The naturally propagated counterpart will be obtained from a fry fence, and each day equal numbers of fry of both sources will be marked by the removal of different fins and released simultaneously.

In 1968 facilities were built on Headquarters Creek, a pink-producing tributary to the Tsolum River system. A run of 3,500 pinks, of which 37% were females, entered the stream. Of the latter, 276 (21%) were retained, and an estimated total of 263,000 eggs was taken. Technical difficulties associated with temporary facilities led to the introduction of silt and organic detritus into the incubators and was responsible for excessive mortality among the eggs obtained from the first part of the run. During the middle of November a total of 220,000 of the original 263,000 eyed eggs were planted in four 4 × 8 ft gravel boxes. Average survival to this stage, at 83%, is at least 5% below what might have been expected under good conditions. The expected output from the hatchery is from 160,000 to 180,000 fry.

At the new Station facility at Rosewall Creek, experiments are in progress on chum salmon stock, obtained from Big Qualicum River in early December. These experiments are designed to measure effects of differences in, and interactions between, factors such as egg density, rates of flow, and modes and times of planting. Most of this work is primarily aimed at refinement of our propagation techniques. Continuation of further research into physiological and other requirements awaits completion of the new laboratory in Nanaimo.

8. Stream Ecology: Secondary Production — J.H. Mundie and D. Mounce

Studies were continued on secondary production in flowing water in relation to salmonids. Taxonomic and numerical analyses are being made of foods of coho fry in Robertson Creek, a controlled flow accessory outlet of Great Central Lake, Vancouver Island. Diet is being compared with organic materials drifting downstream. Fry are almost entirely dependent on insects; few other invertebrates enter the diet. About 70 species of insects occur in the creek. It has been possible to trap these quantitatively, as emerging adults, from April to November for 2 years, to establish identities and life cycles.

Examination of daytime foods of newly emerged fry shows the familiar dependence of the fish on small chironomid larvae (mainly Cricotopus, Nanocladius) and ephemeropteran nymphs (mainly Baetis). From May to October Simulium larvae and chironomid larvae (e.g. Rheotanytarsus) are important in the biomass of the daytime diet of fry. These insects are themselves dependent on materials carried in suspension in the stream, and here the influence of the lake is apparent. The presence of these larvae in the drift under conditions of stable flow requires examination. They originate in localized areas well upstream of the fry.

Analysis of drift shows that 50 different potential foods may be present over 24 hours. Expected diurnal periodicities of drifting invertebrates, especially Ephemeroptera, Trichoptera and pupal Diptera, have been confirmed for May and June, and detailed analysis is being made of the diets of fry over 24 hours in relation to these.

Terrestrial contributions to the food in this environment are negligible. The role of siltation of the gravel in affecting benthic production is being examined in experimental sub-channels where specific conditions of water depth and flow have been set up.

9. Coho Biology

J.C. Mason and D.W. Rimmer

The freshwater fish community of Chef Creek, a small stream on the east coast of Vancouver Island that supports a good run of coho salmon, Oncorhynchus kisutch, is being studied to gain better understanding of the process of coho smolt production. The primary objective is to identify and assess circumstances which may serve to limit the rearing capacity of the stream for coho smolts, and analysis of the fish community has been given first priority.

In studying the fish community, chief emphasis is being placed on the distribution, abundance, growth, food habits and feeding behaviour of each fish species. Experiments in stream pens are being used to measure growth, survival, and behavioural interaction in mixed populations.

The community is a simple one, consisting of five species: coho, cutthroat trout (Salmo clarki), two species of sculpins (Cottus aleuticus and C. asper), and the three-spined stickleback (Gasterosteus aculeatus). The latter species is uncommon.

Species abundance in midsummer has been estimated. Trout contributed 49% of total fish biomass, coho - 39%, C. aleuticus - 10%, and C. asper - 2%. Except for the extreme headwaters, which are inhabited only by trout, 96% of the coho and 45% of the trout populations are concentrated in the upper half of the stream. Sculpins were limited to the lower quarter of the system. Population estimates, based on electrofishing, in midsummer indicate that

there were approximately 19,000 juvenile coho, 9,000 trout and 1,700 sculpins, 80% of the latter being C. aleuticus.

Age-class composition and annual growth of the trout population has been determined. Most of the trout were in their second or third year, but fish in their fourth and fifth years of stream life were found. Non-anadromous fish in their third, fourth and fifth years of stream life were taken in spawning condition from April through July. Sea-run fish enter the stream starting in late fall and remain throughout the winter. Reproductive biology of this type is presently unknown. Apparently the total trout population consists of anadromous and non-anadromous substocks with complex and differing life history patterns.

Both species of sculpins were studied for age-class composition and annual growth. It is inferred that there are eight year classes of C. aleuticus and five of C. asper, the latter species growing the more rapidly. The subyearlings of both species were found in the intertidal zone, penetrating upstream into fresh water less than 400 ft and reflecting a post-hatching period of planktonic existence.

Small numbers of sticklebacks are found in the lower 400 yards of the stream, concentrated in backwater areas, and in the estuary.

Composition of the diet of each species is being studied.

Interaction between underyearling coho and trout during summer was studied in stream pens. Trout survived and grew better than did coho in both riffle and pool habitats, whether or not the two species were confined together. Trout survival and growth were enhanced in the presence of coho, in both riffle and pool habitats. Similarly, coho survived and grew better in riffle habitat in the presence of trout. But coho survived and grew better in pools in the absence of trout. These findings were associated with behavioural interaction involving aggression and feeding.

10. Pacific Salmon Hybrids

F.C. Withler and R.B. Morley

The ova and milt of several sockeye and pink salmon were used to obtain "pure" and "hybrid" lots of eggs. Rearing of the eggs and the resultant young fish to a length of about 10 cm has shown that, under the culture methods used, the young hybrids survived about as well as did the purebred offspring. The hybrid population did not contain a proportion of gross abnormalities much greater than that of the purebred strains. At the time of complete yolk absorption, sockeye fry, when exposed directly to sea water of 30 ppm for 3 days, did not survive. In contrast, few of the young pinks or the hybrids died under these conditions. A few males of a group of pink ♂ × sockeye ♀ hybrids kept in both salt and fresh water are showing signs of maturing this fall (at two years of age).

Sockeye and chum salmon pure and hybrid groups were obtained similarly. These hybrid offspring also survived well under artificial rearing conditions. Abnormalities were few, although a small proportion of the chum ♂ × sockeye ♀ hybrids were without eyes. The pure chums and the hybrids, which had one chum parent, were more tolerant of direct exposure to sea water at the time of complete yolk absorption than were the pure sockeye.

The above crosses and an additional one involving the same three species at the same time have shown that the time from fertilization to hatching, at given temperatures, is governed largely by the males: ova fertilized with chum milt hatch first, similar ova fertilized with pink milt hatch next, and those fertilized with sockeye milt hatch last.

Female influence on hatching time appears to be weaker, but chum eggs hatch first, sockeye eggs next, and pink eggs last, when all are fertilized with the same milt.

Experiments with salmon ova and sperm. Storage of sockeye ova and milt without water at 3°C, as compared to 8-9°C, extended the period of high fertilizability of ova to 70 hours and of milt to 94 hours. Similarly, stored pink salmon ova and milt both retained high fertility up to 46 hours. The work of others suggests that exposure of the stored products to air (as was the case in our tests) is necessary to maintain high fertilizability during storage. Our own tests have shown that fertilizability of sockeye ova declines very rapidly after their immersion in water - few are fertilized after 5 min of immersion at 9.8°C.

Other tests have revealed that under ordinary spawn-taking conditions, the milt of one sockeye male may be used to fertilize successively the ova of at least 60 females, and the milt of one pink salmon male those of at least 90 females. During the "hardening" of sockeye ova, water uptake is rapid from 0 to 20 min after immersion at 9.6°C, but continues at a slower rate for 40 min. Water uptake amounts to about 14% of the initial volume of the ova. Unhardened sockeye ova may be packed in a container to a depth of at least 21 inches for at least 30 min without significantly affecting their subsequent fertilizability.

11. Predator-Prey Relationships

R.R. Parker, J. Walker and S. Hall

Previous research on the early sea life of pink salmon in Burke Channel has suggested that coho during their first few months in the sea are the main predators on juvenile pink salmon. Laboratory studies have indicated a selectivity of coho for the smaller-sized members of the pink salmon prey population. It is inferred that natural selection must be occurring with selection for the earlier migration and fastest-growing pink fry. After 30 to 40 days in the marine environment, the superior growth rates of pink salmon have removed them from predation by coho.

The mechanism of this selection is not understood. This problem is under study by Mr. Walker, a Ph.D. student at the University of British Columbia, as a thesis problem supported by the Fisheries Research Board.

12. Genetics

J.R. Calaprice, R. Hungar, A.J. Solmie, G.E. Johnston and E.W.H. Moore

This investigation is primarily concerned with the heritable component of salmonid population biology. Phenotypic variation in growth, survival, and behaviour of young salmonids from a number of different populations is under study. Experiments were designed which would demonstrate the relative importance of genetic and environmental factors affecting replacement rates in natural populations. Activities during the past year have been primarily pilot studies concerned with the development of experimental techniques.

A study initiated in 1967 in which males and females collected from each of five streams in the Babine system were crossed (polyallele design) was continued into the early summer of 1968. Data on survival, growth, development and behaviour of the crosses were collected at the Scully Creek Hatchery at Lakelse. Preliminary analysis of the pattern of mortality to the "swim up" stage, and behaviour of young salmonids exposed to current suggest that specific factors, genetic and environmental, can be identified and their relative importance established.

The above methodology requires that a large number of crosses be kept separate until such time as they can be marked. A suitable culture facility was designed and constructed at Rosewall Creek. This facility provides a uniform environment for each of 600 rearing compartments.

A number of different marking methods have been under study. The ability to mark and later identify small organisms would greatly reduce the expense and effort required in the culture aspect of the program. Preliminary studies using one method, X-ray spectroscopy, demonstrate the feasibility of tagging fish smaller than 5 cm in length. In this method, tags composed of stable mixtures of chemical elements are suspended in liquid silicon rubber and injected into the tissue where they solidify into rubbery fusiform objects. Tags are then read by monitoring the fluorescence produced by irradiating the fish.

A number of streams on the central east coast of Vancouver Island were studied in order to determine if these would provide suitable experimental sites. Locations where aspects of the breeding structure of populations of coho and pink salmon could be studied and which would also provide a source of material for the crossing program were sought. The asynchronism among different populations of coho, the numbers of fish spawning, and the lack of visibility associated with periodic flooding are factors which make working with local stocks of this species difficult. The distribution of pink salmon spawning in the Salmon River was studied,

and crosses made between members of the population. The eggs were then buried in gravel boxes in Rosewall Creek.

Construction of the facility prohibited the initiation of a full-scale program in 1968. Limited crossing programs were done, both with late spawning coho and with chum salmon. The progeny are being reared at Rosewall in both well and river water to aid in evaluating the facility as a research site.

MARINE FISHERIES GROUP F.H.C. Taylor
(Acting Group Head)

The Marine Fisheries Group consists of five principal investigations: Groundfish, Herring, Crab and Shrimp, Lobster, and other Marine Invertebrates. Almost all investigations in this Group have a close connection with the needs of industry and the Department.

Groundfish. The work depends heavily on the interest and assistance of trawl fishermen, who in return (together with the Department) are kept informed of the status of the resource and the effects of both domestic and foreign fisheries.

Herring. This investigation, particularly in the last two years, has been called upon for advice on the causes of the currently low level of recruitment and on regulatory measures required to restore the stock to higher levels of abundance. Upon representation from the industry a survey of the offshore distribution and abundance of herring has been initiated, supported by funds from the Industrial Development Service. Discussions have recently been begun with the Department on the division of responsibility and the sharing of programs.

Shrimp and Crab. A detailed study is being conducted on the dynamics of shrimp populations to determine need for regulation. Much information has been provided for the industry through the results of exploration for hitherto unexploited shrimp resources. In response to requests from fishermen, a study of prawn trap construction and fishing efficiency was undertaken and recently completed.

Lobster. In response to an earlier request from industry, a study is well underway to determine the feasibility of establishing a lobster population on the west coast of Vancouver Island.

Other Marine Invertebrates. Of the various projects carried on by this investigation, those of direct interest to industry include: the annual forecast of oyster spatfall; testing of raft culture as a means of increasing oyster production; the development of an inexpensive artificial oyster cultch; and estimates of razor and butter clam production and growth.

The work of the Marine Fisheries Group is not restricted to problems of immediate practical importance. More fundamental biological studies, with long-term objectives, assume considerable importance in each investigation. For example, studies on the early life history of various groundfishes, herring, Crustacea and other invertebrates play a significant role in assessing the factors which may be responsible for year-to-year variations in the brood strengths and subsequent recruitment to the fisheries. Basic biological studies are also underway in respect to numerous 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 and C.D. Levings

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 commercially 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 1968 was approximately 42 million lb, about 15% higher than in 1967 but less than the record 55 million lb taken in 1966. Pacific cod remained the dominant species in landings with a total catch of over 16 million lb in 1968. Landings of various species of flatfish totalled just over 10 million lb, the major species being rock sole, as was the case in 1967.

Field operations in 1968 included a Pacific cod tagging operation from the G.B. Reed in Hecate Strait. Approximately 1,800 cod were tagged in February, chiefly in northern Hecate Strait, for the purpose of studying migration and stock differentiation. On the same cruise it was determined that the butter sole, which accumulates for spawning in Skidegate Inlet, has an egg which is transparent (diameter about 1.0 mm), non-adhesive, and demersal within the Inlet. Protein electrophoresis studies were also conducted on a number of flatfish species in cooperation with the Vancouver Station. Other field operations in 1968 involved the collection of eggs from spawning fish for embryological studies in the laboratory.

Age and growth studies were continued with the emphasis on rock sole from waters off the northern end of Vancouver Island. Preliminary results suggest that rock sole in this area have a slightly slower rate of growth than rock sole from northern Hecate Strait waters.

In cooperation with the Physiological Ecology Investigation, laboratory tests to determine the effects of salinity and temperature on embryonic development of some groundfish species were continued. In 1968, tests were completed on petrale sole eggs, as were preliminary tests on the flathead sole. The latter species appears capable of development over a wide range of salinities and temperatures. A progress report on the flathead sole work has been submitted for publication in the Technical Report Series.

2. Rockfish Studies

S.J. Westrheim

This program, heretofore referred to as the Distant Seas Investigation, began in 1962, and was concerned with studies of Pacific ocean perch (Sebastodes alutus) and other rockfish species. Its purpose was to obtain biological information on these little-known species in the northeast Pacific Ocean, and to establish a basis for determining the effects of foreign (USSR and Japan) fisheries.

During 1968, field studies consisted of:

(1) Sampling the Smith Sound stock of juvenile ocean perch (in February) for the sixth consecutive year. Results indicated that the 1962 year-class is still dominant.

(2) Investigating rockfish spawning seasons and ocean perch bathymetric distribution, primarily off southwest Vancouver Island during April-June.

(3) Further collections of hemoglobin electropherograms for the rockfish systematics program conducted jointly with Vancouver Station personnel.

Laboratory studies included:

(1) Ocean perch otolith reading.

(2) Rockfish pre-extrusion larvae identification studies.

(3) Ocean perch age determination and growth analysis.

(4) Ocean perch distribution studies.

(5) Ocean perch racial studies.

(6) Rockfish distribution and systematics.

All ocean perch otoliths collected during the 1967 G.B. Reed cruises have been read, IBM coded, and the results analyzed. The 1968 otoliths collected aboard the G.B. Reed are nearly all read.

Studies on rockfish maturation, spawning season, and larvae identification, which began in 1967, were continued in 1968. Manuscript Reports have been prepared which summarize the preliminary results obtained in 1967 and 1968, respectively. Spawning season varies among species, and the overall spawning period (all species) extends from at least January to July off southwest Vancouver Island. Melanophore patterns of pre-extrusion larvae do not appear to be useful, per se, in identifying post-extrusion larvae. Some

patterns are identical for two or more species, and some individial characters are variable within species. Furthermore, larvae-rearing experiments aboard the G.B. Reed indicated that the larvae undergo significant morphological changes 2-3 days after birth.

Ocean perch age determination and growth analysis, based on the 1963-67 data, is nearing completion. Growth rate declines northward and westward from Oregon to the western Gulf of Alaska. Dixon Entrance appears to be a boundary between two stocks of ocean perch possessing significantly different growth rates.

Ocean perch distribution studies based on the 1963-66 trawl survey of the northeast Pacific Ocean have been summarized in a manuscript which is currently under review. Distribution varied by depth, size, age, and season. Different year-classes were predominant in catches south (1952) and north (1953) of Dixon Entrance. Detailed studies of ocean perch distribution are now underway on two important fishing grounds off British Columbia--Goose Island Bank (Queen Charlotte Sound) and La Perouse Bank (southwest Vancouver Island).

Further studies on ocean perch racial studies involved a collection of ocean perch from the Bering Sea which was provided by the Fisheries Agency of Japan. Morphometric and meristic characters of these specimens will be compared with those of specimens collected aboard the G.B. Reed in the northeast Pacific Ocean.

Rockfish distribution and systematics studies continue on a low level. A Note for the Journal is in press which reports, for the first time, the presence of three more rockfish species in the waters off British Columbia. This raises the total number of rockfish reported for this region to 33. One more manuscript is in preparation which will yield the 34th species, but discrepancies in the literature and the apparent absence of museum specimens (holotypes, paratypes, or syntypes) are hindering progress. Substantial progress has been made in clarifying rockfish systematics in the British Columbia region with the protein electrophoresis techniques developed by Dr. H. Tsuyuki, of the Vancouver Station. The results of our joint studies during 1965-67 have been published.

3. Special Studies

(a) Sablefish Culture Experiment — W.A. Kennedy

In an experiment to assess, from a biological viewpoint, the feasibility of a commercial operation based on capturing sablefish, Anoplopoma fimbria, of about 2 lb and rearing them to commercial size (about 9 lb round weight) for slaughter, considerable progress was made towards the first objective, namely, to develop techniques for keeping the fish alive and healthy.

A batch of sablefish kept since December 1966 in running seawater in an 8-ft diameter tank were still thriving in early 1968. They had been fed mainly herring and had gained about 1/3 lb per fish per month, having been fed about 10 lb herring for every pound gained. By March 1968 three had reached market size and were slaughtered, then sent to the Vancouver Station where, through arrangements with Dr. Neil Tomlinson, they were smoked and submitted to a taste panel with equivocal results. After March, appetite diminished and growth slowed among those which were not slaughtered. On the basis of our experience with other sablefish, poor appetite and slow growth was regarded as the result of feeding nothing but herring. However, there was reluctance to change the diet because arrangements had been made with Dr. R.G. Ackman of the Halifax Station to send him commercial-size sablefish that had been fed herring exclusively in order that their oil might be analyzed and later compared with sablefish that had been fed exclusively on, say, dogfish. Some of the sablefish were only about a pound less than commercial size and the hope of getting them to commercial size on a herring diet persisted for some time. However, after several months of almost no growth the fish began to lose weight and became lethargic and finally some died, ostensibly from malnutrition although food was available. So in July the fish designated for Halifax were put aside (and later sent to Dr. Ackman) and the diet of the rest was changed; first to dogfish plus herring, later to dogfish exclusively. Within a few weeks appetite improved, lethargy disappeared, mortalities ceased, and growth resumed. The experiment with this batch terminated in October.

A second batch of sablefish has been held in an 8-ft diameter tank since March 1968 with no mortality. They have been fed exclusively on headless, gutted dogfish carcasses cut into bite-size chunks. They have gained about 1/3 lb per fish per month, being fed about 5 lb of feed for every pound gained.

Experiments to determine the effect of crowding on mortality and on rate of growth have been somewhat inconclusive because the diet chosen was herring exclusively, and all growth ceased after the experiment had been underway for several months, regardless of degree of crowding. However, on the basis of results from the first few months, it would appear that sablefish thrive as well at 2 lb per cu ft of water as they do when considerably less crowded.

An octagonal pound of netting, reported in Technical Report No. 78, was developed for holding live sablefish; it is made to take the required shape by tightening ropes that are either directly attached to a rigid framework or which, in the case of the underwater part, pass through pulley blocks which are attached to the framework. The framework is supported by a raft which is anchored off the Biological Station. Varying quantities of sablefish have been held in the pound since April 1968; currently there are about 400 lb in it. Sablefish seem to thrive in it and to gain about 1/3 lb per fish per month on a diet of dogfish or herring, fed on alternate weeks. With one exception, there has been no mortality attributable to confinement in the pound. The one exception was a sablefish which died of a deep slash along

one side, the slash being attributed to an attack by a great blue heron. Five sablefish escaped through a small hole.

(b) Age Determination of Pacific Cod W.A. Kennedy

At the present time there is no satisfactory method for determining the ages of Pacific cod, Gadus macrocephalus. Since the ability to assign ages is essential for developing sound management practices, the possibility of determining their ages from scales is being explored. On the basis of intensive examination of scales, collected from a series of random samples of commercially-caught Pacific cod, it now appears likely that a satisfactory scale-reading technique will result.

(c) Identification and Rearing of Groundfish Larvae C.R. Forrester

A contract study (November 1967-October 1968) was undertaken with a Japanese groundfish scientist to work at this Station to: (1) develop and describe techniques for rearing larvae of commercially-important species, and (2) develop a key for their identification throughout the larval stage. Final assessment of the contract study awaits completion of the reports.

(d) Midwater Trawl Tests S.J. Westrheim

In 1968, the Industrial Development Service provided funds for testing the effectiveness of a particular type of midwater trawl gear on herring and rockfishes. Most of the effort was spent on herring, but one cruise was devoted to rockfish schools. Results were promising but inconclusive, in part due to the scarcity of schools at the time of the cruise. A Manuscript Report has been published summarizing the results.

HERRING

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

1967-68. Final figures show that only 19,552 tons of herring were caught in 1967-68, the smallest catch since 1910, with the exception of the strike year of 1952-53. The summer fishery to September 9 produced 11,440 tons, 5,058 from the upper east coast stocks, and the remainder about equally divided among the northern, upper, and lower central stocks. The winter

fishery produced 8,112 tons, 1,885 tons from the Swiftsure Bank fishery in early September, 1,195 tons from the lower east coast stock, and 878 tons from the middle east coast stock. The northern stocks produced 1,255 tons, the upper central, 609 tons, and the lower central, 1,505 tons, all mainly from the short fishery permitted from mid-January to early February.

1968-69. No fishery for reduction purposes was permitted before the annual Christmas layover. It appears unlikely that fishing will be permitted after Christmas. Some small catches for halibut, for sport bait, and for food were made.

5. Herring Sampling, 1967-68

R.S. Isaacson

The almost complete lack of a regular reduction fishery affected the sampling program. Samples (41) were obtained from the summer fishery in the usual way. In all, 97 samples were obtained during the winter fishing period, 47 from the short post-Christmas fishery in northern and central British Columbia. Samples from the Strait of Georgia and the west coast of Vancouver Island were obtained by specially chartered vessels.

In the summer fishery, 0- and 1-group herring (the 1967 and 1966 year-classes) were not represented. Herring of the 1964 year-class (fish in their 4th year) were the dominant age group in all stocks sampled. In the northern and upper east coast stocks, fish of the 1963 and 1962 year-classes (in their 5th and 6th years, respectively) were better represented than fish from the 1965 year-class (in their 3rd year). In the lower central and upper east coast stock, the 1965 year-class formed almost as large a proportion of this stock as the 1964 year-class, and considerably outnumbered fish from the 1963 and 1962 year-classes. There is no summer fishery in southern British Columbia.

Data from catches in the winter fishery around Porcher Island and Prince Rupert Harbour and farther south in Smith Inlet revealed that fish in their 2nd year (from the 1966 year-class) were dominant, followed by fish in their 3rd year (from the 1965 year-class). However, in the Nass area and in the upper and lower central stocks, the 1965 year-class was dominant, followed generally by the 1966 year-class. In the upper east coast stock, the 1965 year-class was dominant, followed by the 1966 year-class. In the Strait of Georgia a marked change was apparent. In the middle east coast subdistrict, the 1965 year-class was dominant but was followed by the 1967 year-class (fish in their 1st year). Then, in the lower east coast stock, the 1967 year-class was dominant and older age groups were relatively poorly represented. It is difficult to establish the extent to which this change was influenced by the use of a chartered seiner fishing for a relatively limited time.

On Swiftsure Bank, in mid-September, fish from the 1966 year-class (in their 2nd year) were predominant, followed by fish from the 1965 year-

class. In the lower west coast stock, catches by a chartered drum seiner showed that fish from the 1964 year-class were dominant, followed by fish from the 1965 year-class. No fish of the 1967 year-class and relatively few from the 1966 year-class were taken.

6. Spawn Production in 1968

D.N. Outram

In 1968, 102 miles of herring spawn were deposited in 185 spawnings along the British Columbia coast, a 7% increase from the very low level of 95 miles in 1967, but still far below the 25-year (1940-64) average of 199 miles. Spawn production in four populations showed a marked increase from the 1967 level. These included the northern (+123%), the lower east coast of Vancouver Island (+181%), the lower west coast of Vancouver Island (+127%), and the upper east coast of Vancouver Island (+73%) subdistricts. These increases were counterbalanced by decreases in upper and lower central, middle east coast, and Boundary Bay regions.

In the Queen Charlotte Islands spawning remained at below average levels in all three subdistricts. In the lower east coast (Q.C.I.) population only 1.4 miles of spawn were found, well below the 25-year (1940-64) average of 15 miles. Less than one-half mile of spawn was found in both the upper east coast and west coast populations. Herring were observed spawning in late June at the head of Masset Inlet, the first spawnings reported in this region since 1940.

In northern and central British Columbia spawning remained below average in all three subdistricts. However, in the northern population, spawning increased markedly from 8.1 miles in 1967 to 18.1 miles in 1968, about two-thirds average. Spawn abundance in the upper central subdistrict was about one-third average, decreasing sharply from 11.9 miles in 1967 to 5.6 miles in 1968. The extent of spawn (18.9 miles) in the lower central subdistrict was slightly less than that recorded in 1967 when deposition was about two-thirds average.

In southern British Columbia the upper east coast, the lower east coast, and the lower west coast of Vancouver Island subdistricts, showed marked increases in spawn abundance from the 1967 level. In the upper east coast population, deposition rose from 10.9 miles to an above average level of 18.9 miles in 1968; in the lower east coast population, spawning increased from 4.6 miles in 1967 to 14.9 miles in 1968; in the lower west coast population, spawn abundance increased from a near record low level of 2.9 miles in 1967 to 6.8 miles in 1968. The 25-year (1940-64) averages for the latter two subdistricts are 25 and 16 miles, respectively. Spawn deposition in the middle east coast (6.2 miles) and upper west coast of Vancouver Island (3.2 miles) subdistricts was the smallest on record. The extent of spawn has averaged 29 miles in the former subdistrict, 16 miles in the latter subdistrict.

7. Status of the Herring Stocks

F.H.C. Taylor

1967-68. In the limited 1967-68 fishery the catch from most stocks, except possibly the upper east coast stock, was insignificant. Spawn deposition while a little greater than in 1966-67 was still far below average. Substantial increases from the critical levels of 1967 in the lower east coast, lower west coast, and northern stocks were offset by decreases in other stocks. In the middle east coast, spawn deposition declined to about one-fifth the 25-year average. In only the upper east coast stock did spawn deposition exceed or even approximate the 25-year average. Abundance in 1967-68 in all but the upper east coast stock thus remained at a low level.

It would appear that the 1965 year-class (age 2+), although the dominant contributor in some of the northern British Columbia stocks, was weak and represents the third poor year-class recruited in succession. In the lower east coast stock it arose from the first of three very low levels of spawn deposition. The significance of the large number of 0-group herring (the 1967 year-class) in samples from the Strait of Georgia is unclear. It could be the result of a change in sampling method, the enforced use of a chartered seiner, or of the actual presence of larger than usual numbers of this age group.

1968-69. Data are not available for the current season. Surveys of the fishing grounds to date suggest that no large bodies of herring are present.

8. The Effect of Temperature and Salinity on Larval Rearing in the Laboratory

D.N. Outram

Environmental factors during the larval stage may determine year-class strength. To determine the most suitable range of temperature and salinity for optimum growth and survival, two tanks of herring larvae were hatched and reared under each combination of three temperatures (averaging 4.8, 8.6 and 12.9°C) and three salinities (averaging 10.6, 19.9 and 30.3‰). The eggs used were artificially fertilized. Fertilization was 96-98% complete, except in two cases where only 85% fertilization was achieved.

Hatching success, the proportion of viable larvae produced, was greatest at the lowest temperature and for all salinities tended to decrease with increasing temperature.

At 4.8°C the larvae on hatching were the smallest, 7.7 mm, as compared to 9.0 mm and 8.1 mm, respectively, at 8.6 and 12.9°C, and grew least, 2.8 mm as compared to 8.0 mm and 9.4 mm. In all salinities at 4.8°C, the physical activity of the larvae was limited and little or no feeding was

observed. The rate of development was also slow; even in those larvae which survived 43 days the yolk sac was not completely absorbed. At 8.6°C, the larvae apparently stopped growing when 16-17 mm in length, even though food, brine shrimp nauplii, were observed in the gut. This cessation of growth suggests that diet may not be adequate.

Three main stages of mortality were observed: a high mortality on hatching; a high mortality immediately following absorption of the yolk sac, presumably due to a failure of the larvae to start to feed; a further steady but lower mortality following absorption of the yolk sac, possibly the result of starvation from inadequate diet. Absorption of the yolk sac occurred at about 6-12 days after hatching at 12.9°C, and 12-18 days after hatching at 8.6°C. Because of the wide unexplained variation between tanks the effects of temperature and salinity on mortality are difficult to determine. At 4.8°C the experiment was terminated 43 days after hatching, at 8.6°C some larvae lived for 81 days although growth had ceased, and at 12.5°C some lived for 63 days.

9. Distribution of Larvae in the Strait of Georgia — F.H.C. Taylor

The program to determine the distribution of larvae in the lower part of the Strait of Georgia was continued in 1968. A survey on a weekly basis from late March until June was carried out, weather permitting, using a small 2-boat surface trawl instead of the modified Hensen or the high-speed Miller net used in previous years. In addition, an attempt was made to study the dispersion of larvae from a particular spawning site in a U-shaped bay. Modified 50-cm Hensen nets were used, one mounted on a sled for towing on the bottom, particularly in shallow water, others used as anchored nets across the mouth of the bay. The sled-mounted net functioned satisfactorily, although catches tended to be erratic. Trouble was experienced with the net plugging if towed through seaweed beds. While the anchored nets made small catches, they did not fish efficiently. Tidal flow was insufficient to keep the relatively heavy nets extended. The 2-boat surface trawl fishes efficiently.

Analysis of the samples collected is underway but not complete, mainly because higher priority in the disposition of available staff had to be given to other programs.

10. The Use of Infrared Aerial Photography to Estimate the Distribution of Intertidal Seaweed Beds — D.N. Outram

Herring deposit their adhesive eggs mainly on seaweed, principally on or just below the intertidal zone. The amount of spawn deposited, estimated from length and width measurements and intensity estimates of each spawning,

will be affected by the patchiness and type of substrate. If the boundaries of the patches of substrate could be plotted, better estimates of the amount of spawn should result. Black and white aerial photography was not found satisfactory; the seaweed beds could not be clearly delineated from the background. However, infrared photography showed promise. Seaweed beds appeared in tones of red, the result of infrared reflectivity from chlorophyl in healthy vegetation.

To evaluate this technique, experimental flights were carried out during periods of low tide on April 2, 1968, at 1,200 and 6,000 feet, and on May 16, 1968, at 2,000 and 4,000 feet, covering eight herring spawning beaches in the lower east coast subdistrict. A twin-engined Beechcraft provided by the B.C. Forest Service was used, with a cruising speed of 110-120 mph.

Seaweed beds were clearly outlined in tones of red, sharply contrasted from the greenish-grey shoreline. Not only were the seaweed boundaries readily distinguishable but also the type of vegetation could be recognized by the tone, texture, and location of the red-coloured areas. Japweed (Sargassum) beds at Evening Cove were identifiable as solid, narrow, continuous bands of deep crimson vegetation growing along the zero-tide level. Floating japweed appeared light pink. Rockweed (Fucus) plants at Hammond Bay showed as discontinuous, patchy areas of red vegetation growing in the upper intertidal zone. Eelgrass (Zostera) beds at Nanoose Bay appeared as broad, often patchy zones of brownish-red vegetation growing in the lower intertidal zone. Sea lettuce (Ulva) plants at Nanoose Bay showed as small, isolated patches of pinkish-coloured vegetation growing throughout the intertidal zone.

11. IDS Offshore Herring Survey

F.H.C. Taylor

A program to determine the offshore distribution of herring was initiated in 1968 with the support of the Industrial Development Service. The 101-ft seiner, Royal Canadian, was chartered and rigged for midwater trawling. A modified Engel net, 1,400 meshes in circumference, was used, fitted with an Elac Netsounder system. Mr. Wilbert d'Entremont, a Nova Scotian fisherman who is experienced in midwater trawling, acted as fishing advisor.

The four herring cruises in the survey were confined to the lower west coast of Vancouver Island from Esteban Point south to the Strait of Juan de Fuca, and covered the period from June 27 to July 14, July 20 to August 7, September 6 to 24, and September 30 to October 18. The period selected represented a compromise imposed by available funds and the requirements of the charterer for a single rather than a split period.

Analysis of the data is underway but not complete. Preliminary results show that:

(1) The midwater trawl is an effective method of catching herring at any depth between the surface and 1-2 fathoms off the bottom.

(2) While concentrations of herring were found on all cruises, the amount increased as the season progressed.

(3) No concentrations of herring were found beyond the edge of the continental slope. Most concentrations were found on the continental shelf within the 50-fathom contour. Six areas of concentrations could be delineated; some or all known to fishermen regularly fishing the area: (i) the mouth of Sidney Inlet, mainly juveniles; (ii) off Lennard Island, adults and juveniles; (iii) off Long Beach, mainly adults; (iv) the southwest corner of La Perouse Bank, mainly adults; (v) the southeast corner of La Perouse Bank, adults; (vi) Swiftsure Bank, adults and juveniles.

(4) The herring, other than juveniles (0+ year old), appeared to be predominantly 1+ year olds (fish in their 2nd year of life) in concentrations (ii), (iii), and (iv) above. In concentrations (i) and (v), 1+ and 2+ year olds were present in about equal proportions, each contributing about one-third of the sample. In both, 3+ year olds were relatively numerous, and in (v) 4+ year olds were more numerous than in other concentrations, making up perhaps more than 10% of the sample.

(5) Juvenile herring in July ranged in size from about 40 to 70 mm with a peak at 50 mm. In early October the juveniles ranged in size from about 62 to 107 mm with a peak at 85-95 mm and in some areas another peak at 70-75 mm.

At the end of the last cruise a few days were spent in the Strait of Georgia. In the lower east coast population, juveniles in October ranged in size from 62 to over 110 mm, with a single peak at 80-85 mm.

Analysis of the data is proceeding and it is hoped that a report will be ready early in 1969.

SHRIMP AND CRAB

12. Shrimp — T.H. Butler

(a) Study of Cape Lazo (Comox) Fishery

The purpose of the study of this fishery, on grounds discovered by this Station in 1954, is to determine the need for regulation. Field work continued during 1968 with experimental trawling on five cruises using Investigator No. 1. Periodic sampling has enabled the determination since 1965 of the age composition of the population subjected to fishing. An apparently normal age structure, present in 1966 and again in 1968, consists of second-year males and third-year females in about equal numbers with fewer fourth-year females.

From April 30 to July 9, fortnightly plankton sampling (vertical hauls) was carried out to collect shrimp larvae. The Canadian Oceanographic Identification Centre in Ottawa is doing the preliminary sorting of larvae. Information on the distribution of larvae is being sought to test the hypothesis that larvae immigrate to the fishing ground from adjacent areas.

Preliminary analysis indicates that fluctuations in year-class strength may be detected in the post-larval stages (0-group). For most of the year, concentrations of shrimps are associated with 9°C bottom temperatures. In late winter shrimps frequent the warmest water on the ground, from 8.0 to 8.5°C. To obtain information on water movements on the ground, 250 bottom drifters, obtained from R. H. Herlinveaux of the Pacific Oceanographic Group, were released during the August and October cruises. To date, about 50 drifters have been recovered by fish draggers, shrimp boats, and Investigator No. 1, but in most cases, exact recovery information is lacking.

(b) IDS Project — T.H. Butler and A.N. Yates

Experimental trap construction and prawn fishing tests were conducted from December 1, 1967 to March 22, 1968. The main objective was to test the suitability and efficiency of available materials for traps. A combination gillnet and prawn-trap boat, M.V. Harlequin, was chartered for the project.

Various shapes and sizes of traps were tested. Triangular and cylindrical traps were found difficult to stow, so oblong traps, 24" × 12" × 12", were used in most of the tests. Comparisons were made, in terms of fishing success, cost and durability, of (1) various materials as trap coverings, and (2) some modifications of trap tunnels.

In overall fishing performance, for short fishing periods (4 to 8 hr) and longer periods (21 hr and longer), traps with plywood and plastic sheeting ("Uvex") sides were about equal and ahead of other types. Next, in decreasing order of mean catch rates, were those having fiberglas, lath, galvanized iron, and burlap sides. Considering also cost and durability, it appears that a plywood trap is best.

During this project, at least, results indicated that neither trap tunnel length (8-10 inches) nor diameter of tunnel opening (2-3 inches) was a factor in determining the catch rate. Tunnels constructed of four sections of plastic fished as well as those formed of nylon netting. Although more expensive, a plastic tunnel can be assembled as quickly as one of netting, and will require less maintenance.

Mean catches (all traps) after fishing periods of 4 hours and 16-20 hours (overnight) were 14 and 15 ounces, respectively. These results, therefore, show clearly that short periods are effective and, along with normal overnight sets, may enable fishermen to operate with fewer traps.

Station Circular No. 87, containing full details of the project, has been released.

LOBSTERS

13. Lobsters — R.J. Ghelardi and C.T. Shoop

(a) Adult Study Population

Data for more reliable estimates of survival-mortality, fecundity, and growth have been obtained. Incomplete analyses indicate that these will fall within ranges of values from an earlier, preliminary study. (Some of these animals have been in Fatty Basin since February 1966.)

Ultrasonic tag detecting, tracking, and recording monitor equipment was field tested by releasing a total of 22 lobsters at Fatty Basin in September, each with an ultrasonic tag attached to the dorsal surface of its carapace. Objectives were to examine the reliability and operation of the apparatus, to design modifications, and to provide preliminary information on movement of lobsters within and out of Fatty Basin. A high failure rate was experienced during the pre-testing phase which eliminated a large number of tags before release; the most likely causes of tag failure were shorting caused by salt water leakage into tag or battery components, and poor battery performance. The performance of the 22 tags attached to released lobsters was excellent. The small, boat-operated hydrophone and receiver worked well,

allowing detection and tracking of individual lobsters at a range of 1,000 ft (ca.), and approximate location within a radius of 60 ft. Operation of automatic monitors for recording movement of tagged lobsters through the two entrances presented special difficulties (mechanical and background noise characteristics); these are being evaluated and will be eliminated before, and if, a large-scale study involving sonic tags is attempted. Tracking with the hydrophone, operation of the automatic monitors, and spot checks in Useless Inlet and Rainy Bay show only short distance movement of tagged lobsters from release point (maximum was 1,500 ft, ca.), with no emigration from the Basin. Tags were recovered from lobsters over a period of 92 days from the date of release. Two methods of recovery were utilized: diving and trapping. The tags were still firmly attached to the animals, and functioning. Sonic tag studies will be continued and extended.

Further extensions and modifications of a concrete tidal pound will be made so as to permit attempts at forced mating (to provide brood stock for culture and other experiments), and to allow observations to be made on possible differences in behaviour and survival of stock drawn from varying areas, and different species, that could eventually lead to selection of a coterie that is particularly well adapted to living in the Pacific.

Predation on lobsters, by mink and terrestrial otter, began in November-December 1967, peaked in May 1968, then abruptly ceased for the ensuing 6 months, to commence again in the following November. In the November-May period, it is estimated between 200 and 400 lobsters were lost.

(b) Hatchery, Larval, Juvenile Studies

The interior design of the hatchery was modified to permit controlled experiments on culture methods. Construction of a constant temperature room and apparatus made it possible to complete a first experiment on the effect of elevated temperature and two different foods (frozen brine shrimp and finely minced clams) on larval growth and survival. At a constant temperature (20°C) and on a diet of frozen brine shrimp, survival to the fourth stage was increased 10 or 12 times over that observed in animals fed on minced clams. The number of days required to achieve the succeeding stage was less, and growth increments higher in brine shrimp fed larvae than those raised on clams. Data on optimal and suboptimal larval growth and survival from this experiment will provide a basis for comparison for larvae hatched in nature next spring.

Controlled observations in tanks demonstrated, unequivocally, that, under experimental conditions, there is an abrupt, permanent change from pelagic to benthic mode of existence about midway through the fourth larval stage.

Juvenile lobsters, hatched in the Fatty Basin hatchery last year, have been maintained and are in their second year of growth in the Pacific. These and the two juveniles now in their third year of Pacific existence have

yielded information on growth and insight into problems related to mass culture.

Survivors from the hatchery operation this year are being used to provide information on culture methods. Two approaches have been taken, one using individual cages for single animals, and an attempt to over-winter two groups of 150 each in concrete tidal pens. If successful, these methods will provide increased numbers of various age groups for growth and behavioural studies (e.g. underwater release and observations on behaviour of individuals), and, also, possibly lead to methods that will allow mass culture of large numbers of any age (size) group desired for an introduction.

A few desultory dives at Alma Russell, site of the juvenile introduction attempted in 1967, have not resulted in any sightings of lobsters. A more extensive and intensive search for survivors will be made before accepting the obvious, perhaps inevitable, inference.

14. Ethological Studies

J.C. Scrivener

In June 1968, a project was initiated under an FRB Fellowship to analyze adult lobster aggressive behaviour. Seventy freshly-caught Atlantic lobsters were obtained in two shipments, during July and August. Over 500 aggressive, two-individual encounters were recorded by the end of 1968.

Intraspecific aggression in the adult lobster seems to involve 16 behaviour patterns, which can be placed into three categories - aggressive, avoidance, and investigative. The aggressive group includes: follow, claws raised-threat, rush, scissor-chelae brought together in a scissoring motion, push, antennae whip, box and rapid turn. The avoidance group includes: back, telson flip-escape, jump, walking, sideways - occurs with backing, and run. The last category contains antennae point and approach.

A preliminary analysis of the recorded encounters indicates that follow, threat, and back are the most important behaviour patterns. They each occupy 20-40% of an animal's total aggressive response time, and form the nucleus from which the animal can proceed to any of the other behaviour patterns. Some common sequences for aggressive animals include: antennae point——>follow——>threat——>rush——>scissor and a return to threat, threat——>push——>antennae whip——>push and a return to threat, and antennae point——>follow——>threat and a return to follow. Some common sequences for a less aggressive animal include: antennae point——>back ——>escape and a return to back, antennae point——>threat——>back——> push——>escape and a return to back. At any point in these sequences the behaviour may revert back to one of the three main behaviour patterns.

Other conclusions are becoming apparent from the preliminary results. An animal's recent aggressive history seems to be very important in determi-

ning how aggressive it will be after molting or loss of a chela. Male lobsters appear to be more aggressive than females, having won 66% of their encounters with females of the same carapace length and weight. Because males are known to have proportionately larger chelae than females, an experiment has been undertaken to determine whether aggression is related directly to chelae size.

The length of an animal's antennae appears to be a factor determining how well an individual can direct its aggression. Most lobsters with total antennae length of 25 cm or longer are able to direct consistently their aggression towards another animal, whereas those with shorter ones show mis-directed aggression towards inanimate objects, with a frequency that is inversely related to antennae length.

This project will be continued throughout part of next year.

MARINE INVERTEBRATES

15. Oysters

D.B. Quayle

(a) The Breeding of the Pacific Oyster in 1968

The summer of 1968 was generally favourable for Pacific oyster breeding. The water temperature at the 3-ft level in Pendrell Sound remained about 68°F for 2 months and in early July rose to 77°F for several days.

The salinity situation in Pendrell Sound in 1968 was normal and the lowest salinity recorded was 17‰, compared to 1967 when 8‰ occurred and caused larval survival difficulties. The 1968 season was marked by abnormally high concentrations of shipworm larvae (presumably Teredo navalis, the Atlantic shipworm), not previously observed, but due to the increased number of rafts.

The first oyster spawning occurred on July 3 when the thermograph temperature read 72°F. The plankton contained about 1 straight-hinged Pacific oyster larva and 65 shipworm larvae per gallon. Further spawnings occurred and plankton samples on July 18 contained an average of 270 early umboned larvae per gallon and a number of later stages. A commercial set was forecast for about July 28. On July 29 the plankton contained 400 advanced stage larvae per gallon, mainly in the Station 5 area. Test shells by August 1 collected 60 spat per shell in the Station 5 area and 20 spat per shell at Station 2.

On August 6 there was a mean of 821 larvae per gallon from spawnings

in the last days of July and still about 3 advanced stages per gallon. This spawning was responsible for a set which produced 23 spat per shell in late August. Shell strings exposed between August 1 and August 12 at Station 2 collected an average of 200 spat per shell.

Based on previous experience, the number of advanced stage larvae in late July should have been ample to provide a much heavier set throughout the Sound than that which actually resulted on commercial cultch. The commercial set was very irregular, ranging from an average of 10 spat per shell on a string to well over 100 spat per shell. The variation may be explained in part, but not entirely, by unclean cultch and overcrowding of the strings and of the rafts. It is unlikely the heavy concentrations of shipworm larvae had any effect since large numbers of oyster larvae reached advanced stages. However, more abnormally shaped larvae than usual were observed (up to 10%) for which there is no apparent reason.

The equivalent of approximately 150,000 shell strings were exposed by two companies. Export was largely to the United States, with approximately 200 tons going to France for the first time.

(b) Raft Culture of Oysters

The raft culture experiment described in detail in the 1967 report was terminated in October 1968. Only 9 of the original 14 rafts were available for study. In general, there was a very significant increase in size of the oysters and at practically all stations the oyster meats had increased from table to soup size.

Fouling at certain stations had increased significantly, at others the interfering fouling had become less. Of interest ecologically is the wide range of fouling in both species and quantity from station to station.

In general, the west coast of Vancouver Island stations were somewhat superior in growth rate over the upper mainland coast stations.

It is concluded that raft culture may be carried on successfully throughout the British Columbia coast. Each individual site, however, should be pre-tested on a small scale. While the experiments have demonstrated satisfactory procedures, many variations are possible and these will no doubt be examined as the system is developed by growers.

The experimental strings produced between 1.5 and 2.5 tons of oysters in the 2 years on the raft. This production could be tripled when carried out on a commercial scale.

(c) Oyster Cultch Development

This investigation with the British Columbia Research Council has been completed as far as the provision of Industrial Development funds is concerned. An apparently satisfactory cultch has been developed along with a manufacturing process. Enough cultch was prepared for a small-scale field experiment. This was exposed in Pendrell Sound in 1968 and collected a set. The final performance will not be known for another 2 years.

Further material is being prepared to straddle more accurately the desired disintegration time.

Commercial seed producers are most interested and are prepared to test market reaction with a considerable quantity of this cultch, providing arrangements can be made to procure the use of a manufacturing machine.

(d) Bacteriology of Oysters F.R. Bernard

In Ladysmith Harbour, raft-grown oysters demonstrated lower coliform and E. coli counts than nearby beach oysters. In most cases surface oysters have a lower count than oysters approximately 6 ft below surface. At 9 ft the count is very much lower.

		Faecal coli MPN	E. coli MPN
Beach stock on Nov. 7/68		2400	790
Raft	Surface	2000	565
	6 feet	2450	1175
	9 feet	1500	75
Beach stock on May 8/68		220	110
Raft	Surface	335	140
	9 feet	120	45

Variation in replicated samples is greater in surface-grown raft oysters than in those suspended 9 ft below surface:

	Surface		9 feet	
	Faecal *coli* MPN	*E. coli* MPN	Faecal *coli* MPN	*E. coli* MPN
	400	170	140	68
	2400	110	400	170
	790	330	140	93
	1700	490	220	45
Mean	1320	270	220	90

(e) Depuration

Changes in the standard 35°C plate counts were measured at 12-hr intervals for shucked and living oysters. At 5°C there was a gradual increase in the shucked oysters to a plate count of >22,000 in 60 hr. In living oysters, counts remained reasonably uniform, dropping slightly to <350 after 60 hr. At 10° and 20°C the living oysters maintained uniform counts but shucked oysters climbed to 29,000 and 165,000 in 60 hr. At 30°C the increase in the standard plate count was rapid and uniform in shucked oysters, but living oysters did not increase appreciably until after 24 hr. When moribund (36 hr), the plate counts increased dramatically and at 48 hr the shucked sample was less than double the dead and moribund oysters (220,000 vs. 155,000, respectively).

35° Plate Counts in Living and Shucked Oysters

	Time (hr)	Temperature			
		5°C	10°C	20°C	30°C
Shucked	..	1,800	Original sample		..
	12	1,500	2,200	4,700	14,500
	24	1,950	6,000	20,000	25,000
	36	2,450	17,500	40,000	90,000
	48	17,200	22,000	68,000	220,000
	60	22,500	29,000	165,000	Spr
Living	12	1,500	1,950	1,700	1,850
	24	1,300	1,350	1,500	2,450
	36	11,500	1,750	1,400	5,000
	48	1,350	1,600	1,600	155,000
	60	1,350	1,750	1,900	+

16. Clams — N. Bourne

(a) Razor Clams

Razor clam landings in the commercial fishery at Masset continued at low levels due to the continuing difficulty in obtaining people to dig the clams, not to decreased clam populations. Continued interest was expressed in construction of a mechanical digger to harvest these clams but none was built in 1968.

Screening of random plots on the beaches at Masset indicated that recruitment was approximately the same in 1968 as in 1967. On North Beach the density of small razor clams (under 20 mm shell length) ranged from 0 to 23 clams per square foot, a mean of 12. In 1967 the densities ranged from 0

to 25 clams per square foot, a mean of 10. On Horseshoe Beach, densities of small clams varied from 0 to 6 clams per square foot, a mean of 3. Twenty plots were screened on South Beach but only one small clam was found.

The growth rate of these small clams was approximately the same in 1966, 1967 and 1968, and there is now good evidence that the first winter ring is laid down when the clams are about 10 mm in length. The second winter ring occurs when the clams are approximately 40-45 mm shell length.

(b) Butter Clam Growth

Butter clam growth rates have been measured in a few localities in British Columbia, but no comprehensive study has been made of their growth rate throughout the province. In 1968 a project was started to measure accurately and to compare the growth rate of butter clams along the entire coastline of the province, and also to compare growth rate at different tidal levels on a clam beach.

Clams were dug in selected areas and were sorted to provide a wide size distribution. The length, height and thickness of the shell were recorded and a plastic tag was cemented to it. The clams were replanted in plots in the same areas where they were dug, 300 clams in each plot.

Eighteen plots were established from the Prince Rupert area in the north to the Gulf Islands area in the south, including the Queen Charlotte Islands and the west coast of Vancouver Island. The plots were located at tidal levels on the beach so they are covered with water for approximately the same duration throughout the entire study area. The plots established to measure growth rates at different tidal heights on a beach were located in the Strait of Georgia area.

The plots will be re-dug in 1969, the clams re-measured and the growth rates calculated.

During this work beach surveys to assess clam populations and size distribution were carried out in areas adjacent to the plots. Small butter clams, 15-30 mm shell length, were common from the Alert Bay area north to the Prince Rupert area. However, this size-class was rare in the Strait of Georgia.

(c) Seal Island Project

Seal Island is a productive clam flat at the northern tip of Denman Island and has been a study area for Biological Station scientists since 1938. A project has been started to study the ecology of this clam beach so that we might be able to explain the causes for yearly fluctuations in clam populations. While the principal concern is a study of the ecology of butter clams, the ecology of other species will also be studied.

In 1968 the flat was mapped both by standard surveying methods and also from aerial photographs taken from a Comox-based Armed Forces helicopter. A map showing the topography, soil types, clam distribution, and position of the water at different times in the tidal cycle is in preparation.

Measurement of some of the physical parameters affecting spawning, growth, and mortality was begun. Tagged clams were planted in three plots on the beach to measure the growth rate of clams and to compare this growth rate with that of clams in other parts of the province. Regular histological samples of butter clam gonads indicates spawning in this area may take place in the early spring, but plankton samples failed to show any evidence of butter clam larvae in the water around the flat. Extensive sampling for small butter clams (under 30 mm) indicates that recruitment in the last 2 years has been very low.

A particularly strong horse clam (Tresus capax) year-class settled at Seal Island and elsewhere in the Strait of Georgia in 1968. Spawning at Seal Island may have taken place in late winter or very early spring. The set was first seen at Seal Island in early June when the clams were about 6 mm shell length. Regular sampling has established the growth rate during the first year and the first winter ring occurs when the clams are about 30-35 mm in length.

The project to assess clam predation by flounders and scoter ducks was completed in 1968. Eight longline sets using a variety of small hooks and six tows with a small trawl were made on the flat. No flounders were taken on the longline and only one small flounder was caught in the trawl. Predation by flounders is probably almost nil. Over 200 scoters were collected, 75% of which had clam remains in the gizzard. Mussels, little neck and Manila clams were the commonest bivalves. Gastropods occurred in 10% of the birds and butter clam remains in only 4%. White-wing scoters are the worst clam predators, surf scoters much less so, and few clam remains were found in the common scoters.

17. Molluscan Larval Studies — N. Bourne

The laboratory program investigating the larval development of the commercially important molluscs in British Columbia was continued in 1968, and several groups of larvae were reared to settlement. Most of the work was on butter clams, although other species were studied. Six groups of oyster larvae were provided to other investigations for feeding experiments.

Limited success was achieved in spawning conditioned clams using the standard techniques: adjustment of water temperatures, addition of sperm extract and chemical stimulants, use of physical stimulants and electric shock. Ten males and one female were spawned with these methods. A method was devised to strip sperm and eggs from conditioned clams and then treat the eggs with

0.1 N ammonium hydroxide. The resulting fertilization was successful; in the best experiment about 30% fertilization was obtained.

Ten groups of butter clam larvae were obtained by the above method and five of the groups were reared through to settlement. At 25°C the larvae did not survive longer than 72 hr. Best survival was obtained with larvae kept at 15°C, but growth of larvae kept at 15°C and 20°C was the same. At these two temperatures a settling size of 260-270 microns was reached in 20 to 25 days. The best single food was Chaetoceros calcitrans, a unicellular alga widely used in bivalve culture in Japan.

Two groups of little neck clams were also reared to settlement. At 18°C-20°C a settling size of 260-270 microns was reached in 20 to 25 days. Some of these clams were marked with a stain and will be used in growth experiments. Best growth and survival was obtained in those cultures which had air bubbled through them.

This project will be continued. Emphasis will be placed on developing a method to spawn adult clams and on studying the effects of different environmental factors on larval development. The larval development of other molluscs will also be investigated.

18. Abalones

D.B. Quayle

Relatively little effort was expended on this problem in 1968.

The disappearance of the abalone populations at Sivart Island in Juan Perez Sound and off Nanoose Bay was checked and the abalones are still missing. This does not seem to be a general condition, for good populations still occur at Hornby Island in Georgia Strait and at the tagging area in Barkley Sound. There have been no reports from commercial divers. It is expected more time may be devoted to this investigation in 1969.

19. Clam Drill Study

F.R. Bernard

Continuing study of the clam drill Polinices lewisi is being undertaken, consisting of final preparation of a paper on the histology and function of the accessory boring organ. Of particular importance is electron microscopy of the cuticle of the ABO. This region has been found to be composed of a dense mass of microvilli in a protein and chitinous matrix. The central epithelium consists of tall secretory cells which contain PAS positive granules. In electron micrography these bodies appear associated with Golgi complexes.

Some progress has been made in the gonadal cycle. Spermatogenesis appears to follow the general gastropod pattern, but oogenesis appears rather individualistic, both in the extreme length of ripe oocytes present and in the fact that early in their career the oocytes migrate from the follicle wall to the centre of the lumen and continue their development in this location.

20. Ecology

D.B. Quayle and F.R. Bernard

(a) Faunal Program

The faunal survey was continued in 1967-68 with 77 dredge hauls taken mainly off the west coast of Vancouver Island. The total coverage is now fairly adequate and sampling wide enough to allow generalized analysis of invertebrate associations and distributional patterns. Future work will be based on more detailed sampling of prescribed areas.

(b) Shore ecology

Dr. J. R. Lewis, the eminent British shore ecologist, spent two months during the summer of 1968 on a generalized study of rocky shore ecology at several sites around Vancouver Island. Discussions and field studies with Dr. Lewis assisted in describing situations and processes of which we were aware but had not defined in so many words. For instance, predation as a factor in succession and climax in shore ecology is broadly obvious but detailed analysis is another thing. The association with Dr. Lewis was most stimulating and a report on the studies is being prepared.

A number of gastropods are being studied to determine the extent and relationship of intra- and inter-population variations in monoecious and dioecious forms. In some cases the phenotype is independent of sexual dimorphism and in such situations it is difficult to determine whether it is the product of ecological pressures or solely the product of the genotype.

A short paper on the sexual polymorphism of *Polinices lewisi* (the clam drill) has been published and a review of the complex polymorphism displayed by *Astraea gibberosa* (Dillwyn) is in final preparation.

(c) Systematics

An anatomic and systematic study of the eastern Pacific Septibranchida has been accepted for publication. This work has critically reviewed all type material and recognized 47 species, including five new ones. For the

first time the general anatomy of several very rare deepwater forms has been described.

A new species of scallop, Cyclopecten carlottensis Bernard has been described. This interesting bivalve was collected off Moresby Island in 1,650 meters and presents a markedly different appearance from all other Eastern Pacific cyclopectens.

A continuing study of the systematics and anatomy of western Canadian marine bivalves is being carried out and work is almost complete on a revision of the recent Thyasiridae.

21. Histological Services — J. Bagshaw

During the last 12 months this department has processed approximately 6,600 slides for investigations from each of the Research Groups.

The following projects were completed for the Marine Invertebrates investigation:

(1) Serial sections of small invertebrate animals stained routinely for the purpose of anatomical description where the animals were too small for gross dissection.

(2) Samples of gonadal tissue processed and sectioned for investigating the condition of the animals' spawning factor.

(3) Special staining for sections of oyster gonads taken at varying times of the year to demonstrate the presence of glycogen in the tissue.

The histological and histochemical description of the accessory boring organ of a gastropod is at present underway.

Much of the work for other investigations also involved the preparation and sectioning of tissue for anatomical descriptions of animals or organisms too small for dissection by ordinary methods.

Some of these tissues, in order to be sectioned and stained satisfactorily, have to be processed by non-standard methods, these being investigated and devised to suit the requirements of individual tissues.

An example of improvisation is the sectioning of the salmon-egg capsule for which no standard method had been devised; a task which was performed satisfactorily enough to have photographs of the capsules published in the Canadian Journal of Zoology.

Serial sections of tissues including whole copepods, individual organs of fish, etc. were often prepared with special stains to search for and demonstrate the presence of microorganisms, such as fungi, yeasts and parasites, or of pathological conditions.

A certain amount of work has also been done on the preparation of tissues for further studies by electron microscopy. This work involves processing and embedding tissues in plastic polymers, which were then sent to U.B.C. to be sectioned and photographed.

PACIFIC OCEANOGRAPHIC GROUP

M. Waldichuk

Programs in the Pacific Oceanographic Group during 1968 continued to be strongly field-oriented, as major investigations were at their operational peaks and a new program (Oceanic-Coastal) was developing. However, 1968 was also a year of consolidation, when spending on new programs had to be curtailed and emphasis was placed on finalizing existing programs and bringing them into the publication stage. We are pleased to report that all positions seconded to POG from the Marine Sciences Branch, DEMR, were filled by the end of the year, and the staff involved with the Weathership program now constitutes a viable unit.

During 1968, the major project in biological oceanography was a time series study of trophic levels in Saanich Inlet. It lasted from May through July, during which time several phytoplankton blooms occurred in the inlet. The grazing of one of these blooms by E. pacifica resulted in the laying of eggs and development of euphausiid furcilia approximately one month earlier than had been seen to occur during a similar study in 1966. From feeding experiments using live zooplankton and young salmon, the growth rate of fish varied between 2.5 and 5.7% per day and was dependent on prey concentration. It was shown that the growth rate of juvenile salmon in nature could be exceeded by feeding very high prey concentrations of of zooplankton. Two basic food chains have been described, one of which is longer and is less efficient in the conversion of energy than the other. Fish may have to obtain its food through a less efficient pathway in the food chain.

The survival and rapid growth of larval herring in the euphotic zone of the Strait of Georgia appear to be related to the availability of three species of copepod nauplii, Metridia lucens, Pseudocalanus minutus and Calanus pacificus. Juvenile pink, coho and sockeye salmon, migrating from the Fraser River, seek food from a different trophic position in the food chain than that of larval fish. Macrozooplankton, particularly Calanus plumchrus, is consistently found in the stomachs of these salmon.

The estimation of secondary production at Station P, using measurements of photosynthesis and zooplankton, has been extended to individual years. Secondary production was least in 1962 and greatest in 1964, during the 6-year period 1960-1966. The second largest zooplankton production occurred during the second lowest year for primary production, and the transfer efficiencies ranged from 10 to 37%. A simulation model has been developed to directly compute daylight phytoplankton production, true net phytoplankton production, zooplankton rations and zooplankton production. Simulated annual cycles of plankton production suggest that the ecological efficiencies vary seasonally and change from year to year, rather than being constant, as it is often assumed.

Microbiological studies in 1968 included investigations in the Nanaimo River estuary, Departure Bay, Strait of Georgia and Saanich Inlet.

The formation of particulate matter by microbiological action, bacteria in natural food of salmon, decomposition of bottom organic materials, and the contribution of microorganisms from the Nanaimo River to the Strait of Georgia were investigated. The infection of copepods by yeasts of the genus Metschnikowia was considered to be serious in the Strait of Georgia during winter and early spring. Studies on the effect of decompression on marine organisms suggests that measurement of activity at depths greater then 200 m should be done in situ or by simulated in situ methods.

The 1968 physical oceanography studies in the Strait of Georgia consisted mainly of numerical analyses of tides, and current observations in the Fraser River plume area. Work has continued on both the theoretical and field aspects of tides and tidal streams in the Strait of Georgia and Juan de Fuca Strait system. The field program associated with the development of the tidal study has only been made possible through the cooperation of the Tidal Branch of the Canadian Hydrographic Service in Victoria. The tide gauge program, in which the University of Washington also cooperated, and which involves the simultaneous operation of 30 gauges throughout the Georgia-Fuca system for a year will be completed early in 1969. Twelve oceanographic cruises determining the distributions of temperature, salinity and (at selected stations) oxygen have also been completed. These cruises afford the first such series of data in the system and will be used in studies concerning bottom water replacement in the Strait of Georgia, diffusional processes and sea levels. As far as possible, the preparation of the data for analysis will involve machine processing. Current observations were continued. During 1968 velocity-profile measurements in the upper 50 m were obtained at 6 stations. There was considerable variability in strength and direction of currents at different depths and from station to station.

Results of drift observations in the vicinity of Iona Sewerage Outfall indicated that, while floats released closer to shore (within 2 miles of the low-water level) travelled northward, those released outside this limit travelled southward. One set of floats released within the "2-mile limit" at high water travelled southward, reaching an area off Porlier Pass within one day. Floats released at the mouth of the main arm of the Fraser River generally confirmed results obtained last year; that is, the main plume water occurring at the mouth at high-water slack flows first toward Porlier Pass, then northward, finally ending up at a point midway between Entrance Island and Roberts Creek within one tidal day. The eventual destination of water depends considerably on whether or not the water stays within the main plume during the ebb.

Field measurements of current velocity employing moored recording current meters were originally planned for May 1968. However, the program was delayed until August, owing mainly to conflicts in ship scheduling and personnel assignments. A Geodyne buoy with an array of current meters was anchored late in the year and appeared to provide a satisfactory set of current data.

A comprehensive physical-chemical study of the oceanic-coastal waters off the British Columbia coast was initiated in 1967. A second survey was completed in April 1968, although it was not as extensive as the first survey in September 1967. A third survey was carried out in October 1968. Continuous profiles of temperature and salinity to a maximum depth of 1,500 m are being obtained at relatively close intervals along lines normal to the coast. Preliminary analyses of the data indicate that the vertical temperature structure is extremely complex in some areas; many small inversions occur, particularly between 100 and 300 metres depth. The horizontal distributions are characterized by many cells and tongues. Analyses of these and historical data (1957-1962) are continuing, to define the relatively permanent features, the seasonal and annual or long-term variability. The Tidal Branch of the Canadian Hydrographic Service have completed mooring tests and preliminary operation of a current meter and thermograph off the west coast of Vancouver Island for the proposed West Coast Buoy Project.

The Weathership program continued on Station P with CCGS Vancouver, but some difficulty was encountered in resuming Line P on a full scale. The use of the STD and XBT systems has been increased to provide better data. Preparations were made to phase CCGS Quadra into the oceanographic program on Line P and Station P during 1969. Statistical analyses of long-time series of geophysical data were continued. Data for sea levels, meteorological parameters and seawater temperatures and salinities were digitized. Computer programs were tested and the mathematical properties of low-pass filters were considered. Mass transports from monthly mean, sea-level barometric pressure data continue to be computed. Numerical analysis of fishery records has identified times of major environmental influence on stocks of herring and coho. Power-transformed, response-surface analysis has provided useful results from 40 years of pink salmon catches.

Oceanographic support was provided in Saanich Inlet, with a series of current measurements, during June and July, and in the eastern Arctic during August-September in under-ice acoustical studies. Observations have been continued on the drill rig SEDCO-135F giving useful information on temperatures and currents at various locations along the west coast of Vancouver Island and in Hecate Strait.

Field programs continued monthly in Ladysmith Harbour and in the Victoria Harbour-Gorge-Portage Inlet system to December when they were terminated. Seasonal surveys were conducted in Alberni Inlet. The seasonal variation of coliforms in Ladysmith Harbour continues to be strongly related to runoff, with highest values in autumn and winter. During August a survey was conducted in Alberni Inlet, Muchalat Inlet, Quatsino Sound and Discovery Passage. A survey was conducted along the Lower Mainland, including the Fraser River estuary, Burrard Inlet and Howe Sound, during September and October. The cool, wet summer contributed to high oxygen concentrations being maintained in all these waters, except in Neroutsos Inlet.

Because there is considerable interest in the wind flushing of coastal embayments, a 6-week field program was completed in Departure Bay during

September and October. The cool, wet summer contributed to high oxygen concentrations being maintained in all these waters, except Neroutsos Inlet.

Because ~~there is con~~siderable interest in the wind flushing of coastal embayments, a 6-week field program was completed in Departure Bay during July-August, when periods of strong westerly winds prevailed. Winds were recorded at two points: near the middle of Departure Bay and at the entrance. Surveys with BT's and in situ salinometers were conducted daily. Temperatures and currents were recorded continuously at a number of depths, for about 35 days. To separate tidal effects from wind effects, sea level was recorded on a tide gauge (courtesy Canadian Hydrographic Service) at the Biological Station wharf. Data have not yet been analyzed, but interesting developments in the thermocline could be seen on BT slides during strong westerly winds in July.

Laboratory experiments were initiated on pollution by water-borne wood solids. The research program was planned in detail for a 5-year study. Laboratory facilities were developed and constructed in the Gear Research Building; data processing was programmed for the Station's IBM 1130 computer; and preliminary experiments were commenced on leaching of different species and sizes of wood with waters having diverse characteristics. To describe the time-dependence of pollution by wood solids of different sizes, a mathematical model was constructed, which it is proposed to test with experimental data.

Daily seawater observations were continued at 17 lightstations. In northern British Columbia, temperatures in spring and autumn were normal, but lower than normal in winter and above normal in summer. Below-normal winter temperatures were also prevalent along the west coast of Vancouver Island. Summer temperatures were near normal in this area. In the Strait of Georgia, temperatures were near normal for the whole of 1968.

The Canadian Oceanographic Information Service commenced in November to provide all characteristics of the thermocline on a single chart, and surface sea temperatures on another chart, issued twice weekly from the Maritime Forces Weather Centre, Esquimalt. POG continued to contribute scientific information, when needed, and participated in reviews of the work through meetings of the West Coast Working Party. Ships for POG have been made available from the Biological Station fleet, as well as from the west coast ships's pool scheduled by the Ships Schedule Panel of the West Coast Working Group, Canadian Committee on Oceanography. The CNAV deperm barge, YBD3, was generously loaned by the Navy for the 3-month study in Saanich Inlet. Planning was continued for a new FRB scientific barge.

1. Biological Oceanography - Strait of Georgia

T.R. Parsons,
R.J. LeBrasseur &
W.E. Barraclough

During 1968 the principal biological oceanographic investigation was carried out during the months of May, June and July in Saanich Inlet on the eastern coast of Vancouver Island. The purpose of this project was to continue food chain studies on juvenile salmon which were started in the same area during 1966. Monitoring of one station in the centre of the Strait of Georgia was continued and certain special investigations, such as studies on the distribution of larval herring off the mouth of the Fraser, and the occurrence of infectious yeasts, were either initiated or continued from 1967 as ancillary projects within the main program.

From the main purpose of this program, as an investigation of the early life stages of fish in relation to their environment and, in particular, to their food supply, it has been possible to describe two basic food chains which may exist in the marine pelagic environment; the one nanophytoplankton———>microzooplankton———>macrozooplankton———>fish, being longer and supposedly less efficient in the conversion of energy than the other, microphytoplankton———>macrozooplankton———>fish. However, it is also apparent that, depending on the type of macrozooplankton produced by these two food chains, more or less energy may be required by a fish in order to capture its prey. Thus, in nature, the "ideal" food chain, which would tend to maximize the survival of young fish, may in some cases be impossible to attain, and instead, a population of young fish may have to obtain its food supply from a less efficient pathway in the food chain.

Finally, in these trophic studies, conditions governing the survival of larval fish cannot be described in the same terms as those governing the growth of juvenile fish. For larval fish, separate theoretical considerations are required, together with the collection of data of specific relevance to the environment of a larval fish. From field studies, conducted as part of the regular monitoring program in the Strait of Georgia, particular attention has been given to variations in the natural food supply of the juvenile salmon and larval herring, lingcod and eulachon. The survival and rapid growth of larval herring in the euphotic waters of the Strait of Georgia, near the Fraser River plume, appear to be related to the abundance and availability of microzooplankton, namely: three species of copepod nauplii, Metridia lucens, Pseudocalanus minutus and Calanus pacificus. On the other hand, the diet of the juvenile pink, coho, chum and sockeye salmon, migrating from the Fraser River into the marine environment, is at a different trophic position in the food chain compared with that of larval fish. Many species of macrozooplankton are consistently found in the stomachs of these salmon and, in particular, Calanus plumchrus.

In addition to the food studies, the field sampling has indicated some possible migratory routes of the pink, chum and sockeye salmon, from the mouth of the Fraser River, through the Strait of Georgia, to Juan de Fuca Strait.

Studies on the food chain of a benthic community have started with consideration being given to the total input of organic material, the accumulation of organic material to a steady-state value within the sediment, and the output of organic material through bacterial decomposition. From studies in a small bay, it has been shown that organic materials sedimented during the summer and winter have different biological properties, as determined by the growth response of a species of marine bacteria, but that both materials were, in general, readily converted to bacterial biomass, which could then be utilized to support the growth of brine shrimp. From the quantities of organic material which have been estimated as entering the Strait of Georgia from a small river, as well as from the amount of material sedimented during the winter in a shallow bay, it appears that the most significant finding in these studies has been that the quantity of terrigenous organic carbon entering the strait is approximately equal to the annual marine primary production of the area. Since it is believed that most of this material is rapidly sedimented and that it is a good substrate for bacteria, it may be tentatively concluded that much of the benthic fauna, in coastal areas with heavy land drainage, is ultimately dependent for its food on the land, and to a lesser extent on the sea per se.

2. Biological Oceanography - Saanich Inlet

As a special study within the general framework of the Strait of Georgia program, the food chain of juvenile salmon was studied in Saanich Inlet during May, June and July 1968. The main purpose of this study was to quantify in toto the various pathways leading up to the food of the young salmon. In addition, experiments were performed on the growth of young salmon which were fed different concentrations and different types of prey. In these experiments it was found that the rate of growth of the fish varied between 2.5 and 5.7% per day and was dependent on the concentration of prey. Electivity experiments showed that all juvenile salmon selected copepods of length 1.6-4.5 mm, in proportion to their abundance, but rejected copepods < 1 mm. Positive electivity on prey larger than 4.5 mm could only be observed following a period of training.

A comparison of the experimental results with the natural growth and feeding of juvenile salmon in Saanich Inlet showed that experimental growth rates of 5.7% per day for animals fed on high concentrations of prey, were greater than those encountered in nature, which ranged from 4 to 5% per day. Prey concentrations in nature were lower than those fed in some experiments, and from stomach content analysis it was apparent that the prey eaten by salmon in nature was at times highly diverse. In general, however, the most often encountered stomach contents showed a prey spectrum which fell into the size category of plankton with dimensions between 1 and 5 mm.

3. North Pacific Productivity

T.R. Parsons, C.D. McAllister and R.J. LeBrasseur

Production studies at Ocean Station P have continued, and more detailed estimates of the relationship between primary and secondary production have been made. In this respect, the estimation of secondary production at Station P, using measurements of photosynthesis and zooplankton, has been extended to individual years. In the period 1960-1966, annual secondary production was least in 1962 (4 gm Cm^{-2}) and greatest in 1964 (18 gm Cm^{-2}). Estimates for individual years suffer from the fact that observations were made only in alternate 6-week periods, but the results give an indication of the possible range of variation.

The estimates suggest that primary production alone is not a sufficient index of changes in secondary production. The second highest estimate of zooplankton production (16 gm Cm^{-2}) occurred with the second lowest estimate of primary production (38 gm Cm^{-2}), and transfer efficiencies ranged between about 10 and 37%.

Large-scale studies over the whole of the northeast subarctic Pacific Ocean have continued with the collection of data from research vessels operating in the area. In addition, some data were collected by the University of Washington from American Mail Line vessels, as part of a joint exercise with POG and other agencies in the area.

Sufficient data on the distribution of nitrate in the area have been collected to show that nitrate does not become depleted during the summer months, north of 45°N and outside of a coastal area extending seaward to approximately the 1000 fathom line. However, the progressive utilization of nitrate during the spring months has confirmed our previous results on the predicted course of the spring bloom over the entire area.

Following the earlier use of the Sverdrup model for an examination of conditions governing production in the northeast Pacific Ocean, attention has now been given to more elaborate models for large-scale studies of ocean production. The model currently being used for these studies employs eight variables to describe the level of production (see Steele and Menzel, Deep-Sea Research, 9: 39-40, 1962). Using this model, computed values of primary production ($mg/m^2/day$) have been tabulated for a large range of different variables, and it is planned to compare these values with actual observations made during a trans-Pacific cruise early in 1969.

4. Plankton Dynamics

C.D. McAllister

The implications of a number of experimentally-determined Ivlev ration curves, under both continuous and nocturnal grazing, for growth by stocks of phytoplankton and zooplankton have been examined using a simulation model

programmed for the Nanaimo Station's IBM 1130. The model has also been used to assess the effects of errors in the fitted Ivlev constants, and in commonly-measured, food-chain parameters for attempts to predict sequences of plankton stocks. Treating the model output as field data, it was shown that the practice of taking temporal and spatial averages of field data can lead to serious errors in estimates of production.

The model has now been modified to directly compute daylight phytoplankton production (that which is commonly estimated by conventional field methods), true net phytoplankton production, zooplankton rations and zooplankton production. Mortality on the zooplankton and non-predatory mortality on the phytoplankton, and preliminary modelling of the effects of nutrient limitation, with regeneration and mixing effects, have been tested. With the present scheme, the ecological and gross growth efficiencies resulting from various combinations of input variables are readily computed. Simulated annual cycles of plankton production suggest that the ecological efficiencies vary seasonally and change between years rather than being constant as is often assumed.

5. Marine Microbiological Studies — H. Seki

During the summer of 1968, microbiological studies were made in connection with the Saanich Inlet project. The major purpose of these studies was to investigate the formation of particulate matter from a microbiological point of view. Studies were made on the relative importance of bacteria in the natural food for young salmon. In addition, routine studies were carried out on the marine microbiology of the inlet (e.g. measurement of total bacteria, heterotrophic bacteria, yeasts, microbial uptake of glucose).

In cooperation with other scientists, studies were made on the decomposition of organic materials deposited in Departure Bay. The result of these studies demonstrated the importance of bacteria in the benthic food chain, and estimates were obtained of the rate of cycling of certain elements in a near-shore benthic environment.

The contribution of microorganisms and organic materials to the Strait of Georgia from the Nanaimo River has been studied. Statistical analysis of microbiological data showed that non-halophilic microorganisms (freshwater organisms) predominated in water of less than 2% salinity. When there was a large quantity of organic materials present, however, the survival of freshwater bacteria in the marine environment increased.

The disease of copepods by yeasts was observed to be serious, especially during winter and early spring. The yeasts were identified as belonging to the genus Metschnikowia. Investigations are now continuing on their importance in the ecology of the Strait of Georgia.

Studies on the effect of decompression on marine microorganisms have been carried out. These suggest that measurement of microbial activity at depths greater than 200 m should be carried out in situ, or at least by a simulated in situ method (i.e., incubation should be done at in situ pressure after sampling).

Studies have been started to estimate the microbial biomass on different substrata in the euphotic zone of the Strait of Georgia. From these studies, it is expected that some conclusions may be drawn on the microbial role in the decomposition of plankton and detritus in the food chain of the sea.

6. Physical oceanography - Strait of Georgia

S. Tabata,
P.B. Crean,
L.F. Giovando &
J.A. Stickland

The 1968 physical oceanographic program for the Strait of Georgia consisted mainly of:

(a) Tidal circulation studies by Mr. P.B. Crean.

(b) Current observations in the Strait of Georgia by Drs. S. Tabata, L.F. Giovando and assistants.

(a) Tidal Circulation Studies in the Georgia-Fuca System

P.B. Crean

In the course of the past year, work has continued on both the theoretical and field aspects of tides and tidal streams in the Strait of Georgia and Juan de Fuca Strait system.

Considering initially the former aspect, the problem is essentially one of reproducing mixed tides in a deep, narrow sea having a complex boundary geometry. Thus, if the correct amplitudes and phases of the tide can be calculated throughout a one-dimensional system, the mean cross-sectional velocities are also determined. These velocities undergo marked spatial and temporal variations and are important in considering mixing processes in the system.

Using a single-fluid, one-dimensional, multi-channel hydrodynamical-numerical model of the Georgia-Fuca system, based on available data, reasonably good reproductions of the semi-diurnal and diurnal tide have been obtained. The work has been carried out using the IBM 1130 computer at the Biological Station. Four major schematizations have been evaluated and include cases where the northern end of the Strait of Georgia is considered, respectively, to be closed or open to the ocean tide in Queen

Charlotte Sound. Where appropriate, these schematizations include, as separate channels, Queen Charlotte Strait, Knight Inlet, Broughton Strait, Johnstone Strait, Discovery Passage, Bute Inlet, Malaspina Strait, Jervis Inlet, Howe Sound, Rosario Strait, Haro Strait, Admiralty Inlet, Hood Canal, Puget Sound, and the waters bounded by the Gulf Islands and Vancouver Island. The effects of quadratic and linear friction, convective acceleration and changes in the boundary conditions have been examined. A program has also been written which predicts the tide, based on up to 7 components, for any location in the system for which harmonic constants are available. A report based on this phase of the work is in preparation.

The field program associated with the development of this study has only been made possible through the cooperation of the Tidal Branch of the Canadian Hydrographic Service in Victoria. The tide-gauge program, in which the University of Washington also cooperated, and which involves the simultaneous operation of 30 gauges throughout the Georgia-Fuca system for a year, will be completed early in 1969. Twelve oceanographic cruises determining the distributions of temperature, salinity and (at selected stations) oxygen have also been completed. These cruises afford the first such series of data in the system, and will be used in studies concerning bottom-water replacement in the Strait of Georgia, diffusional processes and sea levels. As far as possible, the preparation of the data for analysis will involve machine processing.

The new data will be used for the refinement of the model and its extension to include other factors of oceanographic importance.

(b) Current Measurements in the Strait of Georgia — S. Tabata, L.F. Giovando & J.A. Stickland

Current measurements were made from anchored vessels at 7 locations. It is to be noted that 4 out of 7 stations were located near Point Grey. The reason for this is that information on water movement in this area has recently been sought by various organizations. Hence, more emphasis was placed on observations in the waters along the eastern shores. During the approximately 2 weeks' operations in June, the Greater Vancouver Sewerage and Drainage District provided personnel and work boats to assist in the observations. In addition to current measurements from anchored vessels, drift observations were made using the newly-designed "Terhune" drogues.

Two flights in the Coast Guard helicopter and one in a chartered helicopter were made to assist in drogue tracking. They provided very useful information; however, owing to adherence to air control office rules, flying in the area presented some difficulty.

Results of drift observations in the vicinity of Iona Sewerage Outfall indicated that while drogues released close to shore (within 2 miles of the edge of the sand banks) travelled northward, those released beyond

this limit travelled southward. However, one set of drogues released within the "2-mile limit" at high water travelled southward, reaching the vicinity of Porlier Pass within one day.

Drogues released at the mouth of the main (south) arm of the Fraser River generally confirmed results obtained last year; that is, water issuing in the main "jet" at the river mouth at high water slack flows first toward Porlier Pass, then northward, finally ending up at a point midway between Entrance Island and Roberts Creek within one tidal day. The eventual destination of water depends considerably upon its position within the plume during the ebb. Water at the southern edge of the outflow appears to end up between Roberts Bank and Galiano Island within one tidal day. On the other hand, water at the northern edge tends to veer and may even flow toward Sturgeon Bank within 1/2 tidal day. A more detailed analysis of the drift observations and current-meter measurements has now recommenced.

Moored current meter program. Field measurements of current velocity employing recording current meters were commenced in 1968. In late May, a Stonechance navigational buoy was anchored midway between Sand Heads Lighthouse and Porlier Pass, and a Geodyne buoy anchored 5 miles west of Iona Jetty. These "dummy" buoys, without current meters, were placed in position for a few months to familiarize mariners with them as "obstructions".

The Stonechance navigational buoy was reported missing in early August and has not been located yet. The Geodyne buoy placed at F-11 was retrieved during mid-August, and was re-anchored at the same location after defective parts were replaced. Two current meters, a Plessey and a Geodyne, were placed at 50 m and 200 m, respectively, and data were recorded over a period of one month.

A similar current meter array was placed at a location halfway between Entrance Island and Halibut Bank in mid-October, and retrieved in early December. All measurements were made, in part to examine the currents at depths relatively free from surface disturbances, and in part to obtain information upon the performance of the two types of current meters.

7. Isentropic Analysis of Water in the Northeast Pacific Ocean — S. Tabata

The examination of the circulation of water in the northeast Pacific Ocean using isentropic analysis is being continued. At σ_t-surfaces, acceleration potentials relative to the 1000-decibar surface have been computed by the Marine Sciences Branch of DEMR (Ottawa). These are used to examine the geostrophic currents on the σ_t-surfaces. The outputted values are then machine-plotted on a Polar-stereographic projection chart (scale 1:7,500,000) using computer facilities available locally. To date, data from 10 main cruises have been plotted.

8. Oceanic-Coastal Program

A.J. Dodimead

A physical-chemical study of the waters, extending to approximately 200 miles off the coasts of British Columbia and Washington, was initiated in 1967 to study the mechanisms associated with the spatial and temporal variability of the properties and currents of the oceanic waters and of those overlying the continental shelf. In 1968, the field program consisted of a 2-week cruise in April and a 3-week cruise in October (Fig. 1). Continuous profiles of temperature and salinity were obtained to a maximum depth of 1,500 m. Surface samples were analysed for phosphate, silicate, nitrate and chlorophyll a. Profiles of nutrients and dissolved oxygen concentrations, and samples of zooplankton were also obtained. In addition to the cruises, an anchored buoy, with current meter and temperature recorder, was moored off the west coast of Vancouver Island during October and November. The latter project is being undertaken in cooperation with the Canadian Hydrographic Service, Marine Sciences Branch, Victoria, who have carried out the design, laying and retrieval of the moorings. These latter measurements are being supplemented with similar measurments from SEDCO-135F, a drill rig, which has been located in Hecate Strait, Queen Charlotte Sound, and off the west coast of Vancouver Island during the past year.

The major effort during 1968 was the preparation and execution of the field program, the routine processing of the oceanographic data, and the completion of the chemical analyses and calculations. Some preliminary studies have been made of the seasonal and annual variability in the surface distributions of temperature and salinity, of the geopotential topography and of the distribution of the non-seasonal waters.

(a) Sea Surface Temperatures, April and October 1968

In April 1968, sea surface temperatures ranged from 6.5° to 8.8°C. The coldest waters were found offshore, while the warmest occurred as a tongue off the coast of Vancouver Island, and as a small cell adjacent to the coast. These temperatures are considered to be average for this time of year.

In October 1968, sea surface temperatures ranged from 10.0° to 15.5°C. The coldest waters were those overlying the continental shelf. From here, temperatures generally increased seaward to a maximum at approximately 100 miles offshore, and then decreased.

(b) Sea Surface Salinities, April and October 1968

The surface salinity distribution in April 1968 reflects the winter convergent situation which usually still prevails at this time of year. Low-salinity water is confined onshore, resulting in a relatively marked

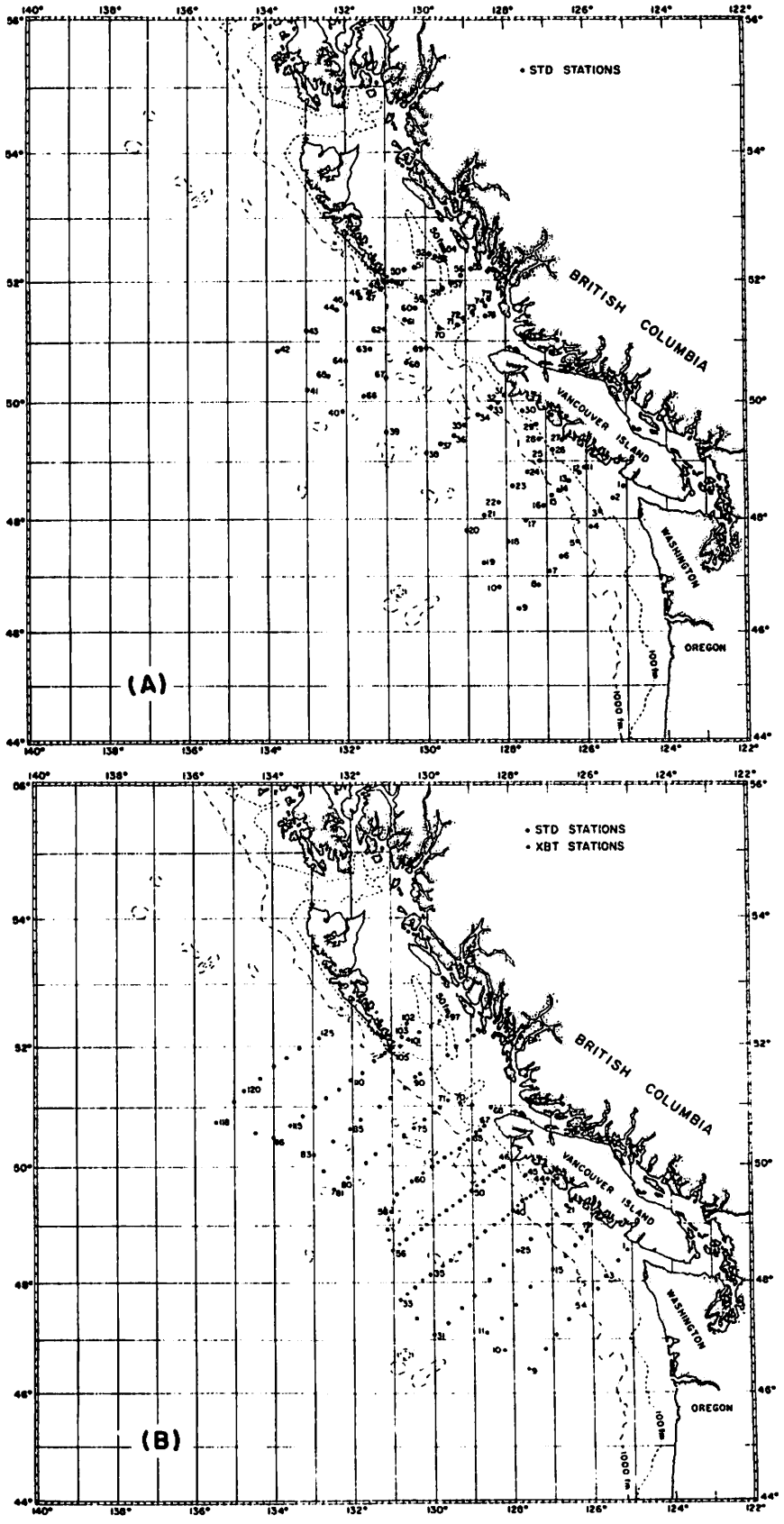

Fig. 1. Station positions, (A) 16-27 April 1968 and (B) 30 September-16 October 1968.

gradient near the coast. By October, the gradients were generally absent, as a result of the offshore movement of low-salinity water during the summer and early autumn period.

The easterly intrusion of comparatively high-salinity water off the northern end of Vancouver Island in the autumn of 1967 was also present in autumn 1968, but within the tongue, salinities were higher in 1967 than in 1968. There was a southeasterly intrusion of high-salinity water off the southern Queen Charlotte Islands in autumn 1967. In 1968, the intrusion was located about 60 miles southeast of its 1967 position. The persistence of these intrusions is being studied, and a mechanism for their formation is being sought.

The distribution of low-salinity water was further offshore in 1967 than in 1968. The difference may only be a result of the onset of the winter onshore movement of surface water in 1968.

(c) Geostrophic circulation, September-October 1967 and April 1968

The geostrophic circulation at the surface relative to 1,000 decibars in September-October 1967 was dominated by tongues and eddies. The intrusion along Longitude 128°W extending northward to about Latitude 49°N is a characteristic feature. The eastward intrusion off the north end of Vancouver Island extended well onshore, restricting the northward flow from the region south of the intrusion. It may have been the cause for the formation of the numerous cells, and may have contributed to the southward flow adjacent to and over the continental slope off Vancouver Island. Similarly, the southeastward intrusion off the Queen Charlotte Islands may have been the cause of the relatively large eddy seaward off the southern tip of the islands.

Similar features to those at the surface have been noted in the geopotential topographies of the non-seasonal waters. Some of the features seem to be related to the bottom topography where seamounts are present.

In April 1968, there was no significant change in the geostrophic circulation from that observed in autumn 1967 in the southern part of the region. However, to the north there was one notable difference, in autumn 1967 an intrusion or cell with a counterclockwise flow was present off the Queen Charlotte Islands. In spring 1968, the flow in this region was clockwise and strong. The latter feature may be a result of the further development of the large cell that was present west of Queen Charlotte Sound in autumn 1967, and which only moved slightly northward in the intervening 5 months.

(d) Temperature Distribution on the Surface σ_t = 26.60, October 1967 and April 1968

Temperature distributions on the surface of σ_t = 26.60 have been used to study the seasonal and annual variability in the distribution and circulation of the non-seasonal waters (below 150 m depth) off the coast of British Columbia. In September-October 1967 and April 1968 the temperature distributions on this surface were very similar, particularly off the west coast of Vancouver Island, implying that there was little change in the position of the offshore divergence of the eastward flow, and in the strength of the California undercurrent during winter 1967-68.

The eastward intrusion off northern Vancouver Island, noted in the surface water, was also present in the non-seasonal waters. Thus, the northward flow of these relatively warm waters was also restricted.

Waters overlying the continental slope north of Latitude 51°N were warmer in Autumn 1967 than in spring 1968.

9. Station P - Line P

C.A. Collins and D.A. Healey
(D.E.M.R.)

The program of oceanographic observations from the Canadian weatherships CCGS St. Catharines and CCGS Stonetown, was initiated in July 1952 with BT observations twice-daily at Station P and bi-hourly en route to and from Station P. In August 1956, the program was enlarged to include the systematic oceanographic observations at Station P from one ship, the St. Catharines. This program has continued regularly on each cruise of the ship, with some modification from time to time, and provides data through alternate 6-week periods.

In April 1959, a program was initiated to make serial temperature and salinity observations along the line (Line P) from Swiftsure Bank to Station P. Initially, 7 stations spaced about 200 km apart were occupied, but now 12 are taken along the line.

A grid survey of 8 stations around Station P was initiated in 1966, but was discontinued owing to manpower deficiency. An attempt was made to reinstitute this survey during the October-December 1968 patrol of the CCGS Vancouver, but this was unsuccessful.

During 1966-1967, the Department of Transport commissioned two new oceanographic weatherships, the CCGS Vancouver and CCGS Quadra (5,400 tons, 18 knots speed), both of which are well equipped for oceanographic observations at Station P. In March 1967, the Vancouver replaced the St. Catharines, and thereafter oceanographic observations have been continued from this ship. The Quadra replaced the Stonetown in October 1967. Only the Vancouver was

equipped with sampling and sensing instruments to carry out oceanographic observations in 1968.

At present, the crews of both ships make BT observations every three hours, the times coinciding with those of routine meteorological observations, and collect daily samples of water for salinity determinations.

From the Vancouver, one deep cast per week is made for temperature, salinity and dissolved oxygen content. An extensive program of primary productivity is conducted. Biological observations include horizontal and vertical plankton hauls, and a weekly cast for microzooplankton determination. Samples are also collected for the U.S. Naval Radiological Defense Laboratory, Scripps Institution of Oceanography, and the U.S. Atomic Energy Commission.

In May 1968, a sampling program was initiated for the University of Washington. Two profiles of C^{14} in the sea were obtained from the Vancouver.

During 1968, a Hytech Salinity-Temperature-Depth recorder was used experimentally both on Station P and Line P. An attempt to interpret the salinity records so obtained has been postponed until more experience has been gained with this instrument. Continuous recording of surface salinity, nitrate, and chlorophyll a along Line P has been postponed until an uncontaminated supply of sea water can be obtained aboard one of the ships.

Considerable time in 1968 was spent in developing computer programs for the processing of physical oceanographic data. An equal amount of effort was spent in preparing the Quadra to join the Vancouver in taking oceanographic observations in February 1969, thus eliminating the 6-week gaps in future Station P data.

10. Statistical Analysis of Long Time Series — C.A. Collins

During 1968, data have been digitized, computer programs tested, and low-pass filters considered.

(a) Data Digitization

Computer digitization is being carried out on the following:

(1) Sea level data, supplied by the Canadian Hydrographic Service, Victoria, for Tofino, Tasu Sound, Prince Rupert and Bella Bella for May 1962-May 1963.

(2) Meteorological data, supplied by the Meteorological Branch, Department of Transport, for Sandspit, Tofino, Estevan Point, Prince Rupert, McInnes Island for May 1962-May 1963.

(3) Historical coastal seawater data. The Canadian Oceanographic Data Centre is digitizing all these data, supplying them to us by 1 April 1969.

(4) Surface temperature and salinity data, obtained in the weathership program, as well as historical Japanese and U.S. Navy data observed near Station P. The Computer Centre at the Biological Station is digitizing these data.

(b) Computer Programs

Computer programs for cross-spectral analysis using a fast Fourier transform or, alternatively, the Blackman and Tukey covariance method, have been supplied by John Taylor, MSB Headquarters, Ottawa, and by Dr. Chorkin Chan, University of Victoria Computing Centre. These have been checked and are now running on the University of Victoria IBM 360/44.

The mathematical (Parzen) properties of the following low-pass filters are being considered: Godin's triple-running mean scheme, the Lanczos-square filter, and a cosine-Lanczos filter.

11. Calculation of Time Series of Geophysical Parameters and the Numerical Analysis of Fisheries Variability — W.P. Wickett

Mass transports for the North Pacific Ocean continue to be a most useful index of annual variations in the marine environment. Surface transport vectors have been computed and plotted by the Station computer for the period 1946-1967. Transports in the Norwegian Sea have been computed in addition to the above to enable comparisons to be made with observed oceanographic data. Tait's (Scot. Home Dept.) values for the Faroe-Shetland Channel transport are very similar, for the spring and summer months of 1952, to total transport calculated between 0° and 10°W at 60°N. Potaichuk's (VNIRO) mean temperatures of the water column at 69°20'N for the month of June 1950, to 1958, varied directly as the integrated total transport at 60°N 20°W, during the preceding months of February to June.

Numerical analysis of fishery records has pinpointed times of major environmental influence on stocks of herring and coho salmon. Herring year-class strength in the east coast of Vancouver Island areas is optimized

with zero meridional transport during the winter of spawning, and with 0.5 ft difference in sea level, between Point Atkinson and Tofino, during May and June (the larval period), according to power-transformation and response-surface analysis. Coho catches for the coast south of Cape Caution vary directly each year with the July precipitation anomaly for the lower British Columbia coastal stations during freshwater residence, and the May and June sea-level anomaly, noted above, preceding the fishing season. The first factor has been shown before to affect recruitment of the young fish to the sea. The second factor appears to be related to availability of the fish to the fishermen.

The power-transformed, response-surface analysis provided particularly useful results using 40 years of pink salmon catches. Escapements of spawners bear no useful relation to subsequent catches - escapements have been adequate. Annual variations in catch are explained by environmental fluctuations, as suggested by previous, simpler, numerical analyses.

There are indications that the migration of marine animals is partly explained by a simple model that they, like ships, will be set by current encountered during an ocean cruise. A significant relation exists between the per cent of fur seal pups stranded, in Alaska plus British Columbia, and surface transport along 035° T from 50°N 130°W, during January and February. The percentage of Fraser River sockeye caught in Johnstone Strait each year is inversely related to transport along 142° T direction from 45°N 135°W, during December to March, following the smolts entering the sea.

12. Support Oceanography

R.H. Herlinveaux

Oceanographic support is provided for both fisheries investigations at this Station and for defence research by the Defence Research Establishment Pacific, Esquimalt, on underwater acoustics in the Arctic. In each case, environmental information is collected in a joint program with other investigators. The objectives are to determine the relationship of environmental parameters to fish movement or to sound propagation.

Data have been collected during 1968 from observations in Jervis Inlet, Saanich Inlet, the eastern Arctic, and on the drill rig SEDCO-135F. Some of these have been analyzed in part, but much more work still has to be devoted to analysis of the data, collation with other information collected in the past and reporting of results.

(a) Saanich Inlet

As part of intensive time-series studies of production processes, an oceanographic program was carried out to describe the time variance of the physical features in Saanich Inlet, and especially in the main biological

sampling area. This consisted of a longitudinal section to describe the salinity, temperature and turbidity distributions with time. To accompany these, a current meter was operated continuously at 2 m in the central main sampling area.

A complete vector trajectory plot from x- and y-components was carried out on a computer, as shown in Fig. 2. This plot shows what can happen to a water mass in a sampling area. At times, there was a marked cross-channel movement for as long as 7 days in the sampling area, then the whole system slowed down for 12 days, during which the water mass stayed within a ± 2 mile square area. Then it moved out rapidly for as long as 3 days, followed by a movement to the southeast through the sampling area. From this plot, it is possible to calculate a resident time for any particle at the 2-metre depth.

Splendid cooperation was received from the Tidal Branch of the Canadian Hydrographic Service and from the Officer in Charge of the Underwater Weapons Range in making available current meters and vessels, respectively.

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

Oceanographic observations have been carried out on the continental shelf of British Columbia from the offshore drilling rig, SEDCO-135F, which is on contract from Southeast Drilling Incorporated to Shell Canada Limited. The rig has occupied several locations along the west coast of Vancouver Island, in Hecate Strait and Queen Charlotte Sound. The analyses of the 1968 data are far from complete, but provisional results are given below.

West coast of Vancouver Island (off Tofino). During January 25-29 a maximum current of 1.0 kt and a minimum of 0.5 kt were recorded, with a net set southerly at 10 metres. On March 26 and 27, currents with a maximum of 0.8 kt and a minimum of 0.4 kt, with a net southerly set, were observed. Surface drift card releases from the drill rig (100 released; 1 returned) resulted in a retrieval at the mouth of Winter Harbour after 4 months, giving a net movement of approximately 120 nautical miles, or 1 nautical mile per day.

Hecate Strait (16 miles east of Sandspit). Bottom observations on April 22-24 showed that the tide flooded northward and ebbed southward. During the period of observations, the winds were predominantly from the southeast and southwest quadrant. The net movement at the bottom was definitely biased toward the northward. Further observations are required to determine if this was a wind effect or a general feature of tidal action in the area. Surface drift-card returns indicated a set to the northwest quadrant at about 7 miles per day.

Hecate Strait (southwest). A computer program was carried out on

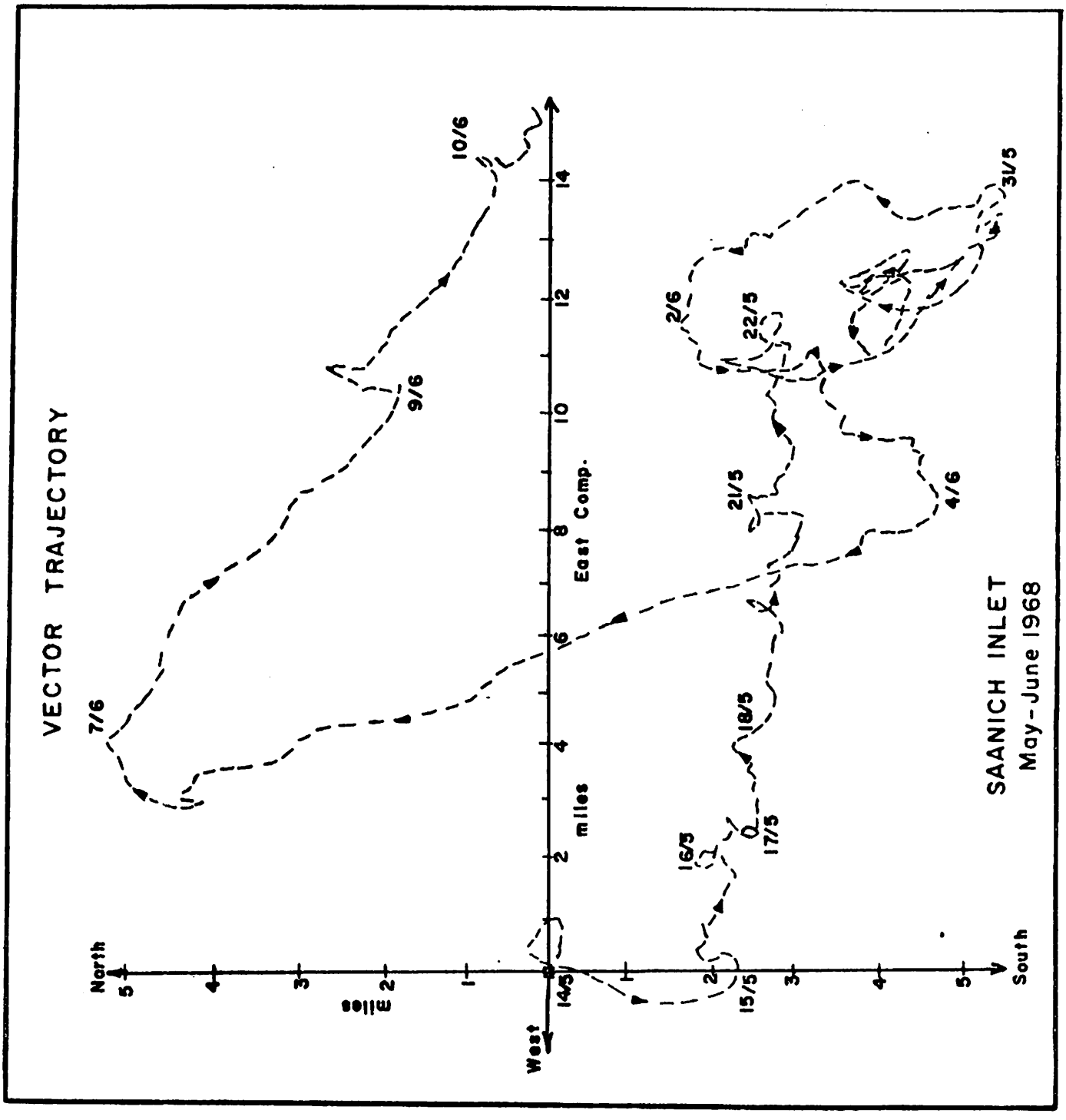

Fig. 2. Computer output plot of the 2-m water movements showing the vector trajectory of the x- and y-components in the sampling area of Saanich Inlet.

data collected August 20-27 to find the parameters of a tidal ellipse, based on coefficients for the cosine and sine portions of the northward and eastward components. This program was carried out by Dr. C.A. Collins. Figure 3 is a vector trajectory of the data for the 7-day period. The water movements at 41 fathoms (75 m) tended to be counterclockwise, flooding to NNE and ebbing to SSW, which is parallel to the land configuration in this area. The net movement during the period August 20-27 was to the SSW at about 3.6 miles per day.

Generous cooperation was received from personnel of the Exploration and Production Division of Shell Canada Limited, and Southeastern Drilling Incorporated.

(c) Eastern Arctic Oceanography

During August-September 1968, a program of research and data collection was carried out in the Canadian Archipelago by personnel from Defence Research Establishment Pacific and the Pacific Oceanographic Group. The primary purpose was to recover Recording Instrument Packages (RIP) from the bottom, which were laid the previous year.

Included in this program was a cooperative study on the use of the undersea work boat Pisces in the Canadian Arctic. The primary purpose for taking the Pisces along was to ensure the recovery of RIP's from the Arctic Sea floor. However, other studies were carried out and their purpose was:

(1) To explore the possibility of carrying out bottom geology studies and obtaining bottom samples.

(2) To use Pisces as an underwater observatory to study the habitat of undersea mammals.

(3) To carry out under-ice, acoustic, back-scattering measurements and acoustic noise measurements.

(4) To carry out bottom surveys for biological organisms.

(5) To carry out a test on navigational ability using contour charts and gyro compass.

(6) To observe physical processes in the water column using fluorescein dye pellets.

(7) To identify biological organisms in situ (scattering layers).

The results of these studies indicate that, because the Pisces can be transported anywhere in Canada within 24 hours and be operational in a matter

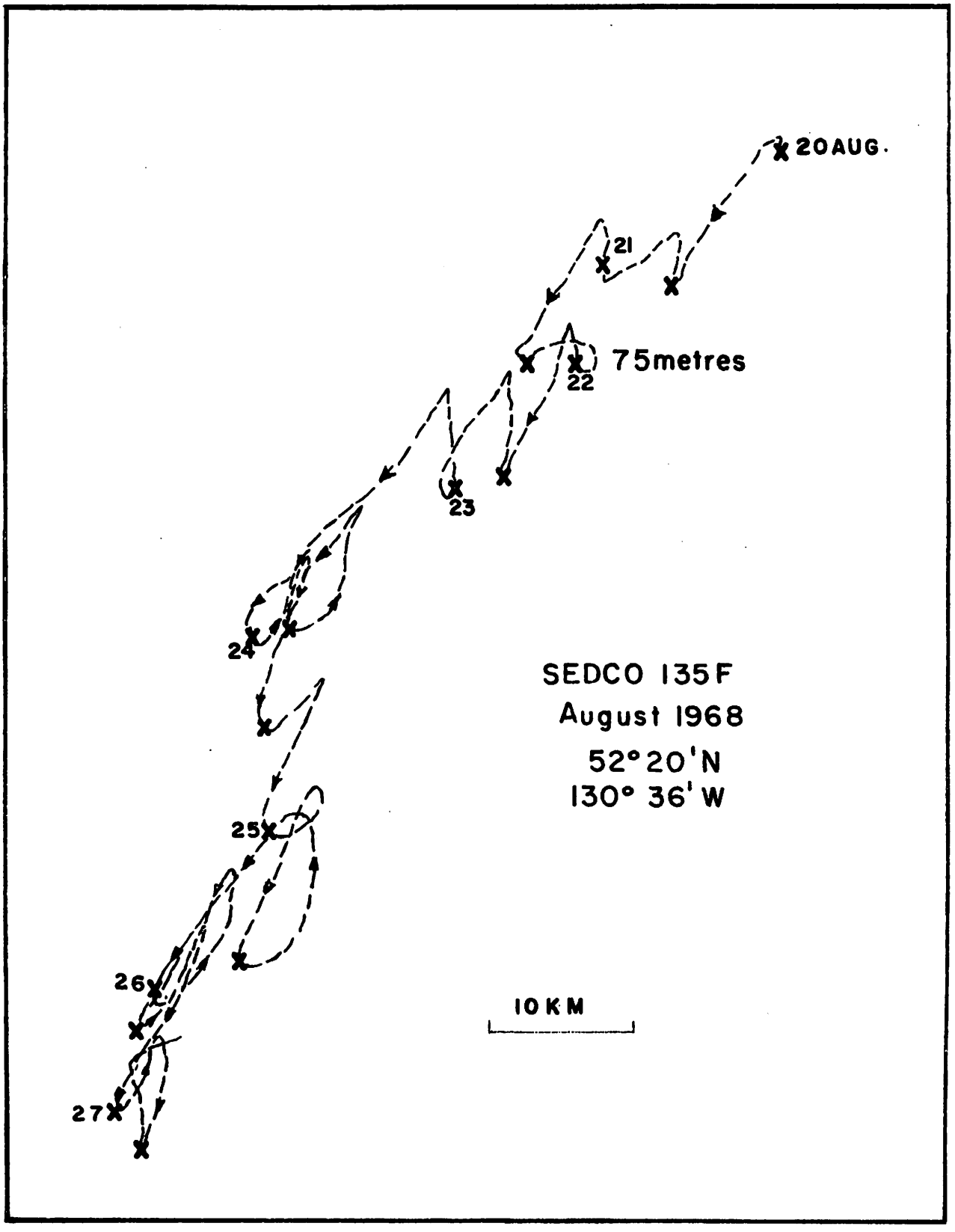

Fig. 3. Vector trajectory of the data collected during a 7-day sampling period taken from the oil rig in Hecate Strait.

of hours, it would be a valuable addition to the scientific community in studies similar to those outlined above.

The oceanographic program also included oceanographic stations and BT's in most of the areas travelled, and was essentially a repeat of last year's observations. Bottom biological samples, including seaweeds and parasites, and many rolls of films of bottom organisms were taken. The identification of all samples brought back is nearing completion and the results will be published soon.

The cooperation received from the Bedford Institute of Oceanography, in supplying the oceanographic equipment, and from Captain Tooke, ship's officers, and men of CCGS Labrador, in assisting with the operation, was greatly appreciated.

13. Pollution Studies

(a) Ladysmith Harbour

M. Waldichuk, J.H. Meikle and D.A. Blank

Oceanographic surveys continued in 1968 on a monthly basis, with one winter time series during March in Ladysmith Harbour. All field work on this project was terminated in December.

Once again, the seasonal effect of runoff appeared in the coliform counts, with a confirmed coliform MPN (Most Probable Number) in the outer harbour of nearly 1000/100 ml in autumn and winter and less than 10/100 ml in summer. There appeared to be no marked tidal effect in counts observed near the sewer outfall, collected every hour for 30 hours in March, although surface samples occasionally exhibited confirmed coliform MPN of 1600/100 ml. The highest consistent confirmed coliform counts were found in samples at the mouth of Holland Creek (>1600/100 ml in autumn and winter; ca. 500/100 ml in summer), which drains a garbage dump.

Cooperation was received from the Division of Laboratories, B.C. Health Branch, Vancouver, in processing of samples for bacteriological analysis.

(b) Victoria Harbour-Gorge-Portage Inlet

M. Waldichuk, J.H. Meikle and W.F. Hyslop

Monthly monitoring surveys in this system were continued through 1968 and terminated in December. Also, monthly samples were collected in the drainage basins of the two tributary streams, Colquitz River and Craigflower Creek.

Very dense growth of algae and rooted aquatics appeared again in Portage Inlet during May and June, as a result of increasing enrichment by nutrients. Phosphate levels in Colquitz River, below the discharge points of the treatment plants, exceeded 30 µg-at/l in summer again. Dissolved oxygen determinations were made during the year in Swan Lake, which is in the Colquitz River drainage and lies below a winery discharge. It did not become anaerobic in 1968, probably because of vast improvements in the treatment of wastes in the winery. Observations of diurnal changes in dissolved oxygen during mid-August showed a range from about 5-15 mg/l, which was considerably less than noted in an earlier year when oxygen concentrations dropped to 2 mg/l at night and went up to 20 mg/l in the daytime.

(c) Pollution-Oceanography along the Lower B.C. Mainland and in Existing Pulpmill Areas around Vancouver Island

M. Waldichuk & J.H. Meikle

A survey was conducted along the Lower Mainland, including the Fraser River estuary, Burrard Inlet and Howe Sound, during September and October. Because of a wet, cool summer, there appeared to be no evidence of serious oxygen depletion anywhere. All data collected in surveys along the Lower Mainland from 1957 to 1966 have been published in a data record.

During August a survey was conducted in Alberni Inlet, Muchalat Inlet, Quatsino Sound and Discovery Passage. Dissolved oxygen continues to be acutely low in Neroutsos Inlet near the sulphite pulp mill at Port Alice. A herring kill near Quatsino Narrows was reported by the Fisheries Officer near the time of the survey, but it is unknown whether this was due to the effects from the pulpmill wastes.

(d) A Study of Wind-Flushing in Departure Bay

M. Waldichuk, J.H. Meikle & D.A. Blank

Because there is considerable interest in the effect of winds on flushing coastal embayments, a 6-week field program was completed in Departure Bay during July-August to examine this effect.

Surveys were conducted with BT's and with *in situ* salinometers 5 days a week. Temperatures were recorded continuously at two locations at the surface and at one location near the bottom. Current observations were recorded continuously in mid-Departure Bay at 2, 5 and 20 m with Neypric (BBT) current meters, with cooperation of the Canadian Hydrographic Service, for about 35 days. Also, one month's continuous measurements were made with a Geodyne current meter suspended near the bottom from the oceanographic tower. All current meters performed remarkably well, giving 100% complete records. A tide gauge (courtesy Canadian Hydrographic Service) recorded sea level at the Biological Station wharf.

Wind measurements were made near mid-Departure Bay and near the entrance to the bay, with cooperation of the Meteorological Branch of the Department of Transport. There were sustained periods of westerly winds, which should have caused considerable movement of surface water. The data have not yet been analyzed, but it is hoped that some useful quantitative information will be obtained. The mixing by wind was clearly evident from day-to-day changes in traces on BT slides, where the thermocline was noted to undergo marked modifications in character. The set of current data taken near the bottom, which are the only ones processed so far, showed periodic pulses of current, with long lapses (up to a day) of no measurable current. It is uncertain whether this was all tidal or whether there was also a wind component.

(e) Effects of Water-Borne Solids — A.E. Werner

The long-range effects of the disposal of wood and fibre refuse into the marine environment received attention. Observation in the field indicated that, apart from concentration, size of the waste-matter particles is of crucial importance in determining the progress of pollution intensity with time.

In an attempt to get an integrated picture of all the relevant processes, a program of research was initiated which comprises study of: settling and clarification; rate of wood decay (by leaching, chemical and microbial action); pollution effects attending decay as expressed by chemical and toxicological parameters; and their decline by oxidation.

The following experimental data were obtained: particle size distributions in the various sewage streams of four different pulp and paper mills; density, surface tension and viscosity at three different temperatures for river water, clean and polluted sea water, and mixtures thereof; density of three common pulpwood species at five different particle sizes at three temperatures. Some of these data are still in process of evaluation by computer.

Apparatus for determining hydraulic diameter of particles was designed and constructed. A preliminary calibration run gave very satisfactory results. A settling trough was designed and constructed by the Station shop. Methods for determining leaching rates and overall decay rates and gas evolutions were developed.

A mathematical model was constructed which attempts to describe the time-function of pollution intensity, as it depends on the particle size of wood. The parameters of the rate-functions are to be derived from data being collected in this experimental program.

14. Daily Seawater Observations — H.J. Hollister

Daily sea-surface temperature and salinity observations were made at 17 shore stations along the British Columbia coast in 1968. Observations were terminated at one location, East Point lightstation, in March, and they were commenced at two new locations, Sisters Island and Sheringham Point lightstations, in May.

At the shore stations in the northern British Columbia regions of Dixon Entrance and Hecate Strait, monthly mean seawater temperatures ranged from a minimum of 5.8°C in February to a maximum of 13.9°C in July. During the first two months, temperatures were 0.6°C below normal, and in the summer months of June and July, sea temperatures were 1.1°C above normal in the Hecate Strait region. Temperatures during the spring and autumn months in these regions were normal. Sea temperatures at the shore stations along the west coast of Vancouver Island reached a minimum of 7.1°C in February, and increased to a maximum of 13.3°C in August. Below-normal winter temperatures were also prevalent in this region. Temperatures were near normal during the summer months, except at Race Rocks in Juan de Fuca Strait, where the temperatures were 0.5°C below normal during the period May to August. Temperatures at the new station at Sheringham Point were 0.5°C higher than at Race Rocks, which is 15 miles further east in Juan de Fuca Strait.

In the Strait of Georgia region, temperatures at the shore stations ranged from a minimum of 6.7°C in February to a maximum of 17.8°C in July. Temperatures were near normal during the whole of 1968. The new station at Sisters Island had temperatures which were about 0.5°C higher than at Chrome Island, which is 10 miles closer to the Vancouver Island shore.

Salinity data are available from most stations until June. There is an overall trend in these first 6 months for lower-than-average salinities, caused by persistently above-normal precipitation on the coast. Salinities were particularly below normal (1 to 3‰) at McInnes Island in Hecate Strait during the period February to May. Other locations, where significantly below-normal salinities occurred during the period February to April, were Pine Island, Race Rocks and Entrance Island.

15. The Canadian Oceanographic Information Service — L.F. Giovando

The Canadian Oceanographic Information Service was established in 1961 to fulfill the oceanographic needs of both fisheries and the military. In Canada, the basic requirements of these two groups are essentially the same, only the application of the information received is different. The service is officially termed Oceanographic Services for Defence (OSD), since the major logistic and administrative facilities have been provided

by the military. On the west coast, OSD is housed in the Maritime Forces Weather Centre (MFWC), Canadian Forces Base (CFB), Esquimalt, B. C. Administrative control of the West Coast Working Party (WCWP), OSD's "management committee", is vested in the Maritime Commander Pacific.

During much of 1968, MFWC continued to produce the weekly series of four charts assessing the temperature structure above about 300 feet in the northeast Pacific Ocean. However, it became increasingly clear that the quantity of bathythermograph data being received was rarely sufficient to permit drawing area-wide contours of layer depth or of the lower limit of the seasonal thermocline. Therefore, commencing in November, all characteristics of the thermocline (top, bottom and magnitude) were depicted on a single chart. Contours will be provided as the data input allows. On the other hand, an increase in the sea-surface temperature data now permits the issuance of meaningful charts twice a week.

The area originally covered by the chart has been altered to enclose less of the "transitional" area, which lies at the southern boundary of the subarctic water mass. At certain times of the year, it appears impossible to carry out data analysis, for the transitional area, which would be consistent with that in the subarctic area.

The charts are still issued to all interested parties by mail or by radio facsimile. The information is unclassified, only its interpretation may become restricted.

PATHOLOGY AND PHYSIOLOGY GROUP

L. Margolis

The four "Investigations" comprising this group are Microbiology, Parasitology, Physiology, and Physiological Ecology. In all investigations the research carried out in 1968 was a continuation and extension of lines of research reported in 1967.

Projects in Microbiology included identification of the bacteria associated with stream-incubated salmon eggs; and studies on (1) the pathogenicity of Gaffkya homari for native B.C. crabs and shrimps, (2) means of immunizing salmon against kidney disease, and (3) a Vibrio causing a lethal disease of cultured chum and sockeye salmon. The final stages in identification of salmon egg-associated bacteria were carried out by G.R. Bell during sabbatical leave at the Torry Research Station, Aberdeen, Scotland. The overall aim of the salmon egg project is to determine if bacteria play a role in mortality of incubating salmon eggs.

Parasitological investigations are mainly directly or indirectly related to using parasites as biological indicators of fish stocks (e.g., distinguishing salmon stocks of different origins in areas of mixing) or to determining their effects on the fish hosts. Several studies on trematodes and copepods are reported. A special parasitological issue of J. Fish. Res. Bd. to honour former Board Member Prof. T.W.M. Cameron was organized and edited.

The work in Physiological Ecology designed to determine the effect of various physical environmental factors on early development of marine fishes was extended to Pacific cod and flathead sole; further studies were conducted on petrale sole. New techniques of data analysis, using non-linear response surface methodology, have been developed. Studies associated with developing means of assessing the effects of water pollution on fish were continued in investigations of the swimming capacity of juvenile coho salmon in relation to temperature.

A continuation of the Physiological studies relating to the bioenergetics of sockeye salmon included (1) determining the effects of fish size and ration level on metabolic rate at various temperatures, (2) assessing the effects on growth (at 15°C) of various salinities, (3) determining the relationship between moisture, protein, and fat content of various levels of ration and various temperatures, and (4) determining the effect of temperature on rate of digestion.

MICROBIOLOGY — G.R. Bell

1. Microbial Flora of Salmon Eggs — G.R. Bell and G.E. Hoskins

The bacterial flora of healthy, fertilized salmon eggs incubated in gravel and in flowing water of Robertson Creek was similar to that found previously for eggs incubated in the Qualicum River, Vancouver Island. Myxobacteria belonging to the genus Cytophaga are a characteristic component of the flora. Taxonomic methods used at the Torry Research Station, Aberdeen, Scotland are now being applied to the isolates to check identifications.

To date, direct evidence that egg-associated bacteria are involved in egg mortalities is lacking. Related studies on the structure and properties of the salmon egg capsule reveal that it is resistant to proteolytic, chitinolytic and salmon egg hatching enzymes. The properties of the capsule will be studied further, but its inertness suggests that it may provide an effective barrier against invasion by associated proteolytic bacteria and also serves to prevent premature hatching due to hatching enzymes released by neighbouring eggs.

2. Gaffkya Studies — G.R. Bell and G.E. Hoskins

Laboratory studies with the lobster pathogen Gaffkya homari showed that infection of crabs by methods other than injection is unlikely. Injected crabs and shrimp developed acute or chronic infections. High water temperatures (15°C or higher) favour the acute form of the disease. Other factors, however, also influence severity (inoculum size, strain of pathogen used).

The search for G. homari on the Pacific coast was continued but with negative results. A total of 628 samples were examined. Samples included crabs from the Tofino area and crabs, lobsters, sea water and bottom sediments from the lobster transplant site at Fatty Basin.

3. Bacterial Kidney Disease — T.P.T. Evelyn

Studies on the nutritional and cultural growth requirements of the kidney disease bacterium were concluded and the results are being prepared for publication.

Facilities for studying bacterial kidney disease in sockeye salmon were set up. The study is intended to provide a better understanding of

the disease and to determine whether immunization against the disease is feasible. Experiments now in progress seek to determine: (a) whether long-term protection (up to 12 months) results following a single injection of heat-killed bacteria in adjuvant, (b) methods other than injection by which infection may occur (feeding, exposure of healthy fish to fish infected by injection), and (c) the effect of temperature (15°C and 7°C) on the time to death of fish infected by injection.

4. Miscellaneous — T.P.T. Evelyn

A study of an acute and fatal bacterial disease of cultured chum and sockeye salmon was completed. At the time of the disease outbreak (July 1968), the fish were being held in running sea water at 15°C. Causative bacteria from both species of fish were found to be biochemically identical and belonged to the genus Vibrio. The results of this study, and those now completed on a strain of the freshwater pathogen, Aeromonas salmonicida, which was isolated in 1967 from a marine fish (Anoplopoma fimbria), are being prepared for publication.

PARASITOLOGY — L. Margolis

5. Biology of Hemiurid Trematodes

(a) Life Span, Maturation and Growth — L. Margolis and N.P. Boyce

Analysis of data on the life span, maturation, and growth of Tubulovesicula lindbergi and Lecithaster gibbosus in captive stocks of naturally infected pink and chum salmon was completed. Tubulovesicula lindbergi was found to mature in 2-4 months and to live at least 31 months, growing during that time from about 0.6 mm to more than 4.5 mm in length; Lecithaster gibbosus matured in 1-2 weeks and had a life span of about 2-9 months, growing from 0.5 mm to almost 1.9 mm. There was considerable variation in growth rate within each species. Among specimens of L. gibbosus faster growth apparently was associated with a shorter life span. Retardation of growth and maturation at high intensities of T. lindbergi infection is suggested. These results appear to be applicable to the course of infection in nature.

The long life span of T. lindbergi, coupled with an apparently discontinuous distribution around the North Pacific rim, suggests that this species should be useful in identifying the origin of salmon stocks on the high seas.

(b) Life Cycle of Lecithaster gibbosus N.P. Boyce

Further studies on this trematode have focussed on the larval stages found in the digestive gland of snails of the genus Thais. The germinal sac in which cercariae are produced appears to be a structure intermediate between a sporocyst and a redia. The lack of a clear distinction between sporocyst and redia has only recently been observed for certain other members of the trematode family Hemiuridae. The release of cercariae by captive snails has been monitored for several months. This release appears to be sporadic (one heavily infected snail was found to withhold cercariae for as long as 9 months). Experimental manipulation of environmental features that are known to influence shedding in other species (salinity, temperature, photoperiod, underwater period) has provided no clues to a cercariae-shedding stimulus in this case.

6. In vitro Culture of Anisakis larvae (Nematoda) N.P. Boyce, L. Margolis and T.E. McDonald

Larvae of this genus are commonly found in the body cavity, viscera, and muscle of marine fishes. Their specific identity cannot be determined because of the absence of distinguishing morphological characters. The natural definitive hosts of the several known species of Anisakis are various cetaceans. As an alternative to experimentally rearing the larvae in a cetacean host to obtain adult worms for identification, an attempt is being made to grow them in an artificial culture medium. In the culture medium, larvae obtained from herring moulted in about one week to presumably the 4th stage. It is likely that only one further moult is required for the adult stage to be attained. The culture experiments are currently in progress.

Anisakis larvae are of importance from two points of view. Firstly, their presence detracts from the market value of fisheries products and, secondly, in countries where raw fish is commonly eaten, e.g. the Netherlands and Japan, they create a medical problem. Severe gastric and intestinal ailments in humans have been attributed to the penetration of the stomach and intestinal wall by Anisakis larvae.

The development of a culture medium in which to grow Anisakis would not only enable us to identify the species occurring in British Columbia fishes but would provide us with a means of making further detailed studies of this parasite.

7. Special Parasitological Issue of the Board's Journal — L. Margolis

A special issue of the Board's Journal, dedicated to Professor T.W.M. Cameron, a former Board Member, has been organized and edited. It will appear in April, 1969, as Volume 26, No. 4, and will contain 31 papers, from invited contributors, on a wide variety of topics dealing with parasites of aquatic animals, mainly fishes. Two papers, however, concern parasites of marine mammals. Protozoans, all helminth groups (Trematoda, Monogenea, Cestoda, Acanthocephala and Nematoda), and parasitic copepods are represented. The subjects of the papers include morphology, taxonomy, life history studies, ecology, population dynamics, physiology, phylogeny, pathology and general effects on the host, transmission, and laboratory culture of parasites. Parasites as biological tags providing information on fish migrations and phylogeny of the hosts are discussed in three papers.

8. Parasitic Copepods — Z. Kabata

During the period under report the work on parasitic copepods of fishes consisted of three main topics.

(a) Preparatory Work for the Investigation of Salmincola

Prior to the study on the biology and the effects of this parasite on salmon it was necessary to re-examine the taxonomy of the genus to determine the identity of the Salmincola species parasitic on Pacific area salmonids. The work called for a revision of the entire genus (29 species recorded in the literature). In addition, it was necessary to examine also the closely related genus Achtheres (9 species). It was found that of the 9 species of the latter genus, 3 belong to Salmincola and the 4th cannot be identified with certainty, owing to the loss of the type material and paucity of description. In spite of the fact that some Achtheres had to be transferred to Salmincola, the revision reduced the latter genus to 14 species. The remaining ones proved to be synonyms of these 14. It was shown that the parasite of Oncorhynchus, the only one occurring on all species of this genus of fishes in North America and Asia, is Salmincola californiensis. The landlocked Salmo species harbour two species of Salmincola, S. edwardsii and S. carpionis.

(b) The Biology of Phrixocephalus cincinnatus and its Effects on the Host

The host of this parasite is a predatory flatfish, Atherestes stomias. The parasite lodges in the eye of the fish and was suspected to cause

blindness. This host-parasite system affords a good opportunity for the study of the effects of a single parasite species on the host population.

Two field trips were made, in May-June and August. The investigations were hampered by the fact that the life history of the parasite and its early stages were unknown. By the end of the first field trip it became clear that a large proportion of the pertinent data escaped observation, because of this handicap. Repetition of the investigation in August led to the discovery of the developmental stages of the parasite and of the initial phase of its association with the host fish. It is now clear that the parasite causes complete blindness in extreme cases, but that the full impact of its presence comes with the moment of the parasite's death and its decomposition within the eye. It still remains to be assessed what are the effects of the parasite in terms of its check on the host population. A paper on this investigation has been prepared and is now in press.

(c) General Faunal and Taxonomic Studies

A small proportion of time was devoted to the study of the taxonomy of parasitic copepods of fishes. The study was based on material received from extraneous sources and partially brought over from Scotland. Beginnings were also made of a survey of the parasitic copepods of western Canadian fishes. A collection of these parasites was made and is now being studied. Some results of the taxonomic studies were published in the course of the year, or are in press.

PHYSIOLOGICAL ECOLOGY D.F. Alderdice

Investigations are concerned primarily with the manner in which structure or function of various developmental stages of selected commercial fishes are affected by differences in their physical environments. A dual line of research effort includes: (a) studies on the development of marine fish eggs, and (b) studies on the physical capacity of juvenile coho salmon. Results of the former provide information toward understanding the dynamics of specific fish populations; the latter applies to a continuing investigation of means of assessing biological problems in water pollution.

9. Development of Marine Teleost Eggs

D.F. Alderdice, C.R. Forrester and F.P.J. Velsen

Pacific cod (Gadus macrocephalus). Utilizing eggs from a Gulf of Georgia stock, experiments were conducted in 19 different salinity-temperature -dissolved oxygen combinations in the incubation medium to determine the

effects of these variables on aspects of early development. Measured effects included: total hatch, per cent viable hatch, incubation period and mean larval size at hatching.

Conditions for maximum survival to hatching were determined to be in the vicinity of 15.6‰ S, 3.7°C, and 9.0 ppm O_2. Eggs are euryhaline and survival is high from 25‰ S to levels lower than 12.71‰ S, the lowest tested. Temperatures associated with 50% survival or better range from 2.5 to 8.5°C; maximum survival is found between 3.0 and 5.0°C. Survival decreases rapidly below 3.0°C. Developing eggs tolerate low dissolved oxygen levels; maximum survival is maintained to about 3.0 ppm dissolved oxygen for temperatures between 3 and 5°C. A tendency was noted in some incubation conditions for eggs to develop to full-term embryos without subsequent hatching. This tendency was observed most frequently at high temperatures (9.3°C), high salinities (26‰ S) and low oxygen levels (3.60 ppm). It appears that temperature may be a major controlling factor governing southern distribution of the Pacific cod.

Petrale sole (Eopsetta jordani). Eggs were obtained from a spawning population off the west coast of Vancouver Island. Eggs were fertilized in water from the spawning site (33.60‰ S, 6°C at 330 m depth) and incubated in 13 different salinity-temperature conditions. Measured effects of the incubation medium included: total hatch, per cent viable hatch, incubation period and larval size at hatching.

Survival of eggs to hatching was maximized in the vicinity of 29.5‰ S and 6.6°C. Conditions resulting in 50% or better survival to hatching ranged between 20 and 35‰ S, and 5 and 7.5°C. Temperatures below 3.5°C and above 9°C appear to inhibit full-term development of embryos. Samples of larvae from some tests were held for 10 to 16 days following hatching under conditions identical to those of incubation until exhaustion of the yolk supply. Although growth rates were not appreciably different (from 6.3 to 8.1°C), there was a tendency for the lower temperature larvae to reach a slightly larger size before exhaustion of the yolk. These and earlier (1967) results, in conjunction with oceanographic information from the spawning area, provide information on the dynamics of development and dispersal of petrale sole larvae under natural conditions.

Flathead sole (Hippoglossoides elassodon). Preliminary studies were conducted on eggs obtained from a Gulf of Georgia spawning stock. Eggs fertilized in water at 26.92‰ S were incubated in 13 different salinity-temperature combinations. Measured effects of the incubation medium included: total hatch, per cent viable hatch, incubation period, and larval size at hatching.

In the first 24 hours following fertilization in 27.50‰ S eggs increased in average diameter from 1.3 to 2.7 mm with the formation of a prominent perivitelline space. From fertilization to hatching in 25.00‰ S at 6°C the salinity of neutral buoyancy of eggs decreased from near 25‰ S to near 19.5‰ S. Newly hatched larvae were neutrally buoyant in water of about

17.6‰ S. Successful development occurred in all salinities (range - 12.85 to 37.15‰ S) but was more consistent in the higher temperatures (from 6 to 9.65°C). Thermophilic characteristics of the eggs suggest that the flathead sole may be a more "southern" species than anticipated earlier. Samples of larvae from some of the tests were held in their appropriate incubation conditions, for periods up to 22 days after hatching, until absorption of the yolk was completed. Rates of growth were obtained in that period.

Compensation for the effects of temperature were noted on rate of embryonic development. Larvae hatching at low temperatures appeared poorly developed in comparison with those hatching at higher temperatures. However, low temperature larvae reached approximately the same size and stage of development at exhaustion of the yolk as larvae hatched at higher temperatures.

10. Models for Prediction of Environmental Effects

J.K. Lindsey, L.V. Pienaar and D.F. Alderdice

Laboratory evaluation of the effects of environmental variables on biological response has followed a multivariable approach based on response surface methodology. Application of these techniques has led to a substantial increase in appreciation of the manner in which biological responses are affected by environmental factors acting in concert. However, with continuing development in this area of research also has come greater appreciation of the limitations of linear models used to describe multivariable relationships. To overcome some of these limitations, analysis has now been extended to the use of non-linear response surface models.

Hence, maximum likelihood estimates are obtained for the power parameters in the model

$$Y^{Y} = b_0 x_0 + (b_1 x_1^{\alpha_1} + b_2 x_2^{\alpha_2} + \ldots) + (b_{11} x_1^{2\alpha_1} + b_{22} x_2^{2\alpha_2} + \ldots + b_{12} x_1^{\alpha_1} x_2^{\alpha_2} + \ldots)$$

where Y = response

x_1, x_2 = environmental variables

For example, a comparison of predicted effects of salinity (x_1) and temperature (x_2) on total hatch (Y) of English sole (Parophrys vetulus) eggs according to the two models is:

linear,

$$Y = -186.6 + 7.1x_1 + 43.4x_2 - 0.2x_1^2 - 2.7x_2^2 + 0.2x_1x_2 ;$$

non-linear,

$$Y^{0.85} = -2448.5 + 1527.7x_1^{0.19} + 3735.6x_2^{-0.23} - 366.5x_1^{0.38} - 2540.2x_2^{-0.46} - 362.7x_1^{0.19}x_2^{-0.23}$$

The relative likelihood of the linear model compared to the non-linear model is 4.0×10^{-11}.

By comparing other estimates of the power parameters with their maximum likelihood estimates it is often found possible to replace the latter with estimates which retain a high relative likelihood, yet provide a basis for simple changes of scales of the independent variables. Most of the usual transformations may be employed in this manner in the non-linear model.

Thus, in the case of English sole eggs, per cent total hatch as a function of salinity (x_1) and temperature (x_2) reduces to

$$Y = b_0x_0 + (b_1 + b_{11}) \log x_1 + \frac{b_2}{\sqrt{x_2}} + \frac{b_{22}}{x_2} + \frac{b_{12}}{\sqrt{x_2}} \log x_1$$

The non-linear salinity-temperature response surface constructed from experimental results in this example compares quite favorably with the commercial and geographic range of the English sole, and suggests that temperature effects on egg development are a dominant factor in distribution of the species.

11. Swimming Capacity of Coho Juveniles Related to Temperature

D.F. Alderdice, S. Griffiths and L.D.B. Terhune

New apparatus for studying swimming capacity in fishes recently has been calibrated and put into use. This swimming speed tunnel (Fig. 4) has an experimental chamber 2 ft in length and 6 inches in diameter. A recovery chamber is incorporated into the loop so that fish may be recovered in the order in which they fatigue. An electrical barrier of carbon rings set into the cylindrical wall of the test chamber divides it from the recovery chamber. In use the tunnel provides constant temperatures from about 2 to 26°C using internal heaters and an external refrigeration unit. Water velocities are infinitely variable to a maximum of about 4.5 ft/sec.

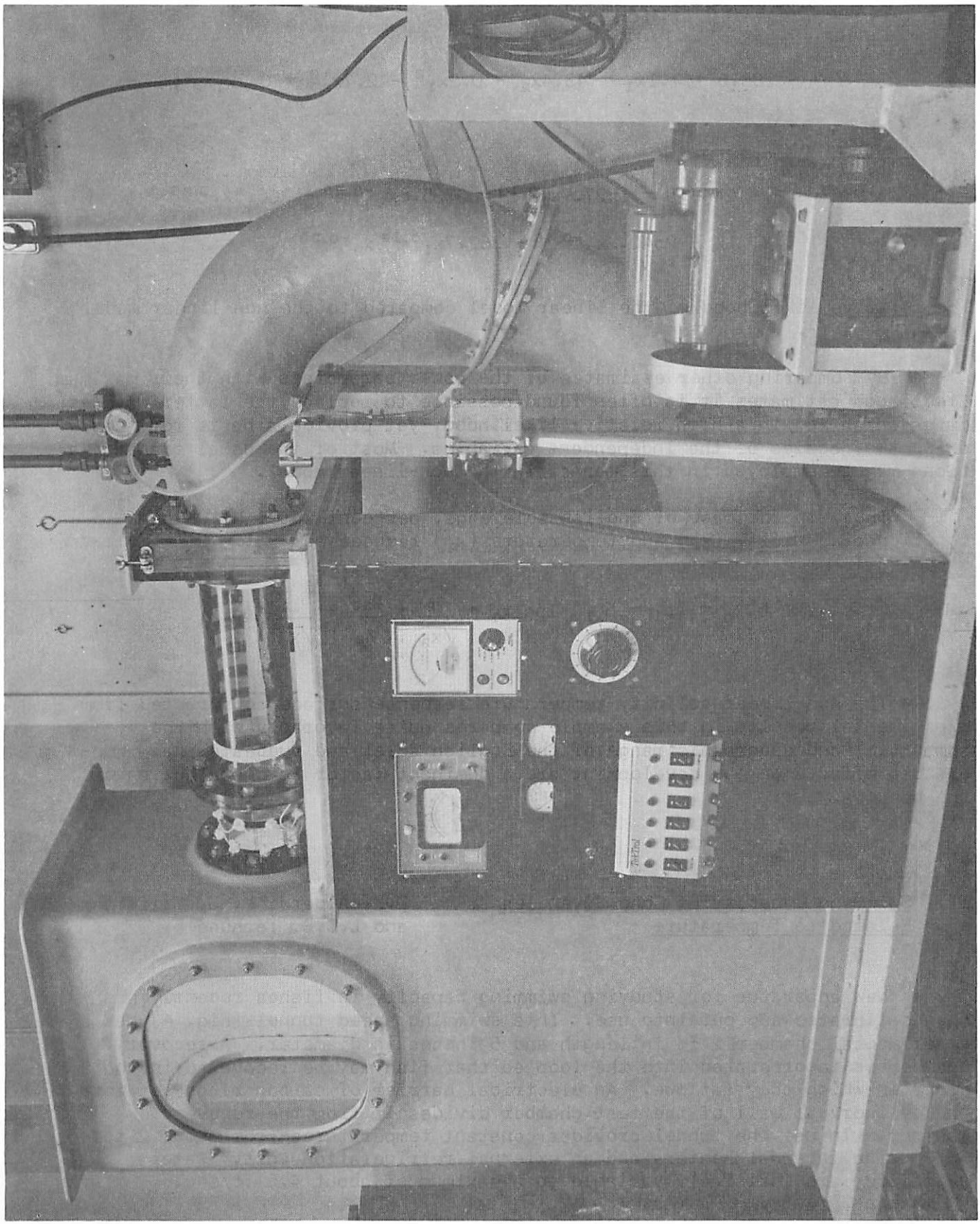

Fig. 4. Swimming speed tunnel.

The effect of acclimation temperature is being studied acutely in juvenile coho over a test-temperature range from 2 to 26°C, and at 3° intervals of acclimation- and test-temperature. The whole temperature "surface" is being investigated in terms of the speed in lengths/sec that juvenile coho of a "standard" length can attain.

PHYSIOLOGY — J.R. Brett

12. Metabolic Rates

J.R. Brett, J.E. Shelbourn, D.B. Sutherland and G.D. Heritage

Size effect at various temperatures. Final experiments on 2-3 gram sockeye at 5°C were conducted, completing a long-term study of the effect of weight (2-2000 g) and temperature (5°, 15° and 20°C) on the metabolic rate of sockeye in fresh water.

Active metabolic rates were found to be independent of weight (W^b) at all temperatures with values for the weight exponent "b" of 1.00 (5°C), 0.967 (15°C) and 0.999 (20°C).

Standard metabolic rates were size-dependent, with b-values of 0.919 (5°C), 0.847 (15°C) and 0.888 (20°C). Limits for these values have yet to be calculated, but it is quite apparent that their mean levels are significantly higher than the generally accepted weight exponent of 0.8. Not only have the techniques for determining the relation become more refined, but also the range in species response is apparently greater than formerly defined.

It is now possible to predict the metabolic rate of sockeye for any size, temperature and sustained swimming speed in fresh water.

Feeding effect. Following earlier efforts to determine the metabolic rate of 20- to 30-gram yearling sockeye at different rates of feeding at 20°C, a second series of tests was performed at 10°C and 15°C using ration levels of 0, 1.5, 3.0, 4.5 and 6% of body weight/day. The use of improved techniques did not overcome the great variability in metabolic rate which occurs within groups of fish over a 24-hour period, and among groups of fish on different rations at the same temperature. Considerable activity, with periods of aggressive behaviour, was observed which tends to mask the metabolic demands of actual feeding. Slight disturbances at night also produce undesirable excitability.

Definite trends were apparent, however. These indicated that on a high ration the average daily oxygen consumption rates (in mg O_2/kg/hr) were about 350 (20°C), 250 (15°C) and 200 (10°C), corresponding to the rates obtained for non-feeding sockeye when swimming at 2 lengths/sec. Minimum

metabolic rates for starving fish, swimming freely in circulating water, were slightly higher than the calculated standard rates for healthy fish in the post-absorbative state; average values of 75 mg/kg/hr (10°C), 85 mg/kg/hr (15°C) and 110 mg/kg/hr (20°C) were recorded.

13. Growth Studies

J.R. Brett, J.E. Shelbourn, D.B. Sutherland and G.D. Heritage

Salinity effect. A paired experiment on the effect of salinity (28‰, and fresh water) on growth at six ration levels (starvation to excess) was conducted at 15°C from May to July using sockeye smolts from Great Central Lake, Vancouver Island, with an initial weight of 7 to 8 grams. No significant difference occurred at any of the various feeding rates. Maximum mean growth rate was 1.2% per day, slightly lower than the 1.4% per day found for underyearlings of approximately the same initial weight.

It would appear that abundance of food must account for rapid ocean growth and not the presence of salt, either as a dietary source or as a means for reducing maintenance costs. This conclusion is supported by the lack of any metabolic benefit associated with full salinity, previously discovered from respirometer experiments.

Body constituents. Analysis of the interrelations between moisture, protein and fat content of fingerling sockeye under all conditions of ration (from starvation to excess) and temperature (1-23°C) has revealed a linear relation between Protein (Y) × Moisture (X) described by $Y = 50.53 - 0.459X$, and Fat (Y) × Moisture (X) described by $Y = 50.95 - 0.591X$. These provide sufficient predictive accuracy that the total gross body constituents can be estimated from measurements of water content only, assuming an ash content of 2%. Since feeding experiments with controlled rations involve numerous proximate analyses, the advantage of such a simple procedure is apparent.

Further data compilation has revealed that the proportion of body fat (per cent fat) has a fairly consistent relation to the feeding rate (per cent maximum food intake/day), independent of temperature. Thus a fat composition of $9 \pm 0.5\%$ is associated with 100% of maximum food intake, and a composition of $1 \pm 0.5\%$ with starvation; the in-between values are linearly arranged on an arithmetic scale. The reason for temperature independence stems from the cancelling effect of two temperature-dependent relations; as temperature falls both growth rate and maximum food-intake decrease proportionately.

14. Rate of Digestion

J.R. Brett and D.G. Higgs

Temperature effect. The rate of gastric digestion of yearling sockeye (25-35 g) following satiation feeding on Abernathy pellets was studied at 5°, 10°, 15°, 20° and 23°C. Samples of 10 fish were sacrificed at regular intervals and immediately frozen at -20°C. Subsequently the ash-free dry weight of the stomach contents was determined and expressed as a fraction of the dry weight of the fish. At any one temperature rate of digestion was proportional to the mass of food remaining in the stomach. The time for complete digestion (calculated 99% empty) decreased from 75 hours at 5°C to 18 hours at 23°C. The time for one-half of a sample of fish to exhibit empty stomachs corresponded closely to that for a mean state of 97% gastric digestion, providing a remarkably simple means for determining rate of gastric digestion.

Voluntary food-intake. The state of hunger or appetite may be assessed by determining the amount of food consumed when presented with excess. The return of appetite after satiation feeding was followed in this way, at 15°C. At a calculated time for 90% gastric digestion, voluntary food intake was about one-half maximum; about 5 hours after 99% digestion full appetite had returned.

These experiments provide evidence for an optimum feeding interval for maximizing daily food-intake at any given temperature - a new approach to the problem of enhancing growth.

SCIENTIFIC SERVICES

SCIENTIFIC SERVICES G.L. Robins

FISH CULTURE R.M. Humphreys

The number of tanks available for Fish Culture work has not changed since 1967; 60 tanks were in almost continuous use by 11 scientists. However, plans were prepared for an addition to the building in order to assemble all outside tanks in one area thereby providing a more efficient service, while creating space which could be utilized for experimental work on culture techniques. This addition was intended for completion early in 1969.

In addition to the rearing of fish for physiological studies, several experiments were carried out in the Fish Culture building under the direction of members of the scientific staff. Interspecific hybridization of Pacific salmon continued as well as experiments in sablefish rearing. The use of portable refrigeration equipment as a means of delaying salmon egg development was successfully tested, as was the use of sealed containers containing water and oxygen as a medium for fish transportation.

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 which may be relevant to their fields of research.

Major projects included a portable water tunnel with a 6-inch diameter test section and a maximum flow rate of about 450 gallons per minute. This was completed early in the year for the Physiological Ecology Investigation for fish stamina testing. Design and construction of an opto-electronic plankton size distribution counter for the Pacific Oceanographic Group continued throughout the year. A significant step towards completion of this instrument was made with the development of a suitable counting cell. A system for "reading" salmon scales photo-electrically was commenced for the

Anadromous Fishes Investigation. They were also provided with a data acquisition system with paper tape output. A large amount of support was given to the lobster transplant section in connection with their activities at Fatty Basin, particularly with regard to sonic tags.

Other projects completed during the year included underwater photometer modifications, fish measuring calipers with electronic readout, trilateral ruler system for the provision of space coordinates on fish images, salmon egg counter, clam larvae stirrer, water level alarm, power drop-out alarm, and a towed body design for plankton counters. In addition, technical assistance and consulting services were provided to various investigations in connection with fish shockers, control relays, shipboard data acquisition systems, wet food dispenser, Longhurst-Hardy plankton sampler, and respirometer oxygen control system.

The Group has been consulted on the purchase, construction and operation of various types of apparatus and has done the specification writing for some equipment obtained under contract. Small or emergency repairs have been carried out to various items of Station equipment. New advances in commercial equipment have been examined and brought to the attention of the Station's scientists where appropriate. In some instances, demonstrations have been arranged for research personnel.

STATISTICS AND COMPUTATIONS

J.A. Thomson & L.V. Pienaar

The Station's IBM 1130 computer entered its second year of operation in 1968. During the year, the central processing unit meter logged over 1,700 hours, over twice the amount recorded in 1967.

The most significant contribution in the field of statistical analysis was the derivation of a series of programs for analyzing the shape of a non-linear response surface in two or three dimensions. Other major analyses included work on extensions to discriminant function analysis; development of a circular normal analysis for orientation studies and a revision of various yield-per-recruit programs (Beverton-Holt and Ricker). In addition to specialized consulting, a series of seminars on sampling theory was initiated.

Within the data processing field, the service continued to write specialized programs for various investigations. A new language, ERGO, proved most efficient and useful for preparing tabular material at high speed. Much of the output was used either directly or indirectly for a series of Technical and Manuscript reports. One such report presented a 20-year series of oceanographic data reports incorporating both tabular and graphical output.

During the year the centre started to change over to Disk Monitor System Version two in preparation for the addition of more equipment. This was a long-term project which led eventually to increased speed through the system.

In 1968 there was a marked increase in the number of users writing their own programs. Some of the centre's time was devoted to helping these users with integral parts of the system.

Over half a million data cards were added to the general data files in 1968 and over 300,000 were stored on magnetic tape for safekeeping.

The combination of increasing efficiency in programming routine data processing jobs with increased sophistication in the analytical field is without doubt leading to a higher level of utilization of the computer and of the service as a whole.

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, 1968 to Dec. 31, 1968. The arrangement of investigations and services applies to the major portion of the year.

Director	K.R. Allen, M.A.
Assistant Director	K.S. Ketchen, Ph.D.
Scientific Assistant to Director	G.L. Robins, Ph.D. (from 3 May)
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 (from 8 Jan)
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.
Technician 2	R. Hungar
Technician 2	G.E. Johnston
Technician 2	A.J. Solmie (from 1 Apr)
Technician 1	E.W.H. Moore
Assistant Technician 3	D. Williams (3 Sep to 30 Sep)
Salmon Eggs and Alevins	
Scientist 2 in charge	R.A. Bams, Phil. Drs.
Technician 6	R.C. Wilson
Technician 2	D.G. Crabtree
Assistant Technician 3	C. Bickerton (to 6 Mar)
Assistant Technician 3	R. Biggs (15 Mar to 30 Mar)
Student Assistant	Marilyn Baker (3 Jun to 31 Aug)

Salmon Stock Assessment

Scientist 2 in charge	H.T. Bilton, B.A.
Technician 4	D.W. Jenkinson
Technician 1	Margaret M. Aarts
Assistant Technician 3	Carol A. Gould (to 29 Jun)
Assistant Technician 3	Leslie Chong (2 Jul to 8 Sep)
Assistant Technician 3	R. Cotton (2 Jul to 7 Sep)
Assistant Technician 3	R. Hopper (17 Jun to 31 Aug)

Chinook and Coho Salmon

Scientist 2 in charge	R.A.H. Sparrow, M.Sc. (to 30 Mar)
Technician 2	A.J. Solmie (to 30 Mar)

Chinook and Coho Hatchery Evaluation

Scientist 3 in charge	H. Godfrey, M.A.
Technician 4	E.A.R. Ball
Assistant Technician 3	R. Chiang (6 May to 8 Sep)
Assistant Technician 3	J. Munro (6 May to 31 Aug)
Assistant Technician 3	J. Nelson (13 May to 18 Jul)
Assistant Technician 3	Sylvia Senkow (13 May to 8 Sep)
Assistant Technician 3	D. Wilson (29 Apr to 31 Aug)
Assistant Technician 3	Patricia Wong (16 Apr to 31 Aug)

Babine Development Research

Scientist 3 in charge	J. McDonald, M.A.
Technician 4	A.S. Coburn
Technician 2	J.R. Scarsbrook
Technician 1	R. Morton (16 Apr to 15 Aug)
Technician 1	P. Young (6 May to 21 Jul)
Assistant Technician 3	D. Cliff (20 Jun to 15 Aug)
Assistant Technician 3	D. Evans (6 May to 10 Sep)
Assistant Technician 3	B. Lea (20 Jun to 15 Aug)

Lacustrine Ecology

Scientist 2 in charge	D.W. Narver, Ph.D.
Technician 4	B.C. Andersen, B.Sc.
Assistant Technician 3	B. Allen (13 May to 1 Sep)
Assistant Technician 3	J. King (13 May to 1 Sep)
Assistant Technician 3	J. Worsley (15 Jan to 16 Feb)
Assistant Technician 3	B. Chernoff (13 May to 31 Aug)

Babine Sockeye Production

Scientist 2 in charge	H.W.D. Smith, M.Sc.
Technician 5	F.P. Jordan
Technician 3	J. Martell
Technician 2	I. Miki

Technician 1	F. Masaro (1 May to 28 Aug)
Assistant Technician 3	A. Vanger (15 Jul to 4 Sep)
Student Assistant	June Wingate (13 May to 21 Aug)
Salmon Stream Ecology	
Scientist 3 in charge	J.H. Mundie, Ph.D.
Technician 2	D.E. Mounce, B.Sc.
Special Salmon Projects	
Scientist 4 in charge	F.C. Withler, M.A.
Technician 3	R.B. Morley, B.Sc.
Ethology	
Scientist 3 in charge	C. Groot, Ph.D. (from 2 Jul)
Technician 6	C.E. Turner (from 3 Jul)
Marine Ecology of Salmon	
Scientist 5 in charge	R.R. Parker, Ph.D.
Technician 2	Beverley A. Bravender, B.Sc. (from 2 Dec)
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. (returned from work assignment Japan 30 Aug)
Scientist 2	K.V. Aro, B.A.
Technician 6	C.E. Turner (to 2 Jul)
Technician 3	L.W. Barner (to 21 Oct)
Technician 2	Dorothy P. Dzendolet
Marine Fisheries Group	K.S. Ketchen, Ph.D. (Group Head)
ST 5	Eleanor E. Kehler (Group Secretary) (from 8 Jan)
Groundfish	
Scientist 5 in charge	K.S. Ketchen, Ph.D. (seconded to Ottawa 18 Jul)
Scientist 4	S.J. Westrheim, M.Sc.
Scientist 4	W.A. Kennedy, Ph.D.
Scientist 1	C.D. Levings, M.Sc. (to 15 Jun)
Technician 8	C.R. Forrester

Technician 6	R.M. Wilson
Technician 5	W.R. Harling
Technician 4	D. Davenport
Technician 3	R.M. Wowchuk
Technician 2	M.S. Smith
Technician 1	Doris E. Chilton
CR 3	Janice E. Prest

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.
Technician 4	R.S.K. Isaacson
Technician 4	J.S. Rees
Technician 3	L.W. Barner (from 22 Oct)
Technician 2	A. Rigby
Technician 2	E.W. Stolzenberg
Technician 2	C.W. Haegele, B.Sc. (from 12 Feb)
Assistant Technician 3	S. Pickard (30 Jan to 13 Sep)
Student Assistant	Jane Lake (1 May to 31 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)
Technician 5	F.R. Bernard
Technician 3	P.A. Fraser
Technician 2	D.W. Smith, B.Sc.
Student Assistant	D. Bianchin (2 May to 31 Aug)

Shrimp and Crab

Scientist 3 in charge	T.H. Butler, M.A.
Technician 4	A.N. Yates

Lobster

Scientist 3 in charge	R.J. Ghelardi, Ph.D.
Technician 5	C.T. Shoop
Assistant Technician 2	C.R. Hill
Caretaker 2	Ann J. Hill

Pacific Oceanographic Group	M. Waldichuk, Ph.D. (Group Head)
ST 5	Sandra B. Bowers (Group Secretary)
Pollution	
Scientist 5 in charge	M. Waldichuk, Ph.D.
Technician 7	A.E. Werner
Technician 3	W.F. Hyslop, B.Sc. (educational leave)
Oceanic Coastal Program	
Scientist 3	A.J. Dodimead, M.Sc.
Physical Oceanography	
Scientist 3 in charge	S. Tabata, Ph.D.
Scientist 3	L.F. Giovando, Ph.D.
Scientist 2	P.B. Crean, M.A.
Technician 5	A.J. Stickland
Technician 4	J.H. Meikle
Technician 2	R.E.O. Forbes
Assistant Technician 3	B. de Lange Boom (1 May to 31 Aug)
Student Assistant	Linda Scott (1 May to 31 Aug)
Biological Oceanography	
Scientist 4 in charge	T.R. Parsons, Ph.D.
Scientist 2	C.D. McAllister, M.A.
Scientist 2	R.J. LeBrasseur, M.A.
Scientist 2	W.E. Barraclough, M.A.
Technician 5	J.D. Fulton
Technician 4	O.D. Kennedy
Technician 3	D.G. Robinson, B.Sc.
Technician 3	J.R. Skelding (to 16 Nov)
Assistant Technician 3	M. Hardon (29 Apr to 17 Aug)
Assistant Technician 3	R. Hobbs (1 May to 17 Aug)
Assistant Technician 3	S. Sheehan (1 Apr to 1 Aug)
Student Assistant	Wendy Muir (6 May to 31 Aug)
Fishery Ecology	
Scientist 3	W.P. Wickett, M.A.
Support Oceanography	
Technician 7	R.H. Herlinveaux
Daily Seawater Observations	
Technician 7	H. Hollister

Weathership (Line P) Program	
Technician 3	K.A. Gantzer
Technician 3	J. Wong, B.Sc.
Technician 2	R.H. Bigham
Technician 2	O.H. Joergensen, B.Sc.
Pathology and Physiology Group	L. Margolis, Ph.D. (Group Head)
ST5	L. Mavis Colclough (Group Secretary) (from 8 Jan)
Parasitology	
Scientist 4 in charge	L. Margolis, Ph.D.
Scientist 4	Z. Kabata, D.Sc.
Scientist 2	N.P. Boyce, M.Sc.
Technician 2	T.E. McDonald, B.Sc.
Student Assistant	A. Dorothy Dale (1 May to 30 Aug)
Physiology	
Scientist 5 in charge	J.R. Brett, Ph.D.
Scientist 2	J.E. Shelbourn, M.Sc. (educational leave from 20 Sep)
Technician 5	D.B. Sutherland
Technician 3	G.D. Heritage, B.Sc.
Student Assistant	D. Higgs (1 May to 31 Aug)
Microbiology	
Scientist 3 in charge	G.R. Bell, Ph.D. (sabbatical leave from 1 Aug)
Scientist 3	T.P.T. Evelyn, Ph.D.
Technician 4	G.E. Hoskins, B.Sc.
Graduate Assistant	W. Wowchuk (13 May to 31 Aug)
Physiological Ecology	
Scientist 3 in charge	D.F. Alderdice, Ph.D.
Technician 4	F.P.J. Velsen
Graduate Assistant	R. Otto (1 May to 31 Aug)
Scientific Services	G.L. Robins, Ph.D. (Group Head)
Photography and Illustrating	
Technician 3	C.J. Morley
Technician 3	A.A. Denbigh

Library	
Librarian 3	Emily A. Young
CR 2	Shirley M. LaPlante (from 15 Jul)
CR 4	Evelyn M. Wardropper (to 8 Feb - retired)
Computations & Theoretical Population Studies	(supervised by the Director)
Scientist 2	J.A.C. Thomson, M.Sc.
Scientist 2	L.V. Pienaar, Ph.D. (from 10 Mar)
DA 2	Gloria G. Fedechko
DA 2	Margarate Mitchell
CS 1	Arlene M. Sandnes (from 16 Aug)
Graduate Assistant	J. Lindsey (16 Apr to 22 Aug)
Fish Culture	
Technician 6	R.M. Humphreys
Technician 2	W. Caulfield (to 24 Sep - retired)
Technician 2	W. Griffioen (from 16 Apr)
Technician 1	D. Pozar
Assistant Technician 1	S. Akenhead (24 Jun to 27 Jul)
Chemical Laboratory Services	
Technician 6	K.V.C. Stephens
Development & Instrumentation Research	
Scientist 2 in charge	W.H. Bell, M.Sc. (returned from educational leave 3 Jun)
Scientist 2	J.S. Ford, B.Sc., P.Eng.
Technician 7	L.D.B. Terhune
Technician 3	M.C. Armstrong
Technician 3	R.A. Cook
Technician 3	G.T. Atkinson
Technician 3	D.J. Redman (from 25 Nov)
Technician 2	A.J. Boyden (to 6 Sep)
Histology Laboratory Services	
Technician 4	J.W. Bagshaw (supervised by D.B. Quayle)

Administrative & Technical Services	I. J. Strong, B.A.
Secretarial Services	
Supervising Clerk in charge and Director's Secretary	Ethel E. Robinson
CR 5 (Secretary to Dr. Ricker)	Dorothy Gailus
CR 4 (Files)	Margaret K. Philp
CR 4	Ruth Cote
CR 2 (Assistant Files)	Audrey Ballantyne (to 9 Jul)
CR 2 (Assistant Files)	Lois B. Endel (from 22 Jul)
CR 2 (Multilith Operator)	Sonia S. Solunac (to 9 Aug)
OE 1 (Multilith Operator)	Rosalie I. Williams (to 30 Nov)
OE 1 (Multilith Operator)	Gloria D. Melluish (from 2 Dec)
ST 3	Terezia Beg
ST 3	Audrey K. Clements
ST 3	Eleanor E. Kehler (to 7 Jan)
ST 3	Josephine M. Bain
ST 3	Christine J. Hansen (to 19 Sep)
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
Technician 2 (Stores)	J. Lucop
CR 4	S.C. Grando
CR 3	R.R.D. Curry
CR 3	Chris M. Gorton
CR 3	Mary Arbanas
ST 5	Doris Luvisotto
ST 2	I. Linda Riddell
Storeman 1	J. Naysmith
Buildings and Grounds	
Admin. Officer 1	M.S. Wilson
Maintenance Supervisor 5	A.G. Paul
Caretaker 5	J.R. Jardine
Caretaker 3	J.H. Merner (to 1 Apr - retired)
Watchman	J.M. McArthur
Watchman	W.W. Thompson
Vessels, Shops and Services	
Admin. Officer 3	J.H. Brennan
Technician 4	K. Sutherland
Technician 3	A. Brown
Technician 3	M. Ilich

Research Vessels

MV G.B. Reed

Captain	J. Liston
Chief Engineer	R. May
Second Engineer	J. Swindell
Third Engineer	W. Colp
Relief Vessel Engineer	D.M. Clerke (from 16 Oct)
Relief Vessel Engineer	W. Van Beest
Relief Vessel Engineer	W.H. Craigie
First Mate	E.R. Pollard
Relief Officer	C. Stewart
Second Mate	W.S. Sutherland
Relief Officer	W.R. Lindsell (to 15 May)
First Cook	M.A. MacLean
Second Cook	W.J.E. Hewitt
Boatswain	A.J. Fletcher
Oiler	F. Kreger
Oiler	G.L. Buxton (to 22 Aug)
Oiler	J.M. Mitchell
Oiler	R.H. Slasor (from 22 Aug)
Oiler	R.I. Edwards
Oiler	W.A. Owen (to 1 May)
Twinehand	E.C. Ryan
Twinehand	G.A. Wiseman (from 15 Jan)
Twinehand	P.C. Emerson (to 30 Mar)
Twinehand	M. Stanley (from 23 Apr)
Twinehand	A.E. Bailey
Twinehand	R.A. Dean
Twinehand	J.D.A. MacKay (from 1 Apr)
Twinehand	R. Marshall (to 23 Apr)
Twinehand	J.F. Morris (to 3 Dec)
Chief Steward	D.W. Addison
Steward	J.J. Backmann
Waiter	J.W. Johnson (from 19 Aug)
Waiter	W.D. Buhr (to 18 Jun)
Deckhand	R.H. McLaughlin
Deckhand	W. Wolden
Deckhand	R.R. Hooper (to 6 Jun)
Deckhand	R.N. Ostle
Deckhand	K. Drohojewski (to 26 Mar)
Deckhand	R.H. Edwards (to 11 Dec)
Deckhand	A. Gow (from 8 Jan)

MV A.P. Knight

Captain	C. Watson
Chief Engineer	W.P. Winstanley
Second Engineer	L.V.M. Soper
Mate	W. Ryles (from 1 Aug)
Cook-Twinehand	W.H. Lutz
Twinehand	S.O. Gibson

MV Investigator No. 1

Captain	J.T. Ferguson
Engineer	R. Page
Mate	W.D. Nichol
Cook-Twinehand	L. Stennes

Small Craft

Technician 2	R.E. Hirst
Technician 2	D.B. Donnelly (from 1 Jul)
Technician 1	H. Neate

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

C.A. Collins, Ph.D.	Research Scientist 1, Ocean Station P, Statistical Analysis of Time Series (from 29 Jan)
C.S. Wong, Ph.D.	Research Scientist 1, Ocean Station P, Air-Sea Exchange of Carbon Dioxide (from 23 Dec)
D.A. Healey, M.Sc.	Scientific Officer 2, Ocean Station P, Internal Waves (from 21 Feb)
K.B. Abbott-Smith	Technician 2, Ocean Station P
C. DeJong	Technician 2, Ocean Station P (from 5 Feb)
B.G. Minkley	Technician 1, Ocean Station P
R.L.K. Tripe	Technician 1, Ocean Station P (from 15 Aug)

NON-STAFF RESEARCH WORKERS

H.P. Arai, Ph.D.	Honorary Research Associate
Mary Needler Arai, Ph.D.	Honorary Research Associate
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 Fellow
T. Yusa, Ph.D.	Under FRB contract (to 31 Oct)
E.L. Cooper, Ph.D.	Under FRB contract (18 Mar - 30 Sep)
J.R. Lewis, Ph.D.	Under FRB contract (30 Jun - 31 Aug)

PUBLICATIONS

1. Primary Publications

Alderdice, D. F., and C. R. Forrester. 1968. Some effects of salinity and temperature on early development and survival of the English sole (Parophrys vetulus). J. Fish. Res. Bd. Canada, 25(3): 495-521.

Alderdice, D. F., and F. P. J. Velsen. 1968. Design of a controlled-environment incubator for small marine fish eggs. J. Fish. Res. Bd. Canada, 25(3): 585-588.

Allen, K. Radway. 1968. Simplification of a method of computing recruitment rates. J. Fish. Res. Bd. Canada, 25(12): 2701-2702.

Bell, Gordon R. 1968. Distribution of transaminases (aminotransferases) in the tissues of Pacific salmon (Oncorhynchus), with emphasis on the properties and diagnostic use of glutamic-oxolacetic transaminase. J. Fish. Res. Bd. Canada, 25(6): 1247-1268.

Berkeley, C. 1968. Records of earthworms from Vancouver, British Columbia. J. Fish. Res. Bd. Canada, 25(1): 205.

1968. A checklist of Polychaeta recorded from British Columbia since 1923, with references to name changes, descriptions, and synonymies. II. Sedentaria. Canadian J. Zool., Vol. 46, 557-567.

Bernard, F. R. 1968. The aquiferous system of Polinices lewisi (Gastropoda, Prosobranchiata). J. Fish. Res. Bd. Canada, 25(3): 541-546.

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Bilton, H. T., and D. W. Jenkinson. 1968. Comparison of the otolith and scale methods for aging sockeye (Oncorhynchus nerka) and chum (O. keta) salmon. J. Fish. Res. Bd. Canada, 25(5): 1067-1069.

Butler, T. H. 1968. The shrimp fishery of British Columbia. FAO Fish. Rep., (57) Vol. 2, p. 521-526.

Caulfield, W. 1968. Method for counting coho fry in small streams. J. Fish. Res. Bd. Canada, 25(4): 823.

Foerster, R. E. 1968. The sockeye salmon, Oncorhynchus nerka. Bull. Fish. Res. Bd. Canada, No. 162, 422 p.

Godfrey, H., D. D. Worlund and H. T. Bilton. 1968. Tests on the accuracy of ageing chinook salmon (Oncorhynchus tshawytscha) from their scales. J. Fish. Res. Bd. Canada, 25(9): 1971-1982.

Jordan, Fred P., and Howard D. Smith. 1968. An aluminum staple tag for population estimates of salmon smolts. Progressive Fish-Culturist, 30(4): 230-234.

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1968. Some Chondracanthidae (Copepoda) from fishes of British Columbia. J. Fish. Res. Bd. Canada, 25(2): 321-345.

1968. Two species of Caligus (Caligidae) from New Caledonia. Crustaceana, Suppl. 1, p. 1-10.

1968. The appendages of Lernaeolophus sultanus (H. Milne Edwards, 1840) (Lernaeoceridae). Crustaceana, Suppl. 1, p. 103-111.

1968. Copepoda parasitic on Australian fishes. VII. Shiinoa occlusa gen. et sp. nov. J. nat. Hist., 2: 497-504.

1968. Copepoda parasitic on Australian fishes. VIII. Families Lernaeopodidae and Naobranchiidae. J. nat. Hist., 2: 505-523.

Kennedy, W. A. 1968. Effect of the FP-66 tag on sablefish growth. J. Fish. Res. Bd. Canada, 25(10): 2247-2249.

Larkin, P. A., and J. G. McDonald. 1968. Factors in the population biology of the sockeye salmon of the Skeena River. J. Anim. Ecol., 37: 229-258.

Levings, C. D. 1968. Fertilized eggs of the butter sole, Isopsetta isolepis, in Skidegate Inlet, British Columbia. J. Fish. Res. Bd. Canada, 25(8): 1743-1744.

Manzer, J. I. 1968. Food of Pacific salmon and steelhead trout in the North-east Pacific Ocean. J. Fish. Res. Bd. Canada, 25(5): 1085-1089.

Margolis, L. 1968. Review of the Japanese species of Cystidicola, Metabronema and Rhabdochona (Nematoda) from salmonoid fishes. The Research Bulletin of the Meguro Parasitological Museum, No. 2, p. 23-44.

Narver, David W. 1968. The isopod Mesidotea entomon in the Chignik lakes, Alaska. J. Fish. Res. Bd. Canada, 25(1): 157-167.

Neate, Harry. 1968. Gear modifications for the electro-fishing of under-yearling coho salmon. Progressive Fish-Culturist, 30(3): 181-182.

Parker, R. R. 1968. Caligus longicaudatus Brady, 1899 (Caligidae : Copepoda). Bull. Br. Mus. nat. Hist. (Zool.), 15(8): 355-368.

1968. Marine mortality schedules of pink salmon of the Bella Coola River, central British Columbia. J. Fish. Res. Bd. Canada, 25(4): 757-794.

1968. Caligus appendiculatus F. Müller, 1852 (Crustacea : Copepoda): a request for suppression under the plenary powers. Z.N.(S.) 1839. Bull. zool. Nomencl., Vol. 25, Parts 2/3, p. 105-106.

Parker, R. R., Z. Kabata, L. Margolis and M. D. Dean. 1968. A review and description of Caligus curtus Müller, 1785 (Caligidae : Copepoda), type species of its genus. J. Fish. Res. Bd. Canada, 25(9): 1923-1969.

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Parsons, T. R., and R. J. LeBrasseur. 1968. A discussion of some critical indices of primary and secondary production for large-scale ocean surveys. Calif. Mar. Res. Comm., CalCOFI Rept., 12: 54-63.

Pienaar, L. V., and W. E. Ricker. 1968. Estimating mean weight from length statistics. J. Fish. Res. Bd. Canada, 25(12): 2743-2747.

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Pozar, Dusan F. 1968. An automatic wet-food dispenser. Progressive Fish-Culturist, 30(2): 113-115.

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Ricker, W. E., Rene Malouin, Peter Harper and H. H. Ross. 1968. Distribution of Quebec stoneflies (Plecoptera). Naturaliste can., 95: 1085-1123.

Seki, H., J. Skelding and T. R. Parsons. 1968. Observations on the decomposition of a marine sediment. Limnol. Oceanogr., 13(3): 440-447.

Shepard, M. P., A. C. Hartt and T. Yonemori. 1968. Salmon of the North Pacific Ocean. Part VIII. Chum salmon in offshore waters. Intern. North Pacific Fish. Comm., Bull. No. 25, 69 p.

Sparrow, R. A. H. 1968. A first report of chum salmon fry feeding in fresh water of British Columbia. J. Fish. Res. Bd. Canada, 25(3): 599-602.

Strickland, J. D. H., and T. R. Parsons. 1968. A practical handbook of seawater analysis. Bull. Fish. Res. Bd. Canada, No. 167, 311 p.

Taylor, F. H. C. 1968. The relationship of midwater trawl catches to sound scattering layers off the coast of northern British Columbia. J. Fish. Res. Bd. Canada, 25(3): 457-472.

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Turner, C. E., and H. T. Bilton. 1968. Another pink salmon (Oncorhynchus gorbuscha) in its third year. J. Fish. Res. Bd. Canada, 25(9): 1993-1996.

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2. Interpretive Publications

Anon. 1967. Soles and flounders of the Pacific. Fish. Canada, 19(9): 10-11. [Prepared by members of the staff of the Nanaimo Station.]

Forrester, C. R. 1968. Utilization of fish for animal food in B. C. Fish. Canada, 20(10): 17-21.

Ghelardi, R. J., and C. T. Shoop. 1968. Will Atlantic lobsters breed in B. C. waters? Fish. Canada, 20(9): 7-12.

Ketchen, K. S. 1967. The trawl fishery for Pacific cod. Western Fish., 73(6): 36-40, 42, 44-45, 56-62.

1968. Trends in marine fisheries along the Pacific coast of North America. Trans. Am. Fish. Soc., 97(1): 82-88. [Also appeared in Fish. Canada, 20(11): 10-16.]

LeBrasseur, R. J. 1968. Marine biology in Saanich Inlet. Pacific Search, 3(2): 2.

Ricker, W. E., and K. H. Loftus. 1968. Pacific salmon move East. Fisheries Council of Canada, Annual Review, p. 37-39, 43.

Smith, M. S., and T. H. Butler. 1968. Shrimp exploration on the British Columbia coast 1967. Fish. Res. Bd. Canada, Nanaimo Biol. Sta. Circ., No. 85, 41 p. [Also appeared in Western Fish., 75(6): 22, 24, 34-35.]

Taylor, F. H. C. 1968. What happened to the herring? Western Fish., 75(5): 24, 26, 28, 30-32.

Waldichuk, Michael. 1968. Sewage pollution in confined coastal waters. Pacific Search, 3(1): 2 p.

1968. Biological effects of water pollution. Chemistry in Canada, 20(9): 15-18.

1968. Waste disposal in relation to the physical environment — oceanographic aspects. Syesis, 1: 4-27.

Werner, A. E. 1968. Gases from sediments in polluted coastal waters. Pulp and Paper Mag. Canada, 69(5): 127-136.

Yates, A. N. 1968. Experimental prawn trap fishing, December 1, 1967 to March 22, 1968. Fish. Res. Bd. Canada, Nanaimo Biol. Sta. Circ., No. 87, 29 p. [Also appeared in Fish. Canada, 21(9): 15-19.]

3. Sub-Publications

Andersen, Bruce C., and David W. Narver. 1968. Techniques for sampling zooplankton and underyearling sockeye salmon in the midwater of large lakes. Fish. Res. Bd. Canada MS Rept., No. 1009, 5 p.

Anon. 1967. Ocean weather station "P", North Pacific Ocean, August 5 to October 31, 1966. Canadian Oceanogr. Data Centre, 1967 Data Rec. Ser., No. 6, 164 p.

1967. Ocean weather station "P", North Pacific Ocean, October 28, 1966 to January 9, 1967. Canadian Oceanogr. Data Centre, 1967 Data Rec. Ser., No. 8, 111 p.

1968. Ocean weather station "P", North Pacific Ocean, January 16 to April 12, 1967. Canadian Oceanogr. Data Centre, 1968 Data Rec. Ser., No. 2, 126 p.

1968. Hudson Bay, Hudson Strait and Arctic, July 21 to September 9, 1967. Canadian Oceanogr. Data Centre, 1968 Data Rec. Ser., No. 4, 123 p. [Prepared by R. H. Herlinveaux and F. G. Barber.]

1968. Ocean weather station "P", North Pacific Ocean, April 7 to July 6, 1967. Canadian Oceanogr. Data Centre, 1968 Data Rec. Ser., No. 5, 140 p. [Also appeared as INPFC Doc. No. 1082, 140 p.]

1968. Observations of seawater temperature and salinity on the Pacific Coast of Canada, 1966. Canadian Oceanogr. Data Centre, 1968 Data Rec. Ser., No. 8, 100 p.

1968. Ocean weather station "P", North Pacific Ocean, July 3 to September 14, 1967. Canadian Oceanogr. Data Centre, 1968 Data Rec. Ser., No. 9, 148 p.

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Aro, K. V., and J. McDonald. 1968. Times of passage of Skeena River sockeye and pink salmon through the commercial fishing area. Fish. Res. Bd. Canada MS Rept., No. 984, 169 p.

Ball, E. A. R., and H. Godfrey. 1968. Lengths and ages of chinook salmon taken in the British Columbia troll fishery and the Fraser River gillnet fishery in 1965. Fish. Res. Bd. Canada MS Rept., No. 952, 130 p.

1968. Lengths and ages of chinook salmon taken in the British Columbia troll fishery and the Fraser River gillnet fishery in 1966. Fish. Res. Bd. Canada MS Rept., No. 954, 143 p.

1968. Lengths and ages of chinook salmon taken in the British Columbia troll fishery in 1967. Fish. Res. Bd. Canada MS Rept., No. 998, 93 p.

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Barraclough, W. E., D. G. Robinson and J. D. Fulton. 1968. Data record. Number, size composition, weight, and food of larval and juvenile fish caught with a two-boat surface trawl in Saanich Inlet April 23-July 21, 1968. Fish. Res. Bd. Canada MS Rept., No. 1004, 305 p.

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Butler, T. H., and M. S. Smith. 1968. Shrimp sampling and temperature data obtained during exploratory fishing off British Columbia, 1966 and 1967. Fish. Res. Bd. Canada Tech. Rept., No. 61, 92 p.

Cameron, William M. 1968. [A report prepared in 1939-1940 and submitted in partial fulfilment of requirements for the degree of Master of Arts at the University of British Columbia.] The tagging ratio and its use in the estimation of a spawning salmon population. Fish. Res. Bd. Canada MS Rept., No. 991, 38 p.

1968. [A report prepared in 1939, based on investigations in 1938-39.] A preliminary investigation of the natural spawning, incubation and alevin-age of the pink salmon (Oncorhynchus gorbuscha). Fish. Res. Bd. Canada MS Rept., No. 995, 25 p.

Clemens, Wilbert Amie. 1968. Education and fish: an autobiography. Fish. Res. Bd. Canada MS Rept., No. 974, 102 p.

Dodimead, A. J. 1968. Temperatures and salinities of the Northeast Pacific Ocean during 1965 and 1966 with Appendix — Data record of bathythermograms April-August, 1965 and 1966. Fish. Res. Bd. Canada Tech. Rept., No. 54, 89 p. [Also appeared as INPFC Doc. No. 1062, 89 p.]

1968. Oceanographic conditions in the central Subarctic Pacific Region, winter 1966. Fish. Res. Bd. Canada Tech. Rept., No. 75, 21 p. [Also appeared as INPFC Doc. No. 1081, 21 p.]

Dodimead, A. J., and R. H. Herlinveaux. 1968. Some oceanographic features of the waters of the Central British Columbia coast. Fish. Res. Bd. Canada Tech. Rept., No. 70, 133 p.

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1968. Quantitative benthic investigations. IV. Biomass summaries and major taxon rank orders (mainly Straits of Georgia and adjacent inlets), May 1965-December 1967. Fish. Res. Bd. Canada Tech. Rept., No. 60, 89 p.

1968. Quantitative benthic investigations. V. Species data from selected stations (Straits of Georgia and adjacent inlets), May 1965-May 1966. Fish. Res. Bd. Canada Tech. Rept., No. 73, 315 p.

Forrester, C. R., and D. F. Alderdice. 1968. Preliminary observations on embryonic development of the flathead sole (Hippoglossoides elassodon). Fish. Res. Bd. Canada Tech. Rept., No. 100, 20 p.

Forrester, C. R., and J. E. Prest. 1968. A summary report of the British Columbia trawl fishery in 1967 and some aspects of its investigation. Fish. Res. Bd. Canada Tech. Rept., No. 89, 29 p.

Fulton, John. 1968. A laboratory manual for the identification of British Columbia marine zooplankton. Fish. Res. Bd. Canada Tech. Rept., No. 55, 141 p.

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Printed in Canada by the Canadian
Government Printing Bureau for the
exclusive distribution by Fisheries
Research Board of Canada,
Nanaimo, B.C., Canada