~~R. J. LeBrasseur~~

RESTRICTED

K Simpson

FISHERIES AND MARINE SERVICE

RESEARCH AND DEVELOPMENT DIRECTORATE

PACIFIC BIOLOGICAL STATION
NANAIMO, B.C.

ANNUAL REPORT
and
INVESTIGATORS' SUMMARIES

1974

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Dr. W. E. Johnson, Director

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INTRODUCTION

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W. E. Johnson

The 1974 principal objectives of the Pacific Biological Station remained much the same as those defined in earlier reports. They are generally concerned with increasing knowledge of the biology of Canada's aquatic resources in the Pacific region and of the environment which supports them, for application in the protection, management, and enhancement of these resources and their habitats. Priorities for west coast fisheries are changing rapidly and to ensure the continued relevance of research and development programs to the needs of fishery managers and commercial and recreational resource users, both a strengthening and realignment of programs in the three current Pacific Biological Station research sections are now well under way.

In the Fisheries Population Section, strong thrusts have been sustained in the major groundfish, salmon and herring population programs. Surveys of latent groundfish resources, principally on rockfishes were continued in 1974 in Queen Charlotte Sound. Explorations in the deep water of the Strait of Georgia revealed concentrations of hake and pollock. The main activity of the Salmon Population Program was centered on a large-scale Canada-U.S. mark and recovery program on chinook and coho to assess the effectiveness of current and new hatchery techniques and to help determine the ocean distribution and areas of intermingling of U.S. and Canadian salmon. Development of X-ray spectroscopy to determine the country and river of origin of ocean-caught salmon is now well advanced. With the rapid development of the new herring roe fishery, efforts of the Herring Program in 1974 were concentrated on reorganization of stock assessment and population analysis techniques to provide a better data base in cooperation with fisheries managers. This involved redefining stocks in terms of management units. In the Crustacea Program investigation of the cause of a decline in abundance of prawns was begun along the central coast. Also an extensive survey of the shrimp potential in southern Queen Charlotte Sound was conducted in order to provide better information for a newly developing commercial fishery. Similar surveys in the previous year off the west coast of Vancouver Island encouraged a substantial expansion of the fishery in 1974. The program on Other Invertebrates was focused primarily on a joint study of Pendrell Sound with oceanographers from the Marine Sciences Directorate, the purpose being to determine whether the industry can continue to depend on that area for seed, and whether spatfall forecasts can be improved. A program on Hydroacoustics is developing techniques for determining the distribution and abundance of herring, rockfish and several other pelagic species on grounds off the west coast of Vancouver Island. A digital integration system is providing useful information on the density and abundance of schooling species.

The Salmon Enhancement, Aquaculture and Fish Health Section includes a large number of programs of study to develop and improve methods of increasing salmon production, including sea farming and to prevent and control disease amongst cultured and wild stocks. Within the Salmon Enhancement Program, a sockeye behavior study was conducted to determine the optimum density in artificial spawning channels; a new technique for hatchery rearing of pink salmon shows considerable promise along with a new technique of rearing

transplanted eggs within the receiving stream. Carefully controlled experiments are well underway to test various factors (time of release, temperature, feeding) which will maximize the return of hatchery-reared coho and chinook salmon. Concurrently studies of the aquatic and aerial food supply to coho in natural streams are nearing completion, thus setting the stage for construction of a semi-natural stream which will provide optimum natural feeding and rearing conditions. Application of new technology to the question of introducing self-sustaining pink salmon runs into the barren cycle of streams having a pronounced "on-off" characteristic, is underway at Bear River. The Aquaculture Program consists of two parts: physiological studies on methods of accelerating growth of fingerling salmon before release into a fishfarm holding facility and operation of a pilot fishfarm itself with the view to rearing salmon to pan-size in a simulated commercial venture. Although initial results are encouraging, serious problems of disease must be overcome. A microbiology program concerned with Fish Health is providing new ways of controlling and preventing disease amongst impounded salmon by the use of injected vaccines and oral immunization. A disease diagnostic/consultation service was formally introduced in 1974, available to government-operated salmonid enhancement facilities and to commercial fishfarms. As part of the Fish Health Program, a parasitology program is providing information on parasitic diseases of fish, parasites in marketable fish projects, and the dangers of spreading harmful parasites through diversion of streams from one watershed to another.

The Fisheries Ecology Section includes programs to provide fisheries information essential to management, particularly with respect to various developments which pose a threat to important resource habitats. Of major importance is a study of the Nanaimo River estuary to determine the role of the estuary as a nursery area for young salmon and hence provide a basis for assessing the pros and cons of estuary development for industrial purposes. In addition, new information is being collected on the ecological relationships of various species of fish in the nearshore and offshore waters of the Strait of Georgia. A program on effects of environmental change at Carnation Creek is continuing to provide baseline data from which to measure the impact of logging practices expected to begin in 1975. A standardized monitoring program was introduced in 1974 to provide baseline information from which to evaluate the effects of further development of the Babine watershed as a site of mining, logging, community construction and recreational activities.

INVESTIGATORS' SUMMARIES

F I S H E R I E S P O P U L A T I O N S S E C T I O N

K. S. Ketchen

This section conducts programs of study basic to management of a wide variety of anadromous fishery resources, including exploratory fishing for new stocks and fishing grounds and assessment of long-term yield potentials to foster rational development of west coast fisheries.

GROUNDFISH

S. J. Westrheim

The Groundfish Program is concerned with the reaction of commercially important marine fish (except halibut) stocks to exploitation and environmental factors. Advice is provided on status and management of stocks to industry and appropriate agencies. Principal species landed by Canadian vessels during 1963-72 were Pacific cod (46%), rock sole (14%), lingcod (11%), and Pacific ocean perch (9%). Approximately 17 additional species account for the remaining 20%.

The basic activities of the Groundfish Program are: (1) monitoring the commercial fishery; (2) biological investigations; and (3) participation in domestic and international meetings dealing with research and management problems.

1. Monitoring the commercial fishery

The commercial groundfish fishery is monitored on a continuing basis to: (1) provide current statistical and biological data needed for managing the stocks: and (2) provide long-term time series data essential to the study and understanding of fish populations. Monitoring activities include: interviewing vessel captains for detailed catch locations, and fishing effort expended; sampling landings for species composition and biological data such as length, sex, and age of individual fish; and sampling catches at sea to determine discard, qualitatively and quantitatively.

Reports were published in the Circular, Technical, or Manuscript Report Series dealing with: (1) catch statistics of the 1973 domestic trawl fishery, and the 1960-72 trawl fishery in the Strait of Georgia; (2) an inventory of biological samples collected from the domestic fishery in 1973; and (3) trawl mesh-selection studies; and (4) IDB-supported trawl cruises.

2. Biological Investigations

Biological investigations dealt with: (1) identification and assessment of latent groundfish resources; (2) rockfishes; (3) Pacific cod; (4) lingcod; (5) blackcod; and (6) dogfish shark.

(a) Latent resources

During 1974, we completed our survey, begun in 1971, of groundfish resources in the deeper waters ($\geq$ 80 fm) of Queen Charlotte Sound and Hecate Strait; and began a similar survey of the deeper waters ($\geq$ 60 fm) in the Strait of Georgia.

In the Queen Charlotte Sound-Hecate Strait region, the 1971-74 survey encompassed 5,700 sq miles, only 30% of which is currently exploited, at a moderate to light level. Principal resource is rockfish -- primarily Sebastes alutus on trawlable bottom and S. proriger on untrawlable bottom. Estimated annual maximum sustained yield of rockfishes from the region is 80 million lb, while the actual catch is 20 million lb. All major results of the 1971-74 survey have been published in the Manuscript or Technical Report Series.

In the Strait of Georgia, an echo-sounder survey was completed, during February 1974, of the deeper waters ($\geq$ 60 fm), and a limited amount of on-bottom and off-bottom trawling was conducted during February, March, and May 1974. Total area surveyed was 1,100 sq miles. The principal result to date has been the discovery of substantial quantities of hake and pollock inhabiting the midwater levels over the deep basins. Results of the 1974 surveys have been reported in the Manuscript Report Series.

During June 1974, we assisted personnel from the Vancouver Technological Laboratory in collecting specimens of various commercially abundant rockfish species in Queen Charlotte Sound for technological studies, including storage life of fillets.

(b) Rockfish biology

Rockfish studies included: (1) Pacific ocean perch length-weight relationships in the North Pacific Ocean (published in JFRBC); (2) reproduction (final draft of results nearing completion); (3) age determination for 27 species (computations nearing completion); and (4) species' interrelationships (compilation nearing completion). Rockfish field studies will be sharply reduced after 1974 in order to provide time for higher-priority programs. We have delineated the large, latent rockfish resources for the industry, and thus have satisfied a commitment agreed to in 1973.

(c) Pacific cod biology

Pacific cod studies were reactivated in 1974, after a 10-year hiatus, to determine, if possible, the maximum sustainable yield, or fishing rate, the more important stocks can sustain. This objective is also a commitment to industry agreed to in 1973. Initial work in 1974 dealt with anomalies in age determination, and an assessment of distribution based on trawl surveys and tagging.

(d) Lingcod biology

Lingcod studies have proceeded at a low level of effort. During 1974, we began a small-scale study of techniques for age determination using scales and fin rays.

(e) Blackcod biology

A final report published in the Technical Report Series, summarized the results of holding blackcod collected during the 1972 tagging experiment.

(f) Dogfish biology (undertaken by K. S. Ketchen, with some technical assistance from Groundfish personnel)

In October 1974, the A.P. KNIGHT was employed for several days in collecting data on the size composition of pregnant female dogfish in the Gulf Islands area. This was the last in a series of annual surveys to obtain information to support or refute current estimates of growth rate. A paper reporting on the results of studies through 1973 is now in press.

Use of growth-rate estimates in study of the length-frequency distribution in unexploited populations of dogfish suggests that the instantaneous natural mortality rate among mature females may be as low as 0.03 to 0.07.

3. International commitments

Groundfish Investigation personnel participate at the technical level in meetings of the International Groundfish Committee, International North Pacific Fisheries Commission, and the Canada-U.S.S.R. Scientific Meetings on Fisheries. Time expended in travel and attendance during 1974 was 93 man-days. Considerable additional time was expended in preparing reports for these meetings and analyzing reports submitted by other scientists.

In addition, during 1974 an INPFC report was prepared, in conjunction with authors from Japan and United States, entitled "The Historical Groundfish Statistics of the North Pacific Ocean." This will be published in the Bulletin series of INPFC.

SALMON POPULATIONS PROGRAM — J. McDonald

The purpose of this program is to provide the biological information and analysis required to improve production and management of our Pacific Salmon resource.

In 1974, our effort was directed in three ways:

(1) to meet Regional and National requirements with respect to international commitments and negotiations involving salmon,

(2) by participating in a large-scale cooperative U.S.-Canada mark and recovery program designed to assess the effectiveness of current and new hatchery techniques for chinook and coho and to help determine the ocean distribution, areas of intermingling and extent of interceptions of each other's salmon stocks,

(3) by developing X-ray spectroscopic techniques to provide an effective way of assessing the country and river of origin of salmon caught in coastal waters or on the high seas.

1. International salmon

Negotiations with the United States continued with the objective of reaching an agreement regarding interception of each other's salmon and allowing each country to receive full benefits from her own enhancement programs. Formal discussions were held in February 1974, and another round is planned for February 1975.

This year, this Station assumed responsibility for leading the technical work required to assess the effects of proposals for agreement made at the last meeting and to prepare for the next. Specific jobs were to: (1) arrange for, and carry out, an exchange of pertinent scientific information with the United States, (2) examine new information on U.S. hatchery production of chinook and coho and to estimate the current and future contributions of these fish to intercepting Canadian fisheries, (3) update information on the ocean distribution of Canadian and United States salmon stocks, areas of intermingling and estimates of annual interceptions, (4) help develop for the next round of negotiations various alternate Canadian strategies and possible agreements and to assess for each the advantages and disadvantages to Canada.

We continued to meet commitments regarding the International North Pacific Fisheries Commission (INPFC). A considerable part of the work was the preparation of comprehensive reports reviewing the biology of salmon species in the North Pacific. The report on coho (senior author, H. Godfrey, Canada) was accepted by the Commission and is in press. The report on chum salmon (senior author, F. Neave, Canada) will be submitted in January 1975. Further progress was made on the reports of pink and chinook by Canadian co-authors, Aro and Godfrey. It is expected that these reports will be completed and submitted to the Commission in 1975.

A report entitled "Canada's Pacific salmon and steelhead trout: a review of existing knowledge, international agreements and additional information required to protect this resource from foreign fisheries," was prepared in cooperation with other members of the Station's staff and submitted to the Director in October.

2. Chinook and coho production evaluation

H. Godfrey and
E. A. R. Ball

During the first half of 1974, the Investigator-in-charge continued as Co-chairman of the Station's Georgia Strait Committee in developing the Georgia Strait Program, and assumed the position of Scientist-in-charge of the Pelagic Studies Sub-program. In June he became Program Director and Canadian Coordinator of the joint Research-Development and Operations "Chinook and Coho Production Evaluation" Program. Part of this program is a cooperative Canada-United States project, and the responsibility of the Canadian coordinator is to coordinate program requirements with the several State and Federal agencies concerned. The program is concerned with releases of marked and unmarked chinook and coho juveniles, and recovery by sampling returning adults in fisheries and escapements, from California to southeastern Alaska.

The Canadian program has been developed in two parts: Part 1 - Catch Sampling and Mark Recovery; Part 2 - Wild Stock Marking. To date, funding for the program is being made on the basis of Special Submissions to the Regional Director General, Fisheries Management.

From the Canadian point of view, the program has four principal objectives: (1) determine contributions of Canadian hatchery and wild stocks to Canadian and U.S. fisheries (particularly relevant to the continuing Canada-U.S. salmon negotiations); (2) provide information needed for selection of best sites for new enhancement projects; (3) provide information required for fisheries management, including hatchery operations (especially on migration routes and timing; on effects on both production and catch, of time, place and size of release; on diets and genetic manipulations); (4) satisfy U.S. requirements for similar information by identifying their fish in Canadian catches.

The principal marking device employed by both countries has been the coded wire nose tag, whereby numerous separate experimental groups can be identified. In addition, multiple fin marks were used for several releases. In total, the two countries have employed more than 300 separately coded tagging experiments.

In 1974, there were available to the coastal fisheries the survivors of more than 12 million marked U.S., and more than 1 million marked Canadian chinook and coho, representing many times that number of associated unmarked fish.

Catch sampling and mark recovery

1. Levels of sampling attempted in 1974 were 20% of commercial catches of both species. In addition, a smaller percentage of the sport catch in Georgia Strait was sampled by voluntary returns of heads of tagged fish (identified initially by having their adipose fins missing), and some field sampling. Sub-sampling of catches was mainly for size and age data. Because of delays in funding, sampling did not begin until over a month after commencement of the fishing season. The sampling effort is summarized, for catches and samples to 28 September:

Total coho catch (net and troll)	3,549,970	
Number and percent of coho sampled (net and troll)	836,409:	23.6%
Total chinook catch (net and troll)	1,516,522	
Number and percent of chinook sampled (net and troll)	200,493:	13.2%

2. Head tag recoveries. To the end of October, approximately 17,000 nose-tag recoveries were made in commercial fisheries and 13,000 in the Georgia Strait sport fishery. In addition, about 200 multiple fin-clip fish were recovered. To date approximately 20,000 coded wire tags have been recovered from heads and decoded. Many decodings were repeated as a check against decoding problems and to ensure accuracy.

3. Canadian fish in Canadian and U.S. fisheries. Recoveries of tagged Canadian fish are summarized below. However, it should be noted that recoveries in Canadian fisheries include those up to late September, whereas the recoveries in U.S. fisheries are those reported to mid-July only (and more are expected for the July-September period).

	Recovery Area							
Hatchery	West Vancouver Island	Central B.C.	Northern B.C.	Georgia[a] Strait	Juan de Fuca-U.S.	Wash. Coast	Oregon Coast	Alaska
				A - Coho				
Capilano	766	4	0	4,305	89	167	18	0
Rosewall	328	37	9	2,393	3	5	(1?)	0
Qualicum -hatchery	1,087	67	6	4,983	16	58	14	0
-wild	26	5	1	185	0	0	0	0
				B - Chinook				
Capilano	31	1	0	394	0	0	0	0
Puntledge	5	0	0	221	0	0	0	0
Robertson	8	0	0	5	0	0	0	0
Qualicum	59	41	17	1,008	0	0	0	4

[a] Includes Canadian, Strait of Juan de Fuca and Georgia Strait sport fisheries.

A large amount of additional information must be processed and examined before definitive statements can be made concerning these data. Also, for many purposes it will be necessary to consider sampling rates and numbers released before comparisons can be made. Some of this has been done on a preliminary basis, and the major tentative conclusions are: (1) particularly high rates of survival of coho from Capilano, Qualicum and Rosewall hatcheries; (2) some significant differences in survival and contributions to fisheries (ocean distribution) between early and later releases; (3) differences among stocks in ocean migrations and subsequent interceptions; (4) British Columbia coho found as far south as off the central Oregon coast (and probably in significant numbers, considering numbers of marked fish released); (5) differences between wild and hatchery fish (Qualicum coho); (6) Qualicum chinook taken off southeastern Alaska (including Cape Fairweather grounds).

4. U.S. fish in Canadian fisheries. Only a very limited amount of information is available at this date. As of September 30, recoveries totalled 2,086 chinook and 6,364 coho, distributed as follows:

West coast Vancouver Island:	Chinook -	842	Coho -	3,158
Central B.C.	Chinook -	239	Coho -	14
Northern B.C.	Chinook -	393	Coho -	10
Georgia Strait	Chinook -	612	Coho -	3,182
Totals		2,086		6,364

In addition, more than 200 multiple fin-clipped spring chinook salmon were recovered in B.C. waters -- probably all of Columbia River hatchery origin.

Wild stock marking

Stocks from 43 streams have been selected on the basis of the objectives discussed above. They include the Yukon River and three Alaska Panhandle streams, as well as streams on the Queen Charlotte Islands, Vancouver Island and the mainland (from the Nass to the Fraser). These 43 streams were separated into four priority groups, and a marking and recovery (in fisheries and escapement) timetable arranged accordingly. On the basis of what already is known of these streams, it would be possible to conduct exploratory and feasibility studies in 1975, including tests for deriving marked: unmarked ratios (using migrants and/or adults in escapements). It is proposed to mark five brood-year stocks of chinooks in 1976-80, and sample for recoveries in catches and escapements up to and including 1984. This schedule would permit all the selected coho stocks to be marked as scheduled, plus additional ones if required.

3. Stock identification — T. J. Mulligan and L. Lapi

In 1974, emphasis was on upgrading and standardizing equipment and procedures so that a test of X-ray spectroscopic techniques could begin in 1975. The following was accomplished:

1. Examination of the state of the art of X-ray spectroscopy and elevation of our capabilities to that level.

2. Concentration of our efforts in three major areas:

   (a) microscopic X-ray analysis of tissue
   (b) fluorescent X-ray spectroscopy of bulk tissue
   (c) fish culture study of induced elemental "tags"

3. Development of an experimental and analytical protocol for electron microscope X-ray measurements.

4. Acquisition of a new X-ray fluorescence spectrometer and development of related analytical procedures.

5. Initiation of fish culture program for inducing elemental tags.

6. Arrangement of a cooperative program with the State of Alaska in which they will supply samples and money in return for our analyses and evaluation of X-ray fluorescence discrimination techniques.

7. Development of a system of data acquisition and processing to allow the handling of the large volume of data generated in the pursuit of our objectives.

HERRING — A. S. Hourston

Efforts of the Herring Program in 1974 were concentrated on reorganization of the stock assessment and population analyses to provide information in the form agreed upon with Fisheries Operations in 1973 and on testing and improving the data base. This involved redefining stocks in the form of Management Units which form the basis of individual fisheries, expanding the data base for the analyses and redesigning and programming the computer analyses in cooperation with Operations.

The 1974 Annual Pacific Coast Herring Workshop was hosted in Nanaimo on October 30-31 with A. S. Hourston as chairman and coordinator and D. N. Outram as editor of the proceedings. All of the Herring Program staff participated in the presentations.

1. Population biology

A. S. Hourston

The status of stocks in 1973 was assessed by statistical area and forecasts for 1974 were made on the same basis. With the introduction of Management Units in 1974, stock assessment data in the new form are being recompiled back to 1971, when the roe fishery began. This will provide an historical basis for future stock assessments. Managers are being provided annually with estimates in tons of the catch and spawners and of the age composition for the last 5 years for each Management Unit. Forecasts of abundance and spawning requirements for the coming season are also provided to senior managers on a confidential basis.

(a) Forecasts of the 1974 runs

A. S. Hourston, S. Kerr and R. S. K. Isaacson

On the basis of stock assessments for 1973 and average recruitment, the 1974 herring runs were forecast by statistical area and summarized by region. Preliminary analysis of the 1974 run indicated that overall recruitment was appreciably better than average, but was unevenly distributed. Recruitment was excellent on the west coast of Vancouver Island, which was fished at the beginning of the season, and in the Gulf of Georgia, which was closed to the seine fishery. In an attempt to distribute the 50,000-ton quota regionally, exploitation of the abundant west coast stocks was limited. Later in the season, fishermen had to scratch for fish from the northern and central runs where abundance was well below the anticipated level. The need for more accurate regional assessments and forecasts to manage the roe fishery became abundantly apparent as a result of this experience!

Forecasts and actual runs are summarized below in thousands of tons:

	1974 forecast	1974 run	1975 forecast
Queen Charlotte Islands	31	45	34
Northern	47	26	23
Central	51	32	26
Johnstone Strait	27	38	18
Gulf of Georgia	54	182	88
West Coast of Vancouver Island	61	124	109
ALL	272	447	298

(b) Forecasts of the 1975 runs

Because of delays in processing the 1974 data and in testing new analytical procedures, the basic analysis of the status of stocks in 1974 has not been completed in time for initially forecasting the 1975 runs for management. A preliminary gross analysis was therefore conducted which indicated a good escapement in the south and a moderate to poor escapement in the north. Offshore surveys and environmental conditions both suggest poor recruitment in 1975. On this basis, the 1975 run would be expected

to be about two-thirds that of 1974 (i.e. about 300,000 tons), the southern stocks providing over two-thirds of the total run (see table above).

2. Stock assessment — R. D. Humphreys

With the shift in emphasis from the broad geographic approach to stock assessment as practised during the reduction fishery days, to the present situation of concentrating on individual spawning populations or clusters of spatially related spawning populations, has come the need for improvement in the data base. Two projects were carried out for this purpose during the 1974 season.

(a) Assessment of sampling techniques — R. D. Humphreys and J. S. Rees

In addition to the regular sampling of commercial catches carried out by Operations Branch personnel in 1974, a series of samples was obtained to examine the routine sampling procedures for variability in biological characteristics. Five separate catches were sampled from the same fishing locality (to assess the randomness of selection of fish from the school by individual sets). Each of these catches was sampled at five different times during the offloading process (to assess the randomness of the distribution of fish within the hold at the time of landing). The whole process was repeated for a second fishing locality (to assess the extent to which differences between stocks exceed those inherent in the sampling procedures). The data are presently being analysed statistically to determine variability between catches by the same gear taken at the same time and place, variability between samples collected from different sections of the same vessel load, and the effect of sample size on variability.

(b) Estimation of fecundity — R. D. Humphreys

Fecundity is a vital parameter in estimating the numbers of spawners from egg depositions. During the 1974 roe herring season, 4,600 pairs of ovaries were obtained from herring in maturity stage IV or V (i.e. with fully formed ova). These ovaries were preserved in Gilson's Fluid in order to facilitate the breakdown of the ovarian membrane. The samples were washed and cleared of ovarian tissue so that counts could be made of the loose eggs. Fecundity by fish size and age for each major herring spawning on the coast will be obtained from the data.

3. Spawn monitoring techniques — C. W. Haegele

Work was continued on two projects in 1974. One would provide for more quantitative interpretations of the spawn survey reports prepared annually by Fishery Officers. The other would provide for significant improvement in the quality of the data gathered by the Fishery Officers.

(a) Assessment of egg abundance from standard spawn

Intensity levels

In 1974 a study was continued of major factors influencing the estimation of numbers of eggs from herring spawn survey records provided by Fishery Officers. Several herring spawnings on the west coast of Vancouver Island (in Barkley Sound, Nootka Sound, Hesquiat Harbour, Nuchatlitz area) were sampled, yielding 420 spawn samples on 16 substrates at seven intensities of egg deposition. Out of a possible 144 substrate intensity categories, 36 were represented in samples. Because of the sampling techniques involved, several lower intertidal and subtidal substrate species of major significance were not encountered. These include four brown algae (Alaria, Laminaria, Nereocystis and Sargassum) and four red algae (Agardhiella, Gigartina, Iridea and Rhodzmenia). Consequently another 72 categories remain unsampled in addition to the 108 not covered above. Information on time (egg loss after spawning) and position (level relative to tide), provided sub-categories in the above system.

Fishery Officers submitted a total of 241 herring spawn samples from spawnings throughout the B.C. coast. All samples have been processed to the stage where egg counts can be made. Processing involves identifying substrates, categorizating intensities, separating the eggs, counting the number of eggs per linear or square inch of spawn substrate, aging the eggs, measuring substrate height and width, and weighing both total samples and substrates by themselves. The inability of an electronic egg counter to count eggs accurately with sufficient speed has required changing the processing procedures to subsampling the egg samples by splitting and counting the subsamples manually. Sample processing and data analyses will continue in 1975.

(b) Preparation of vegetation maps for major herring

Spawning grounds

One way to improve the accuracy of current spawn surveys is to develop detailed topographical maps of major spawning grounds showing the distribution and patchiness of the various vegetation types. Fishery Officers would then be better able to delineate the dimensions of spawnings and their average intensities.

Two photographic missions were planned for 1974 for the preparation of substrate maps from aerial photographs of all major spawning grounds in Barkley Sound. Exceptionally poor weather conditions in this area for most daylight low tides permitted only one flight under marginal lighting conditions. Shoreline vegetation maps of the northwest section of Barkley Sound have been prepared from these photographs.

4. Life history — D. N. Outram

Studies of temperature and salinity conditions during herring spawning continued in 1974 and a new project on maturity stages was introduced.

(a) Salinity and temperature levels during active herring spawnings

Fragmentary information concerning the spawning of herring in British Columbia waters suggests that both occurrence and success of spawning are confined to regions having bodies of water that are relatively well protected with low salinities and temperatures below 10 C. In southern British Columbia, spawning reaches a peak by mid-March and takes place on vegetation growing within and just below the intertidal zone where wide variations in temperature and salinity are possible.

In 1973 and 1974 salinity and temperature levels associated with widely separated natural spawnings were studied. During the spawning period in 1973 (March and early April) temperatures and salinities along the lower east coast of Vancouver Island ranged from 6.5 to 9.0 C and from 22.4 to 28.4‰ respectively. On the west coast of Vancouver Island during the same period in 1974, temperatures ranged from 5.0 to 7.8 C and salinities from 16.3 to 28.8‰. The total range of temperatures and salinities for these spawnings was 5.0 to 9.0 C and 16.3 to 28.4‰, respectively.

(b) Gonad maturation in Pacific herring

Currently commercial herring fishing is primarily for roe, and we need to understand the gonad maturation process that precedes spawning. A study of the successive stages of ovarian development with time would assist in (1) management of the fishery by enabling predictions of maturation and spawning times and in (2) biological sampling procedures by enabling development of a scale for classifying maturity stages.

Since July 1974 a stock of herring along the lower east coast of Vancouver Island near Porlier Pass has been sampled at intervals to study and delineate the maturation stages using criteria such as gonad shape, colour, length, width, and ripeness, and for histological sectioning and photographs. In late July ovary weights averaging as little as 0.3 g or about 0.5% of the total body weight were recorded. In late August ovaries averaged 1% of the total body weight, in early October about 2.6% and in late October 3.9% when fish averaged 1.6 g. Ripe ovaries in the following spring may be $\geqslant$ 20% of body weight. During the same July-October period average ovary length increased by about 20% (from 5.7 to 6.8 cm). During early maturation paired ovaries were comparable in colour and development, but were frequently dissimilar in length and weight.

CRUSTACEA

1. Mainland inlets prawn project

T. H. Butler and N. Yates

Numbers of prawns trapped from the principal fishing region including such mainland inlets as Knight, Kingcome, etc., rose sharply from 1965 to 1970 and then declined from 1971 to 1973. Fisheries and

Marine Service statistics reveal an accompanying decrease in availability (lb per day). Leading prawn fishermen, interviewed in 1973, reported smaller individual catches, and proposed closures or other regulatory measures.

Consequently a project was started in November 1973 to determine the cause of the decline, and to obtain information on prawn biology and population dynamics required for management. Four cruises were also carried out with A. P. KNIGHT in 1974. Analysis of the results of experimental trapping is underway to provide information on seasonal availability, growth, reproduction, ovigerous periods, and frequency of capture of other animals. Bottom temperature and salinity readings are obtained at most trapping stations.

2. Offshore shrimp projects

(a) Survey of Queen Charlotte Sound shrimp stock

This survey was to determine the locations and sizes of shrimp fishing grounds, and total stock size. Two grounds were surveyed with G. B. REED in April 1974. Near Calvert Island, an area of 153 sq mi contained an estimated stock of 11,200,000 lb of the pink shrimp (Pandalus jordani), and near Pearl Rocks, an area of 11 sq mi contained a shrimp biomass estimated at 549,000 lb. Sustainable annual yields, based on a tentative optimum exploitation rate of 0.45, were:

Calvert Island ground: 5,040,000 lb

Pearl Rocks ground: 247,000 lb

A cruise report, Station Circular 98, was prepared and distributed.

In 1973, one trawler fished the two grounds and landed 155,000 lb at Namu where a mechanical peeler was in operation. Early in 1974, before the G. B. REED survey, three more peelers were installed. Later, from May to late August, three trawlers landed 476,800 lb from the two grounds. Following this operation, an unprofitable one for them, the fishing company returned the rented peelers.

The low production in 1974 is unexplained and will likely remain so because of insufficient information.

(b) Shrimp fishery off Tofino

Results of the survey by G. B. REED in May 1973 were summarized in last year's report. Several trawlers fished the ground during the summer of 1973, and landed 791,000 lb at Tofino. In 1974, five vessels operated from Tofino and Ucluelet with total landings of 1,500,000-2,000,000 lb. A fleet of about 10 U.S. shrimpers was present on the same ground, which lies mainly outside the 12-mi limit, and took about a million lb.

Fortnightly samples were collected from landings at Tofino during the 1974 season and these will provide information on growth, age composition, and mortality rates. It is expected that these research results will be applied in rational management of the resource, and ensure Canadian fishermen an adequate share of the yield, if an international fishery continues.

INVERTEBRATES

Pacific oyster breeding

N. Bourne and G. D. Heritage

Oyster spatfall forecasts were undertaken for the industry in three locations: Pendrell Sound, Hotham Sound and Ladysmith Harbour. Major emphasis was in Pendrell Sound where a successful commercial oyster spatfall was forecast. Weather conditions were generally cool and wet in the spring and early summer but improved after mid-July to provide favourable conditions for oyster breeding. In Pendrell Sound, mean surface water temperatures of 20 C or higher were recorded from July 24 to September 6, except for a 7-day period, August 20-26 and surface salinities remained above 15‰ throughout the breeding period. Spawning occurred in late July; larvae were first observed on July 26 and large numbers of straight hinge larvae were found on July 29. Light spawning continued into September. Spatfall was first recorded during the 24-hr period, August 13-14; maximum setting occurred August 21-22. Mean spat counts at all eight test stations exceeded 40 spat per piece of Pacific oyster shell cultch; and the maximum count was 298. Counts on commercial cultch averaged close to 20. A total of 300,000 strings of Phillipine oyster cultch and about 75,000 Pacific oyster cultch or equivalent were exposed by four companies.

In Hotham Sound a few Pacific oyster larvae were taken in tows on July 30. A light subcommercial spatfall with a mean of four spat per piece of shell was recorded on experimental cultch. No commercial cultch was exposed here.

Modest numbers of oyster larvae occurred in plankton tows in late July and early August in Ladysmith Harbour, and some isolated spatfall has been reported there. However there were no recordings of spatfall on experimental cultch.

Pendrell Sound studies

N. Bourne and G. D. Heritage

In 1974 a program was initiated to determine if the oyster industry can continue to rely on Pendrell Sound for seed and whether the spatfall forecast can be improved. These studies were undertaken because of anomalies in larval development and settlement patterns in recent years and a complete spatfall failure in 1973. The 1974 program included studies on the physical and chemical oceanographic features of the Sound associated with larval oyster development and distribution. The work involved personnel from our investigation, with others from the Marine Sciences Directorate, Victoria; the Pacific Environmental Institute; and the Fisheries Ecology Section.

Preliminary analysis of this summer's results indicate a minimal loss of Pacific oyster larvae from Pendrell Sound out into Waddington Channel. Local currents within the Sound are much stronger than previously supposed and are probably important factors in larval distribution. The central part of the Sound appears to be much superior to the head of the Sound for spat collecting.

Clam ecology studies

N. Bourne

Clam ecology studies were largely held in abeyance in 1974 while effort was diverted to compiling and preparing results of past work for publication. Screening on all three beaches at Masset indicated that recruitment is below levels found in 1973. Analysis of the Seal Island data is being undertaken in conjunction with personnel at the College of Fisheries, University of Washington.

Clam aquaculture

N. Bourne

Experimental studies to determine the economic feasibility of culturing Manila clams in trays were continued in Barkley Sound and Departure Bay. Results to date have not been particularly encouraging. Although clam growth has been satisfactory, survival has been poor. The type of tray used is not ideal and fouling is a major problem. Trays must be taken out and cleaned at least monthly.

Culture of littleneck or Manila clams may have possibilities but further experiments are needed to determine the densities at which various sizes clams can be held. Work is also needed to determine whether it is better to raise the clams to market size in trays or grow them to a size of about 1 cm and then plant them on leases. The possibility of growing these species in conjunction with oysters and in dykes should be investigated.

Paralytic shellfish poisoning (P.S.P.)

N. Bourne

Levels of P.S.P. remained about the same as in 1973 or dropped slightly but were still high enough to necessitate continued closure of the northern part of the coast and much of the west coast of Vancouver Island to commercial clam digging. Ten samples of water suspected of containing Gonyaulax were brought to the Station for examination, but all were negative. No new outbreaks of P.S.P. were reported but large blooms of Noctiluca were reported and observed in the Strait of Georgia in August.

Mussel culture

D. B. Quayle

Examination of the factors that might lead to the establishment of a system of mussel culture in British Columbia waters was continued. Emphasis is on the blue or bay mussel, (Mytilus edulis) with lesser effort on the sea mussel (Mytilus californianus), a typically open ocean species. At this time it is reasonably certain the culture potential rests with the bay mussel.

Factors being studied are:

1. Seasonal gonad changes.
2. Seasonal larval abundance.
3. Seasonal condition factor (fatness) changes.
4. Seasonal settlement; intertidal and submerged.
5. Growth; intertidal and subtidal.
6. Culture on manila and polypropylene rope using both naturally set and collected spat.

To date the evidence indicates that culture of mussels in commercial quantities of the right size (up to 3 inches in length) and quality is possible for British Columbia waters.

Bivalve depuration and nutrition — F. R. Bernard

Studies to determine the uptake and elimination of faecal bacteria by commercial shellfish were completed, while those concerned with the significance of coliform bacteria in sanitary surveys of shellfish and shellfish growing areas were terminated. Work on the physiology and energetics of oysters was completed and prepared for publication.

Faunistic studies — F. R. Bernard

The program to process and publish material collected in faunistic surveys in coastal British Columbia was continued. A contract was let and a first report prepared on the medusae of the Strait of Georgia. Studies of the systematics and ecology of the eastern Pacific bivalves were continued. A collection of bivalves from the Beaufort Sea is being identified and processed for Oregon State University.

In July, Dr. Bernard was transferred to the Fisheries Ecology Section

HYDROACOUSTICS SUB-PROGRAM

F. H. C. Taylor
and L. W. Barner

The purpose of the Hydroacoustics Program is to provide estimates of the distribution and abundance required in inventoring fish stocks of either demonstrated or potential commercial value; in managing specific species; and, in assessing species interaction in particular regions. Digital integration of echo-sounder signals provides estimates of fish density over any desired distance and for any desired depth stratum and is the most flexible and most accurate of the three available basic acoustic estimation techniques for schooling fish.

Surveys were made in August and October of the distribution and abundance of fish, particularly herring, off the southwest coast of Vancouver Island, and in March of herring spawning in Barkley Sound. In the offshore cruises the digital integrator and associated electronic equipment were taken to sea on the G. B. REED, but on the March cruise space on the A. P. KNIGHT permitted only the tape recording of echo sounder output for later laboratory analysis.

The August and October cruises demonstrated the potential of digital echo integration for the rapid determination of the distribution and relative abundance of fish stocks. An area of 1,700-1,800 sq mi could be surveyed in 13-17 days. Distribution maps showing relative density contours were prepared by the end of the cruise. Estimates of abundance required some extra time because of dependence on determination of area, mean depth, and mean density between the relative density contours. Estimates of actual rather than relative abundance can be obtained provided all electronic equipment including the echo sounder is accurately calibrated, the species encountered are separated, and an estimate of target strength available for each calibration is relatively straightforward. Species identification depends on subjective experience in echogram interpretation and on adequate associated fishing. Our equipment does not permit target strength measurements so we must rely on published estimates.

In August the heaviest concentration of herring was in the La Pérouse-Finger Bank area, mainly on the southeast corner, and due largely to a very dense 3/4-mile-long school. Concentrations off the head of Nitinat Canyon and the Washington coast were each about half as large as the southeast corner concentration. The fourth major concentration, on Swiftsure Bank, was the smallest, a fifth to a quarter the size of the La Pérouse concentration.

In October the total amount of herring was about the same or perhaps a little more than in August, but the relative sizes of the various concentrations were considerably different. The La Pérouse concentration was perhaps half as big as in August. On Swiftsure Bank abundance was about three to four times as great as in August, and the concentration off Nitinat Canyon increased by about 60%. Relatively few herring were found along the 50-fm contour off the Washington coast but a large concentration had appeared on the flats between the 50-fm contour and the Juan de Fuca trench. The decrease in abundance on La Pérouse Bank and the increase on Swiftsure are probably related to the start of the inshore migration. The decrease along the Washington coast may relate to the increase on Swiftsure or to the appearance of the concentration on the flats. There was some indication that the Nitinat Canyon concentration was moving towards the Finger Bank.

In August the major concentration of hake lay in a U around La Pérouse Bank and over the Finger Bank. Smaller concentrations were found north of the Nitinat Canyon and off the Washington coast. In October the concentration off La Pérouse appeared to have broken up and was represented by two small concentrations above and below the Cape Beale Spit and by two large concentrations on the Prairies south of the Finger Bank. Two other large concentrations were found along the Juan de Fuca trench. The change in distribution suggests the hake are beginning to move southward, perhaps following the Juan de Fuca trench.

In August dogfish occurred in most tows south of the Finger Bank and were numerous on the Southwest Corner. South of the Finger Bank they were less numerous. In October dogfish were not as abundant as in August but occurred in small numbers in most tows. The largest catch was 686 lb off Nitinat Canyon. Rockfish, mainly Sebastes flavidus occurred in small quantities in a number of tows and are probably a major contributor to the "unidentified" concentrations. Dogfish and rockfish are likely to be included in some of the concentrations of herring and to a lesser extent of hake.

The survey of herring spawning in Barkley Sound was less successful than the offshore cruises. Large concentrations were found in Imperial Eagle Channel, mainly at the mouth off Effingham Island or towards the head around Baeria Rocks. Schools of herring about to spawn were found in Sechart Channel, Mayne Bay, and along the Toquart Bay-Macoah Pass shore. Part of these schools were in water too shallow for access by A. P. KNIGHT. Surveys were carried out by day and by night. At night, unless it was bright moonlight herring schools rose rapidly and dispersed on the surface shortly after dark and did not reform and descend until dawn. Thus the period for night surveys was limited. In moonlight, schools did not ascend to the surface and formed excellent targets.

The 1974 surveys demonstrated that:

1. Distribution and relative abundance of fish over large areas can be determined rapidly.

2. A towed transducer is essential to limit dependence on perfect weather and so extend operating time, to reduce the effect of ship's noise, and to increase the range of high-frequency sounders.

3. The echo integrator and associated equipment must be taken to sea for an efficient operation. Analysis from tape recordings is feasible but requires two to three times the amount of time. Tape recordings however remain essential to check field results.

4. When estimating spawning herring close to shore equipment should be operated from a small boat capable of following schools into the intertidal region.

5. Net tows to catch and identify the species responsible for different types of echograms must be made frequently. Two vessels, one surveying, the other fishing as directed would be ideal.

6. Most of the error in estimates of abundance stems from the estimates of surface area within contours rather than from estimates of average depth or of intensity. Surface area estimates while affected by planimeter accuracy depend mainly on accuracy of contouring, a highly subjective operation dependent on the spacing of the points contoured, -- often a compromise between the size of area to be surveyed and the time available.

FISHERIES OCEANOGRAPHY

W. P. Wickett

A major part of this year's effort was put into the production of upwelling and transport indices for the Atlantic Ocean, done at the request of the Oceanographic Branch, Ottawa. The 1962 volume is at the printers -- the remainder of the series to date will follow shortly. Arrangements were made with the Director, Meteorological Centre, Dorval to supply input data for the Oceanographic Branch's computer. A small scale daily output can be provided as needed by Atlantic investigators. During secondment to Ottawa, a paper was written showing the application of the indices to annual variations of nutrients in the English Channel. A 7-yr lag between nutrient input to the sub-arctic Atlantic and catches of West Greenland cod that was found in a second study may prove useful to ICNAF.

The output of information was increased. Five talks were given on ecological problems; temperature and fish migration to the annual meeting of the Pacific Trollers Association, Victoria; transport of oxygen in spawning channels to a staff workshop, Parksville; marine climatology to the herring workshop, Nanaimo; changes in the marine climate and fish populations on the C.B.C. network, Vancouver, and to the Oceanographic Branch, Ottawa. An invited paper on mass transport theory and the culture of fish eggs has been prepared for delivery next May.

The Station "P" salinity and temperature time-series are being brought up-to-date under contract.

SALMON ENHANCEMENT, AQUACULTURE AND FISH HEALTH SECTION

L. Margolis

This section includes programs of study to develop and improve methods of increasing salmon production, including sea farming, and to prevent and control disease among cultured and wild fish stocks.

SALMON ENHANCEMENT PROGRAM

This program is divided into three sub-programs dealing with: (1) Incubation systems, (2) Juvenile production systems, and (3) Stock establishment and improvement.

I. SUB-PROGRAM: INCUBATION SYSTEMS

(a) Salmon behaviour studies

C. Groot and C. Turner

1. Sockeye salmon spawning density studies

The effect of density of spawners on social interaction and egg deposition in sockeye salmon was studied in pens in a 100-yd section of Fulton spawning channel No. 1. Nine pens, each measuring 8 × 9 yd were stocked with 40 to 200 spawners at increments of 20. The total number of 1,080 fish were loaded into the pens in 3 days.

Female to male and 4- to 5-year-old ratios in the pens were respectively 3 to 2 and 1 to 1, which are similar to ratios observed in the channel in 1972 and 1973. Instantaneous densities created this year ranged from 3.0 to 0.6 yd^2 per female. Fulton channel No. 1 is usually loaded to densities of 1.1 to 1.2 yd^2 per female.

The nine pens were stocked in random order. Sections of 8-ft-wide netting separated the pens to avoid interactions. Three 20-ft high towers, located at strategic points, were used to make visual, film and video observations of fish in the pens and in three 8 × 9-yd plots in the spawning channel.

Observations were made on the sequence in which areas were occupied, on territory distribution, social interaction, longevity, time of dying, and gamete retention. Analysis of the data has just started. A few pertinent observations and conclusions follow:

- At maximum packing density a nest territory of a single female had a diameter of 1 to 1.3 yd. The total defended area was often as large as 5 yd in diameter. As a result, many females (and males) could not occupy a gravel area and waited in dense groupings at the edge of the pens.

- High spawning density prevented females from depositing eggs from individual spawnings in an upstream sequence. This resulted in super-imposition even within a single redd.

- Wave spawning was evident in high density situations. Territories of weak and dying females were quickly occupied by fish from the peripheral groups. These located open areas by regular excursions over the gravel area. These excursions resulted in extensive disturbances as fish moved through established territories.

- Aggressive interaction increased by 4 to 6 times with doubling of number of females from 60 to 120 per pen.

- Spawning occurred primarily at night. Only four egg depositions were observed during daylight hours among a total spawning of 648 females and 432 males.

- Two to four times more salmon died during the night than during the day.

2. Spawning channel movements

One hundred spawners (50 males and 50 females equally divided over 4- and 5-year-olds) were marked with coloured and numbered Peterson disc tags upon entering Fulton channel No. 1. Information on: time spent between entrance and spawning; defending places selected; mobility; and area fidelity were obtained from daily monitoring of fish positions in the channel. Collections of dead fish gave data on longevity and gamete retention. There is great variation in movement patterns between individuals. Generally males move around more than females.

Six fish tagged with radio transmitters of different frequencies (FM-band) could be followed for 3 to 6 days. Increased battery size will make tags operational for as long as 3 weeks.

Analysis of data is in progress.

3. Reporting of sonic tracking studies

A manuscript on sonic tracking studies in the Skeena estuary has been accepted for publication and a manuscript on similar studies in Babine Lake has been submitted to the J.F.R.B.

Results of sonic tracking of sockeye and chum salmon in Georgia Strait have been analyzed and are almost ready for publication as a Technical Report.

(b) Egg and alevin development — R. Bams and D. Crabtree

Main activities during 1974 were related to three distinct objectives.

1. Field testing was continued of an evaluation, in terms of survival to the adult stage, of the effectiveness of a newly developed hatchery method designed for production of unfed salmon fry. A series of three tests has been carried out on pink salmon native to the Tsolum River, Comox Bay, Vancouver Island. The first two tests from 1968-1970, and 1970-1972 were completed and have been reported, (Bams 1972, 1973a and b, 1974). The third consecutive test on the same stock of pinks was carried out from 1972-1974 and is completed except for analysis and reporting. A first, tentative, appraisal of part of the information obtained showed an unprecedented high return of marked fish (3,541), suggesting that survival in the ocean was unusually high for fish of both treatments (natural and artificial incubation), that a substantial gain in production (from egg to returning adult) was achieved with the artificial propagation method, but that survival from fry to adult was somewhat lower in the hatchery stock than in the naturally propagated stock. The difference in relative rates of return was the highest recorded to date. Whereas the expected proportion of naturally propagated fish was .500, we obtained .546; the difference is significant at $p < .001$. The apparent increase in differences between relative mortality rates of the two treatments in successive generations (1970, 1.5%; 1972, 2.5%; 1974, 9.1%) gives some cause for concern because of a possible lethal factor, associated with the hatchery treatment, expressing itself cumulatively in successive generations. Alternatively, an association may exist between levels of egg-to-fry survivals obtained in the hatchery and subsequent ocean survival.

2. Another field test was completed which evaluated, in terms of survival and return to the natal stream, the effectiveness of a new transplanting method for pink salmon. Two simultaneous transplants were compared one of which consisted of pure donor stock, the other of a "hybrid" utilizing donor-location eggs fertilized with local (hatchery stream) males. This test was carried out from 1971 to 1973 with Tsolum River (males) and Kakweiken River stocks (males and females). Following incubation and release from the Tsolum system, returns among captured adults demonstrated both differences and similarities between the two populations which are of significance in gaining understanding of some of the biological factors associated with rates of return of transplanted stock. A primary publication covering the methodology and results of this work has been submitted to the Board's journal.

3. Work related to the sockeye channels at Babine Lake was begun in two areas: first, a literature survey of recent work related to salmonid incubation and a compilation of available data on spawning channels is in progress; and second, a sampling program to determine egg deposition, egg densities and egg and fry survivals was initiated in nine experimental spawning pens in Fulton channel No. 1. These were used by C. Groot last fall in an experiment utilizing known densities of spawners.

(c) Egg and alevin optimization studies — D. Alderdice and F. Velsen

Marine research activities terminated in July 1974. Reporting on completed marine egg and larval environmental baseline studies of commercial fishes continues. Concurrently, the transition is underway to develop similar work on environmental requirements of salmon eggs and alevins. Activities in 1974 will be summarized under these two headings.

Marine baseline studies on Pacific herring

From November 1973 until July 1974, a collaborative research program was conducted as set up under the Canadian-German Scientific and Technical Exchange Agreement. The major project was conducted in Nanaimo, while analysis of samples continues at the Biologische Anstalt Helgoland, Hamburg. Research inquiry as a German priority centred on the effects of cadmium, as a water pollutant, on egg and larval development. Canadian priority centred on the effects of salinity on egg and larval development.

Twelve research projects were completed, from which the following preliminary evidence is summarized.

Effects of cadmium on egg and larval development. Effects of cadmium were determined on gametes prior to and during fertilization, and on eggs exposed to cadmium during incubation. Data were obtained on rate of development of cadmium-exposed eggs, uptake and distribution within the egg, its effect on strength of the egg capsule, and effects on osmoregulation. Anatomical and behavioural anomalies, and hatching success were documents for cadmium-exposed eggs.

Results indicate that cadmium interferes with calcium utilization during embryonic development. High cadmium concentrations (1-10 ppm) result in otic capsule malformation; the otolith precursors are absent, swimming is disoriented and older larvae are unable to develop normal food-capture behaviour. Cadmium treatment prior to fertilization has little effect on herring sperm, but a significant effect on eggs; the egg chorion appears to be altered, reducing fertilization potential of the eggs.

Bursting pressures of eggs indicate that maximum capsule strength is attained within 50 hr of fertilization, and drops slowly thereafter. Low salinity also reduces the maximum level of bursting pressure achieved (i.e., 150-175 g in 5‰; 1,000-1,500 g in 35‰ S). Cadmium delays development of capsule strength (threshold between 0.1-1.0 ppm), an effect accentuated by lower salinities favourable to egg development. Abnormalities of the gut, heart, otic capsules, fins and vertebral column decrease to a threshold near 0.1 ppm cadmium. Above 1 ppm cadmium, hatching is accelerated (10 days early at 10 ppm, 3 days early at 5 ppm), the larvae emerging prematurely.

Effects of salinity on egg and larval development. These studies completed a continuing investigation of salinity effects on egg and larval viability in Pacific herring. Yolk and perivitelline fluid samples were taken generally at 24-hr intervals from fertilization to hatching in eggs incubated at 5, 5→35, 20, 35→5 and 35‰ at 5 C. The two transfers indicated were made at blastopore closure. The evidence indicates that osmoregulation of yolk and embryonic tissue begins near blastopore closure (4-5 days at 5 C).

At blastopore closure, osmoconcentration of the yolk becomes nearly constant. On the other hand, perivitelline fluid osmoconcentration comes into equilibrium within minutes following a change in external salinity. Approximate osmoconcentrations in the five incubation conditions as ‰ S (as NaCl) were as follows:

Salinity of incubation	Yolk, equivalent	Perivitelline fluid, equivalent
(‰)	(‰)	(‰)
5	10	4
5→35	13	23-28
20	11.5	15-18
35→5	10	5-6
35	13	23-29

These data relate to earlier (1972-73) unreported results of the effect of salinity level on viability of egg and sperm, fertilization potential and optimum salinity for egg development to hatching. All of the data indicate that the least stressful equivalent yolk concentrations lie between 11 and 12‰. It is concluded that optimum salinities for Pacific herring egg development lie between 12 and 18‰ S.

For some time it has been presumed that early larval mortality may be associated with oceanographic conditions which tend to move larvae into higher salinities. Survival of larvae 0 to 9 days after hatching was measured in salinities of 0-50‰. Seventy-two hr median tolerance limits occurred at 2-3 35-45‰ S. The evidence indicates that larval survival is maximal between 5 and 20‰, decreasing substantially above 27‰ S.

Predation on herring larvae. Predatory-prey density relations were investigated between herring larvae and the amphipod Hyperoche medusarum. Juvenile stages of the amphipod were observed to be intensive predators on herring larvae in Departure Bay. The amphipods kill or produce fatal injury of larvae after about 30 sec contact. To our knowledge, this amphipod was not known earlier as a predator on herring larvae.

Reporting of earlier work continues with the following publications in preparation.

1975 Scheduled

Alderdice, D. F. 1976. Some concepts and descriptions of physiological tolerance: rate-temperature curves of poikilotherms as transects of response surfaces. Fry Symposium, September 1974 (submitted November 1974).

Optimization of Spawning Channels

In line with 1974-75 budget proposals, a contract is being finalized with the University of Victoria to examine, by laser interferometry, salmon egg respiration in relation to CO_2, NH_3, NO_2 and NO_3 levels. A 4-month literature review of environmental requirements related to incubation of salmon eggs is scheduled to start in December 1974.

New insights into spawning channel problems and operations were obtained in a recent trip to Babine Lake. Initial program proposals for 1975-76 are being developed on that basis.

II. SUB-PROGRAM: JUVENILE PRODUCTION

(a) Hatchery juvenile production

H. T. Bilton and D. W. Jenkinson

Time of release. In April, May and June of 1973, three groups of coho smolts totalling approximately 39,000 fish, were released into Rosewall Creek. In the fall of 1973, 333 jacks from these releases were recovered in Rosewall Creek. During the summer of 1974 up to late September, 2,775 marked Rosewall coho were recovered in the commercial and sports fisheries. Six hundred and seventy-nine of these originated from the April release, 1,052 from the May release and 1,044 were from the June release. Most (2,393) were recovered from the Georgia Strait area. Three hundred and twenty-eight were recovered from the west coast of Vancouver Island, with 149 of these originating from the May release. The adult returns from these releases into Rosewall Creek are currently being monitored. Final analyses of the results of this experiment will be completed in the coming year.

Accelerated growth studies at Rosewall Creek. During the period February 7, 1974 to May 30, 1974, 14,202 coho fry of Robertson-Big Qualicum rivers origin of the 1973 brood year were reared at a mean temperature of 15 C to a mean weight of approximately 10 g. Ten thousand, six hundred and three were marked by removal of the adipose fin and nose tagged using binary coded magnetic wire tags. These were released into Rosewall Creek on June 10, 1974. In addition, 12,665 normally reared (reared for 14 months at ambient temperatures) coho of the same origin but from the 1972 brood year were also marked, tagged and released into Rosewall Creek on the same date. Recovery of adult coho from these groups will be made in the fisheries and at Rosewall Creek in 1975.

Time and size at release experiment. Currently 150,000 coho fry of Big Qualicum River origin from the 1973 brood year are being reared in six outdoor concrete ponds at the Rosewall Creek hatchery. The water temperatures and food are being manipulated so that two lots of each of three size groups (20 fish/lb, 30 fish/lb, and 40 fish/lb) of smolts will be achieved by April of 1975. These will be marked, tagged and released into Rosewall Creek in April, May and June of 1975.

Accelerated growth studies at the Big Qualicum River hatchery site. Expansion of the accelerated growth studies initiated at Rosewall Creek will be carried out at the Big Qualicum River. The installation of a facility capable of rearing 35,000 juvenile coho at a temperature of 15 C is presently underway and will be completed in the near future.

(b) Stream juvenile production

J. H. Mundie and D. E. Mounce

Much of 1974 was spent completing stream studies. Further analysis was made of samples obtained earlier of aerial insects, utilizable by salmonids, from different types of vegetation along the Chemainus River. Variance in distribution is species specific. Of 526 species caught

throughout the year, the midges, springtails and aphids were most common. Of 118 species of chironomids, the genus Corynoneura predominated at the water surface and its numbers were independent of the type of riparian vegetation. This genus is not the commonest in the streams themselves; the flight behaviour of individual genera must, therefore, determine availability of insects to fish.

Similarly in Kinkade Creek in September, although 96% of aerial insects (78 species) were potential fish foods, the commonest were Collembola, aphids and midges. At any one time a sample of 15 fry was found to contain representatives of most of the available foods. Few additional species were found in additional fish samples. The most available items were adult and pupal chironomids.

Availability of aquatic and aerial foods received further attention in an analysis of a year's surface and sub-surface drift from the Big Qualicum River. Results to date, covering March to June, show four times as many organisms in surface as opposed to sub-surface drift; 90% of the surface drift and 97% of the sub-surface are of aquatic origin. These data have a bearing on the rate of exchange of organisms between gravel and water. This rate determines the amount of foods which might be dislodged from stream substrates to feed fish. This problem was approached by the use of gravel-filled troughs in the Big Qualicum River under conditions of stable flow. The detritus and fauna accumulating in the troughs were collected after 3, 6, 9, 12 and 15 days. The sampling was replicated. These collections have yet to be analysed.

An attempt was made to establish a field technique in which the input of aquatic and aerial organisms to riffles could be transported to coho fry occupying downstream pools. Standard flumes with riffle and pool sections were constructed. Difficulty was experienced, however, in obtaining a sufficiently steep velocity gradient in submerged troughs.

The above findings, and the concepts and findings of the last few years, appertaining to optimization of nursery streams, (reviewed in J. Fish. Res. Board Can. 31, 11) are finding application in an experimental prototype rearing channel. This has been designed to contain both high-velocity food-producing areas, and low-velocity habitat for fry. The channel is 500 m alongside the Big Qualicum River, and construction is being supervised by Fisheries Operations' engineering staff.

III. SUB-PROGRAM: STOCK ESTABLISHMENT AND IMPROVEMENT

Establishment of off-year pink runs

F. C. Withler and
R. B. Morley

Application of new technology to the question of introducing self-sustaining pink salmon runs into the barren cycle of streams having a pronounced "on-off" characteristic, is underway. Previous attempts to establish such runs were based on the transfer of fertilized eggs from donor streams into receiving streams in their off-year, with the expectation that the salmon returning from the plantings would perpetuate themselves and increase in numbers to the point where significant new contributions would accrue to the fisheries. To date the attempts, carried out sporadically over a period of 60 years and based on such expectations, have not resulted in self-sustaining runs.

The opinion has arisen gradually that each salmon stock, through selection, is quite finely attuned to the special conditions which prevail in its particular spawning and rearing area, and that the necessary characteristics are hereditary. This impression was given substance by a test carried out in 1971 by R. A. Bams of this Station wherein he demonstrated that pink salmon returning from donor eggs fertilized by milt from males of the receiving stream returned to that stream much better than did the salmon returning from donor eggs fertilized by males of the donor stream.

Accelerated maturation of pink salmon males

Techniques for transferring the male portion of a pink stock's gene pool from the on- into its off-year have been developed. One method, reported last year in this Report, was derived from work headed by Dr. E. M. Donaldson of the Pacific Environmental Institute and involved injection of pituitary gonadotropins and rearing under conditions leading to rapid growth. The work has shown that fertile, 1-yr-old males large and numerous enough to fertilize the several hundred thousand donor eggs required for a test of effectiveness of the gene-pool transfer can be produced.

Cryogenic sperm storage

Work has also progressed satisfactorily on the other gene transfer technique cryogenic preservation of sperm from on-year males so that it can be used a year later to fertilize eggs from a donor stream in the receiving stream's off-year. Development of the method to the end of 1973 resulted in fertilizations of test pink salmon eggs as great as 44%. Testing of the 1973 sperm, kept in liquid N_2 until the fall of 1974, has shown that 1 year's storage has not reduced its fertilizing ability below that of recently frozen sperm. Refinement of the methods in 1974 has provided fertilization rates as great as 71% and an average of about 60%.

Field tests of gene-pool transfer methods

Selection of a test site for assessing the effectiveness of gene-pool transfer techniques for increasing returns in an off-year was completed in the summer and fall of 1974. Criteria established for the site to be chosen were as follows:

1. The stream should have such a pronounced on-off characteristic that there would be no possibility of confusing the returning planted fish with those of a small resident off-year run.

2. The spawning potential of the stream should be such that, should the test of the technique show that it held a high potential for success in a transplant application, the stream could become the site for application of the technique to develop a run large enough to produce a significant addition to the fisheries.

3. The stream should be as accessible as possible from the laboratory headquarters of the project (Nanaimo) to keep costs and effort minimal.

4. The stream should have its on-year in an even-numbered year, so that collection of the eggs from which to produce the 1-yr-old males and collection of the bank of frozen sperm could be carried out in 1974, with the intention of introducing the test eggs in 1975.

After an intensive search of records of spawning escapements in streams of the Queen Charlotte Islands and the Johnstone Straits regions (where even-numbered on-year runs occur) and ground surveys of northern Vancouver Island streams on both the east and west coasts, the Bear (Amor de Cosmos) River was chosen as the site which best met the criteria outlined. The Bear River is located on the east coast of Vancouver Island approximately 25 mi north of the town of Campbell River and empties into Johnstone Strait. It supports an escapement of pink salmon in even-numbered years of approximately 100,000 pinks and supports a fishery which is somewhat discrete in time and location. According to Fishery Officers' records the river contains virtually no pinks in odd-numbered years. Plans for providing access and for construction of hatchery facilities are being made concurrently with arrangements with appropriate Provincial agencies for water rights and the land and forest alienation necessary for the project.

In preparation for carrying out the test fertilizations of donor eggs in 1974, about 10,000 pink salmon eggs were collected from the 1974 Bear River run. These are being incubated at Nanaimo at an elevated temperature (12 C) to promote rapid development, as a first step in producing an adequate number of precocious males. Also, about 100 live male pinks were brought to the Nanaimo Station to produce the frozen sperm bank needed to test this method of gene transfer. Over 3,000 2-ml portions of treated milt have been stored in liquid N_2. (Tests of effectiveness of the milt so stored have produced an average fertilization rate of 60% under standardized conditions.) As a precaution against the introduction of undesirable disease organisms into the Bear River, the 1974 pink spawning runs to prospective donor streams (Adam, Kakweiken, Glendale, Phillips) were surveyed for bacteriological and viral diseases, for comparison with those already present in the Bear River.

AQUACULTURE PROGRAM

J. R. Brett

The program is divided into two sub-programs: (1) Pilot Fishfarm and (2) Physiology.

(1) The objective of the experimental pilot fishfarm is to produce marketable, pan-size salmon by a process of accelerating growth in a freshwater hatchery followed by culturing in floating fish pens at sea. An annual production target of about 50,000 salmon from 100,000 eggs has been set.

The first full year of operating the sea pens has shown that microbiological problems in the form of disease and gill stress from spiculated marine algae can cause high mortality, particularly in chum salmon. There is a need for a greater number of floating nets to permit expanded diversity in the manipulation and testing of stocks of fish in

the search for the best management procedures. It is therefore proposed to moor additional pens close to the present site, off Brandon Island.

(2) The main objective of the physiology program is to advance the understanding and improve the means of accelerating growth by environmental manipulation. In particular the influence of photoperiod on growth of young salmon and its effect on those transferred to sea water at an unusually early time, is being studied. This research will be facilitated by the recent addition of two new environmental control rooms making a total of five such areas. A further objective is to introduce appropriate recirculation systems into the fishfarm hatchery. This requires studies of nitrogenous excretory rates and the development of means for their detoxification.

PILOT FISHFARM

W. A. Kennedy, C. T. Shoop, and W. Griffioen

During 1974 the marine component of the fishfarm, built in 1973, became operational for the first time. Techniques for using this unique facility to best advantage were worked out and routine methods of operation established.

Although part of the freshwater component of the fishfarm was operational by early 1974, the need to use the facility then delayed completion of the remainder until November. It is now totally operational with banks of trays for egg incubation, troughs for fry, and 7-× 9-foot oval tanks for fingerlings. There is provision for using heated water to accelerate growth at each of the egg, fry and fingerling stages.

Some salmon fingerlings had been acquired in 1973 in order to gain experience in rearing. Rearing of these small stocks continued in 1974, and, after losing all the chum salmon to predators and kidney disease, several hundred each of sockeye and pinks plus some chinook and coho were reared to a weight of 300 g or more, i.e., to a marketable size. They were then killed, dressed and frozen as if for market and used for informal assessments of consumer acceptability. About two-thirds of them were cooked and served to dietitians at the School of Home Economics, UBC. The rest were distributed to selected individuals. All species seemed to be generally acceptable as human food.

Eggs of sockeye, chum and coho salmon procured in 1973 were incubated in other facilities and hatched in late 1973 or early 1974. Approximately 35,000 fry of each species were in the freshwater part of the fishfarm by March 1974. Growth was accelerated by heated water and all were given vaccine orally against Vibrio anguillarum.

The chum salmon were transferred to seapens on May 15. The disease furunculosis was diagnosed on June 13; mortalities from the disease were particularly heavy during the first week of July, and by July 15 less than 1,000 survived. The survivors were moved to a small isolated pen, where mink subsequently killed them.

The sockeye salmon were all transferred to seapens by June 24. Vibriosis appeared on July 7 and caused mortalities at a comparatively low

but sustained rate until October in spite of periodic treatment with terramycin. The causative organism was a hitherto undescribed species of Vibrio. Meanwhile Vibrio anguillarum, against which they had been vaccinated did not appear. In late October there was heavy mortality from Chaetoceros convolutus, a large spiculated phytoplankton which became entangled in gill filaments. By the end of November the number of sockeye on hand had been reduced to about 1,700 averaging 68 g each. Although much of the reduction can be accounted for by attrition from disease, including Chaetoceros, we suspect that many fish escaped either through holes or by squeezing through the mesh, and by jumping out; also that otters may have killed some.

Because our hatchery had not been finished when the coho eggs were taken, it was necessary to have them held to the eyed-egg stage at an outside hatchery, where low water temperature delayed development. Although moved to our facility as soon as eyed, they did not hatch until March. As a result, and in spite of our using heated water to accelerate growth, they were too small to acclimate to sea water by late June. Our experience thereafter tended to confirm reports from others that unless coho are about 15 g by the end of June they cannot be acclimated to sea water until late in the year. Despite our repeated attempts to acclimate the fish there was a cessation of feeding and they did not grow. The stock was held successfully in one-third sea water. In late November approximately 20,000 coho (averaging about 23 g) were transferred to seapens, joining about 3,000 coho (averaging about 12 g) that had grown little since their transfer to seapens in August.

A major objective in operating the pilot fishfarm has been to reveal problems that a commercial fishfarmer would encounter, and to find answers. Progress has been as follows:

1. Disease is the greatest single problem. Vibriosis, furunculosis and kidney disease have caused heavy mortalities. The fact that fish treated orally with a vaccine against Vibrio anguillarum were not attacked by that organism encourages efforts to develop vaccines against other species of Vibrio and against furunculosis.

2. The plankter Chaetoceros convolutus can be a serious cause of mortality.

3. Predation by birds, mink and otter can cause heavy mortality in seapens. Using a suitable dog to patrol the seapen floats seems to control such losses.

4. Sockeye salmon escape through a 1-inch mesh (stretched measure) web of knotless nylon at a considerably larger size than girth measurements would suggest, apparently because of the elasticity of the twine and of the high speed at which young salmon sometimes swim.

5. Netpens should probably be made of a heavier twine than ours. Ours are easily torn.

6. Damage to netpens by predatory fish has not been a problem. Seals frequent the vicintiy of the netpens but have caused no damage.

PHYSIOLOGY

This investigation is broadly based on bioenergetic studies of fish, particularly salmon, and the effects of environmental factors on energy exchange. A major aim is to determine the basis for rearing the fastest growing, healthiest fish for use in freshwater and marine aquaculture.

1. Sockeye growth in relation to fish size and ration

J. R. Brett and
J. E. Shelbourn

The interrelation of the two limiting factors, size and ration, on the specific growth rate of sockeye salmon at 15 C was studied. The change in specific growth rate was determined by feeding a series of restricted rations (12, 10, 8, 4, 6, 2 and 1% of dry body weight/day) and one unrestricted ration to sockeye fry (2 g) and sampling them at biweekly intervals for 31 weeks. On excess ration the growth rate fell steadily from 3.6%/day to 0.9%/day, at a terminal weight of 54 g. The corresponding feeding rate decreased from 13.1%/day to 5.1%/day. The relation between size and maximum growth rate can be described by the equation: $\log G = 0.650 - 0.416 \log W$, where G is growth rate (% wt/day) and W is weight (grams). On any restricted ration the growth rate was found to remain constant, below the maximum, until size became the overriding factor, at which point growth rate diminished in accordance with the relation for excess ration.

Two other salmonids (pink salmon and brook trout) show a similar rate of change of growth rate with size (α -0.4 log W). Species, and possibly races of salmonids, appear to be distinguished more by the magnitude of the intercept than the slope of the equation.

2. Dogfish bioenergetics

J. R. Brett and
J. M. Blackburn

The metabolic rate of dogfish was determined in both a tunnel respirometer and a large, covered, circular tank. Swimming performance was very poor in the respirometer, so that a power-performance curve could not be established. Instead, resting or standard metabolic rates were determined; higher rates were induced by causing heavy thrashing (active metabolism). Routine metabolic rates were measured for the spontaneous activity characterizing the behaviour in the circular tank. This irregular, slow cruising was similar to the sort of behaviour of captive dogfish observed in a net enclosure.

At 10 C, for dogfish of 2 kg mean weight, the respective metabolic rates were: 32 (standard), 49 (routine), and 88 (active) mg O_2/kg/hr. Assuming that the routine rate represents a general energy expenditure in nature, this is equivalent to metabolizing about 4 kcal/kg/day. It would require 5 g of fish/kg dogfish/day to meet this expenditure. In terms of a year a 1 kg dogfish would consume twice its original body weight, i.e. about 2 kg (assuming 80% utilization of diet).

At a growth rate of 0.1%/day, assuming a food conversion rate of 12%, and allowing for a 25% increase in activity for capturing prey, the annual requirement per kg dogfish would be 5 kg food.

3. Early growth of chum salmon — J. E. Shelbourn

Chum salmon fry (O. keta) were raised under experimental conditions similar to those for sockeye fry, reported previously. Initial mean wet weights were approximately 0.4 g, and the greatest final weight was 3.0 g after 36 days' growth. The fry were all fed excess O.M.P. diet, and were cultured at 5, 10 and 15 C in fresh water and at 15 C in 28‰ sea water. The growth rates obtained were expressed as specific growth rate ($\%\Delta \ell n_e$/day) and are as follows: 1.7 ± .1% (5 C), 4.2 ± .6% (10 C), 5.7 ± .5% (15 C), and 5.9 ± .7% (15 C-sea water).

4. Multifactor effects of photoperiod, temperature and salinity on chum and sockeye fry growth rates — J. E. Shelbourn and T. R. Mayes

A preliminary examination of growth-rate rank order indicates that growth is better in dilute rather than full-strength sea water at both temperature levels chosen (10 and 15 C) for both chum and sockeye fry. It also indicates a higher growth rate of chums in a lower photoperiod (12 h) than a higher one (18 h), with the reverse being true for sockeye -- both cases independent of temperature.

5. Test of different diets on sockeye salmon — J. E. Shelbourn and T. R. Mayes

Sockeye salmon fingerlings (O. nerka) averaging 20 g were obtained from the pens of the experimental fishfarm to test the effectiveness of locally produced diets against the imported O.M.P. normally used. Soon afterward they were found to be infected with Vibrio so all diets were medicated with terramycin. All tests were in salt water (28‰) at 15 C. Fish were fed excess food thrice daily for 21 days. Specific daily growth rates from the initial to final weights (means of replicated pairs of tanks) were as follows: O.M.P. (imported), 1.8%; O.M.P. (produced locally by T. D. D. Groves), 1.7%; Dry Pellets (Groves' own diet), 1.8%; Dry Pellets (Groves) wetted before feeding, 1.5%.

6. Salinity adaptation of juvenile salmon — W. C. Clarke

Accelerated stocks should be transferred to the sea when they are physiologically ready if rapid growth is to be sustained. In the pilot fishfarm coho transferred at an inappropriate time lost their appetite and stopped growing.

Laboratory experiments were conducted to study the process of adaptation to sea water with a view to developing a measure of the readiness of young salmon to enter the sea. Underyearling coho (7-16 g) exposed abruptly to sea water showed increasing plasma sodium concentrations during the first 15 hr. This was followed by a period of recovery and after 1 week the plasma sodium level returned to a level only slightly higher than that in fish adapted to fresh water. In subsequent tests, the sampling time was standardized at 24 hr after exposure to sea water. Higher plasma sodium levels (i.e., lesser regulatory ability) were observed in 8-8.5 cm coho than in 9-11 cm ones. Further experiments are planned and will include a wider range of fish sizes and water temperatures.

FISH HEALTH PROGRAM

This Station is the Pacific Region responsibility center for fish health research and diagnostic services.

The Fish Health Program has three sub-programs -- Microbiology, Parasitology, and Diagnostics/Consultation, which together are designed to identify, characterize, and map the occurrence in the Pacific Region of the main infectious (including parasitic) diseases of fish, particularly salmonids, and to develop and apply means for their prevention, control and eradication in cultured and wild stocks. The Diagnostics/Consultation sub-program, as the name implies, provides information, advice, and diagnostic services relating to matters of fish health to Fisheries Management personnel, to other government agencies, and to the private sector. Most of the work within the program is related to health problems in cultured salmonids in enhancement and aquaculture facilities such as the routine monitoring of the health of salmonids reared in Fisheries Operations enhancement facilities and in the Station's pilot fishfarm.

In addition to the three sub-programs, the Station's histology service for all staff is included in the Fish Health Program.

Apart from involvement in regional fish health matters, program staff have been heavily committed to activities associated with the development of new national Fish Health Protection Regulations.

SUB-PROGRAM: MICROBIOLOGY (RESEARCH)

1. Gross anatomy of salmon — G. R. Bell

A manuscript on the structural and functional anatomy of Pacific salmon to be used as a guide for fisheries biologists has been completed and will be submitted for publication.

2. Environmental factors on disease induction — G. R. Bell

Because a substantial portion of the mortalities of pen-reared sockeye salmon in Departure Bay appeared associated with blooms of certain marine algae, experiments were conducted to clarify the phenomenon. Exposure of sockeye and coho juveniles to heavy concentrations of plankton harvested from Departure Bay containing 1.27×10^6 cells/litre of the barbed siliceous alga Chaetoceros convolutus resulted in their rapid death. As with the mortalities of pen-reared fish the gills were coated with masses of barbed algae and gill damage was evident microscopically. Physical damage rather than chemical toxicity is most likely the cause of death because crude preparations of cell-free barbs or setae could also kill fish, and because cell-free extracts of ruptured plankton were not toxic. A short manuscript has been prepared for publication with W. Griffioen and O. Kennedy.

3. Consultation — G. R. Bell, G. Hoskins and T. P. T. Evelyn

Consultation and the dissemination of information relevant to fish health are still considered vital aspects of the "research" program. In this regard G. Bell organized and chaired the 15th Annual Western Fish Disease Conference at Nanaimo and was assisted by all members of the microbiology group. Assistance was also given to individuals and groups on aspects of the prevention, diagnosis and control of fish diseases in addition to helping set up a disease control committee at the Station.

4. Committees on fish disease control

a) National and international — T. P. T. Evelyn

Service on Federal and U.S.A. committees continues and the results of this work are given below under items 7a and d.

b) Provincial — G. Bell

Work is continuing on defining the responsibilities and concerns of the "Interagency Committee on Fish Transplants and Introductions," and on devising the most efficient method of communication between fisheries workers and the Committee.

5. Oral immunization - field application — T. P. T. Evelyn and J. Ketcheson

Methods were developed for growing and harvesting large quantities of Vibrio anguillarum (the long-recognized causative agent of vibriosis) and for uniformly applying formalin-killed cells of the organism to fish feed. Sufficient of this vaccine was produced (just over a kilogram) to allow 10-day feedings of all Aquaculture stocks prior to their stocking in Departure Bay. For practical reasons, unvaccinated controls were not included in the aquacultural program, and so a clear assessment of the value of the oral vaccine was not possible. It appears, however, that the vaccine may have been of some benefit because, in contrast to last year's experience with unvaccinated Aquaculture stocks, no problems due to V. anguillarum arose in this year's vaccinated stocks even though the pathogen was apparently present (V. anguillarum was diagnosed in unvaccinated seawater-held stocks at least once at the Pacific Biological Station and several times at the Pacific Environment Institute.)

6. A "new" vibrio fish pathogen — T. P. T. Evelyn and G. Hoskins

During the past year a new form of vibrio disease was recognized in stocks of fish held in sea water at Nanaimo and P.E.I. Strains of the responsible vibrio differed culturally and biochemically from V. anguillarum and may constitute a new species. Because the "new" vibrio occurred in sockeye that had been vaccinated orally against V. anguillarum the new strain was compared serologically with the V. anguillarum strains in our culture collection and found to be quite distinct (it possessed little, if any, antigen in common with V. anguillarum). This finding suggests that

it may be advisable to use a vaccine prepared from both vibrios for fish destined for mariculture.

7. Reports and manuscripts — T. P. T. Evelyn

a) Miscellaneous Special Publication 23 on "Methods for the detection of certain pathogens of salmonid fishes," co-authored with four other F.M.S. personnel, was completed and published.

b) A report was prepared, summarizing the findings of a microbial fish pathogen survey conducted in the Yukon in the summer of 1973. The report, modified and combined with the results of a parasitological survey conducted by other Fish Health Program personnel, is contained under the title "Report on Investigations carried out by Pacific Biological Station Fish Health Program Personnel in the Yukon Territory in 1973" in the document entitled "The Aishihik Hydroelectric Development: Implications for the Fisheries Resource Maintenance," published by the F.M.S., Northern Operations Branch, Pacific Region in October, 1974.

c) A manuscript, co-authored with L. Margolis, entitled "Ceratomyxa shasta in chum salmon (Oncorhynchus keta) in British Columbia," was completed. The manuscript is intended for publication as a "Note" in the J. Fish. Res. Board Can.

d) A manuscript, "Methods for the diagnosis of certain bacterial fish diseases," was prepared with considerable input and advice from other fish disease specialists, for inclusion in a larger work on the diagnosis of fish diseases. The work was sponsored by the Fish Health Section of the American Fisheries Society and plans call for its publication by the U.S. Fish and Wildlife Service in early 1975.

SUB-PROGRAM: MICROBIOLOGY (DIAGNOSTIC/CONSULTATION SERVICE)

G. E. Hoskins

This service hitherto carried out by Bell, Evelyn, Hoskins and Ketcheson in addition to their research work, began officially on May 9, 1974 and has already processed 104 cases, ranging from examination of individual fish to many adults in a run (see Table I). The results and associated consultations have been of considerable benefit to enhancement and aquaculture programs. A complete system for blood analysis as well as microbial and viral diagnostics is being set up and tested so that the health of stocks can be monitored and preventive measures taken against incipient disease.

Some adult migrants used to stock the Capilano, Quinsam and Robertson Creek hatcheries were found to be infected with kidney disease bacteria, Myxidium species, and A. salmonicida (furunculosis), respectively. Significantly, some chinook adults from the Stamp River that were used as a source of eggs for the Robertson Creek hatchery were found to carry an infectious haematopoietic necrosis (IHN)-like virus in their kidneys. The implications of this finding are not clear but it is likely that juvenile chinook and sockeye stocks cultured in this watershed will sooner or later experience epizootics due to IHN.

Disease mapping now in progress will ensure necessary background for the development and operation of enhancement programs. This mapping shows a rather widespread distribution of bacterial kidney disease and furunculosis, even in apparently untouched streams. New concepts of the natural history and distribution of disease agents are gradually emerging.

SUB-PROGRAM: MICROBIOLOGY (HISTOLOGY SERVICE)

Some 270 submissions have been processed ranging from single to several hundred samples. For the most part these require routine processing only, but others required special adaptations of existing methods to show clearly bacteria, protozoa or fungi, for example, in tissues. Many photomicrographs of normal and diseased tissues have been taken for immediate use or for future reference within the histology service.

SUB-PROGRAM: PARASITOLOGY — Z. Kabata

The work of this sub-program included several projects associated with parasitic diseases of fishes and parasites in marketable fish products. In addition to their research projects, staff were involved in service work concerned with diagnosis of, and consultation on, parasites and parasitic diseases of aquatic animals.

The progress of individual projects during the course of 1974 was as follows:

1. Yukon freshwater fish parasite survey — R. Arthur and L. Margolis

This project, conducted by request of the Northern Operations Branch of the Fisheries and Marine Service, Pacific Region, was prompted by a proposed hydroelectric development scheme involving diversion of Lake Stevens (Yukon drainage) into Lake Aishihik (Alsek drainage). The project is now in its closing stages.

Forty-six species of parasites were found in fish in Aishihik Lake; exactly half of that number were found in fish in Stevens Lake. Among parasites present in Aishihik but not in Stevens several are potentially dangerous: Henneguya zschokkei, Hexamita salmonis, Myxosoma sp., Neoechinorhynchus rutili and Discocotyle sagittata. Only one dangerous parasite was found in Stevens but not in Aishihik. It was a tapeworm, Triaenophorus nodulosus. The dangerous potential of Discocotyle sagittata was demonstrated by heavy infection of humpback whitefish in Aishihik causing extreme anaemia and emaciation.

Conclusions and recommendations were submitted to the Northern Operations Branch and appeared in their overall report as Appendix G. The recommendations were:

(1) that barriers should be erected preventing fish migration from either lake into the other;

(2) that pike excreta (carrying with them infective stage of Triaenophorus) should be prevented from reaching Lake Aishihik; this could only be achieved by eliminating pike from Lake Stevens and adjacent waters.

These recommendations were accepted as reasonable and practicable. The need for their implementation disappeared, however, when the decision to link the two lakes was abandoned. It is expected that this project will be wound up by the end of the current fiscal year.

2. Parasites on pollock flesh — L. Margolis and T. E. McDonald

All data on prevalence of parasites (larval nematodes of the genera Anisakis and Terranova, and a larval pseudophyllidean tapeworm) in the flesh of this fish have now been summarized and are ready for final analysis and reporting.

3. Investigation of parasitic disease status of acquacultured salmon — L. Margolis and T. E. McDonald

Beginning in May, monthly samples (15 specimens each) of chum, coho and sockeye salmon were collected from aquaculture ponds and examined for appearance of parasites. None were detected until early August, when larval stages of a copepod, Caligus clemensi, began to appear, accompanied by occasional larvae of Lepeophtheirus salmonis, a related copepod. Infection with C. clemensi continued to build up, reaching 100% incidence by October in coho and sockeye (chum stock was terminated). During October a flagellate protozoan, Cryptobia sp., appeared on the gills of about 80% of examined fish. No endoparasites were found and no natural food objects in the intestinal tracts. The pathogenic importance of Cryptobia is not clear. The copepods, on the other hand, can become a serious problem and even a threat to the success of aquaculture. (Salmoniculture along the coasts of Norway has been very adversely affected by Lepeophtheirus salmonis and potential effects of C. clemensi are not likely to be much milder.) Results of monitoring suggest the necessity of a research program aimed at development of measures to control copepod infections.

4. The tapeworm Eubothrium salvelini and its effect on juvenile sockeye salmon production in Babine Lake and Great Central Lake — N. Boyce and D. Whitaker

Improved techniques were developed for reproducing E. salvelini infection in the laboratory, so that it is now possible to infect large numbers of fry with required worm loads. Sockeye fry infected with various numbers of worms were kept under laboratory conditions identical with those under which control fry were maintained, to observe the effects of infection. The infected fish grow more slowly, but stamina tunnel test at 165 days post-infection showed no significant differences between experimental and control fry.

Preliminary tests on three anthelminthics were inconclusive. Improved methods of administering them to fish are being explored.

Chum salmon fry were successfully infected experimentally, suggesting that E. salvelini under favourable conditions is capable of infecting a wider range of salmonid hosts than hitherto suspected.

Electron microscopy studies of the absorptive surfaces of E. salvelini revealed new structures of unknown function. Examination of these structures will continue.

5. Parasitic copepods of fishes, with emphasis on Salmincola californiensis, a parasite of the Pacific salmon

Z. Kabata and B. Cousens

Search continued for a substance capable of killing adult S. californiensis. It was hampered by an almost complete destruction of infected experimental fish stock in June, caused by disruption of the water supply. For the first time, a substance (a proprietary organophosphate) was found, capable of killing adult females in vitro, when added to water in proportion 200 ppm. This substance, however, is highly labile in water and not easy to administer. Experiments are in progress aimed at finding suitable dosages for external application and administration of this substance as a food additive.

Further experiments on the host recognition by Caligus clemensi confirmed suspicions that the recently discovered sense organ plays some part in this process.

A small amount of time was devoted to development of techniques for rearing parasitic copepods in vitro, in an attempt to secure experimental material. Six species were successfully hatched, two of them having been reared to the infective stage.

F I S H E R I E S E C O L O G Y S E C T I O N

C. D. McAllister

Includes programs to provide fisheries information essential to management, particularly with respect to various developments which pose a threat to important fishery resource habitats.

STRAIT OF GEORGIA PROGRAM

M. C. Healey

Introduction

Activities under the Strait of Georgia Program were initiated as originally recommended. In addition, significant time was directed to development of detailed specifications for two 40-ft fishing vessels and a high-speed shallow draft vessel, under the FMS vessel replacement program. Ministerial requirements for machine processing of estuarine fisheries data for Task Force purposes continued. Considerable effort was expended in establishing satisfactory contractual arrangements for sample analysis. These activities affected work planned for 1974 but will provide direct and indirect benefits in ensuing years of the Program.

With the secondment of Dr. R. Beamish to the Strait of Georgia Program more work was carried out in the pelagic area of the Strait than was originally anticipated. Dr. M. C. Healey joined the Program in October 1974 and in November accepted the role of Program Head. Dr. F. Bernard, to have participated in nearshore and estuarine work, was temporarily seconded to the Environmental Protection Service, Ottawa. However, before his departure a final draft of a brochure on fauna of the proposed Gulf Island Marine Park was completed and is in process of graphic design and publication.

General outline

Georgia Strait may be viewed as an open system, producing or contributing to the production of a wide variety of organisms, some of which are harvested by man. The Strait is heterogeneous both physically and biologically. Possible areas of research are virtually limitless yet funds and manpower are limited. The immediate problems of management require research that will quickly produce new knowledge which can be translated into management practice. Yet our research should not be parochial but should contribute to better understanding of biological principles.

A conceptual model of processes within the Strait was developed which defined possible goals and important parameters and provided a framework for a cooperative approach. The model considers Georgia Strait as a resource-producing system and defines processes which influence the production of particular resources. In discussing problems it was convenient to divide the Strait into recognizable subunits and examine processes within these subunits. Three recognizable subunits are estuaries, nearshore and open

water pelagic. Considering salmon as a resource in which man is interested we may state that salmon enter estuaries as juveniles from freshwater spawning and nursery areas, actively distribute themselves throughout estuarine nearshore and pelagic habitats of the Strait, abandon the Strait for the open ocean or adjacent nursery areas (e.g. Puget Sound, Johnstone Strait), and return to the Strait at some later date passing through the pelagic, nearshore and estuaries on their way to freshwater spawning grounds. Viewed in this way Georgia Strait becomes a resource which is utilized by salmon for part of their life and we may ask questions about how the salmon utilize the straits such as: How are salmon of various sizes and ages distributed among the various habitats of the Strait at different times of year? What determines the numbers or biomass of salmon in a particular habitat? How much total production, mortality, etc. is associated with particular habitats? The life history of the salmon in relation to the straits is diagrammed in Fig. 1. We wish to emphasize that the subunits estuary, nearshore and pelagic are simply conveniences and do not represent homogeneous or isolated habitats. The system is a dynamic one and exchanges between subunits are as important as processes within the subunits themselves.

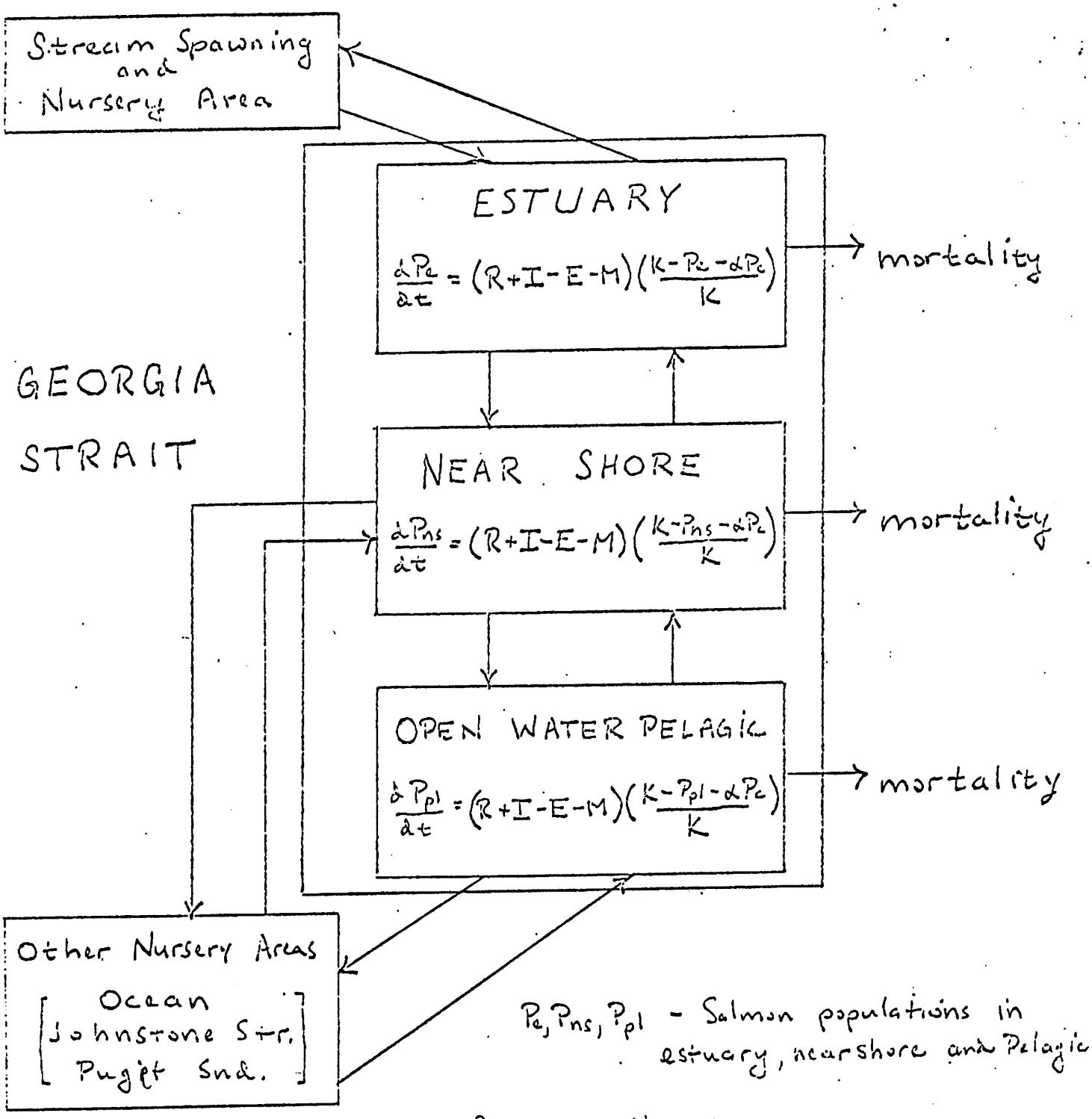
Looking within any subunit one may define the dynamics of the salmon population by analogy to some simple growth model -- say the logistic. Population processes within the estuary subunit are described in Fig. 2. Changes in the number of salmon in the estuary are defined as a function of six parameters: recruitment from stream nursery areas, immigration from nearshore, emigration, death, competition and the carrying capacity of the estuary. Each of these parameters is further recognized to be a function of other variables. Immigration from the nearshore, for example, is probably a function of the estuary population, the nearshore population, growth and time. Mortality is probably a function of the population of predators, diseased vectors, growth and time. Analogous equations defining changes in numbers within each of the other subunits of Georgia Strait may be written. In this way we define important variables which determine the distribution and abundance of salmon in Georgia Strait, both in terms of features of the salmon itself (changes in behaviour related to season, size, age) and its interactions with the environment (predators, disease, competitors, food supply, various physical parameters).

Although the equations are written in terms of numbers they could equally well be written in terms of production or biomass. For example, in biomass terms the differential might be rewritten:

$$\frac{dB}{dt} = (G + I - E - D)\left(\frac{K - B - BC}{K}\right)$$

when B is salmon biomass
G is growth
I is immigrant biomass
E is emigrant biomass
K is carrying capacity in biomass units
C is competitor biomass

outlining exchanges between habitats and Processes within Habitats.

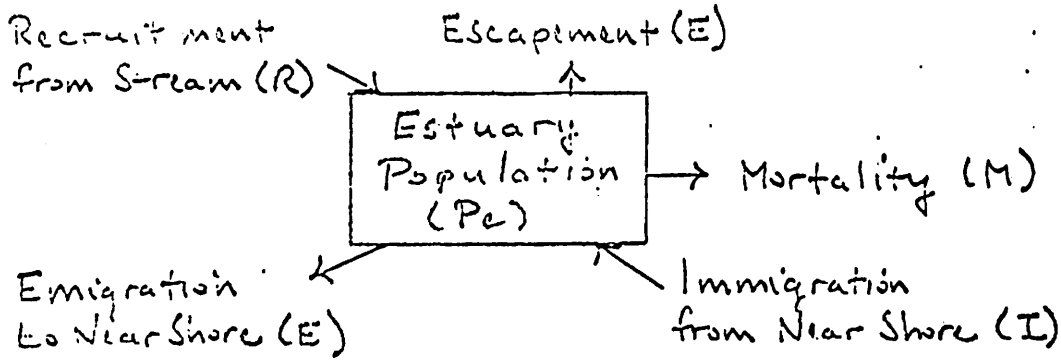


P_e, P_{ns}, P_{pl} - Salmon populations in estuary, nearshore and Pelagic

R - recruitment
I - Immigration
E - Emmigration
M - Mortality
P_c - Competitor population
K - Carrying Capacity

} For each habitat

Figure 2. Dynamics of the salmon population in estuaries. With definition of some of the important variables.



$$\frac{dP_e}{dt} = (R + I - E - M)\left(K - \frac{P_e - \alpha P_e}{K}\right)$$

$$\begin{aligned} R &= f(t, w, P_{st}) \\ I &= f(P_{ns}, P_e, G, t) \\ E &= f(P_{ns}, P_e, G, t) \\ M &= f(P_p, P_d, G) \\ K &= f(F, S). \end{aligned}$$

The 6 variables in the differential are themselves functions of other variables

t = time
w = weather
P_{st} = Stream parameters
G = growth
F = food supply
S = space
P_p = Predator population
P_d = Population of disease vectors

Furthermore, although the example used is the salmon, the model is adaptable to any species. One simply views the Strait as a resource that is exploited by the species.

This is the basic framework within which we have planned our research. However, there are still too many parameters and some selection had to be made of those which we could measure. We, therefore, decided that our main thrust should be on salmon species and how they utilize the Strait and that we would formulate the following hypothesis:

$$\frac{dN}{dt} \propto \frac{d\bar{B}}{dt} \propto \text{Food supply}$$

That is, changes in the abundance of salmon are proportional to changes in mean biomass which in turn is proportional to food supply. The reasons for choosing this type of formulation are largely pragmatic. We can probably measure these parameters and they relate directly to important management questions. In addition we include a subproject on food competition between salmon and other fish species. This relates directly to the original formulation of the model and utilizes sampling programs designed to assess dN/dt and $d\bar{B}/dt$. A third subproject studies the distribution and abundance of hake and pollock. This subproject is not intimately related to the previous two. It represents a response to industry requests for information. However, sampling programs are integrated as much as possible to make most efficient use of manpower and vessels. Studies of hake and pollock do not contradict the philosophy of a unified approach to studies of the Strait since they fit readily into our generalized view of the Strait as a resource-producing system.

Estuary resource ecology 1974

J. Sibert

Nanaimo estuary

In collaboration with Dr. R. J. LeBrasseur, catch and stomach contents analyses were completed for fall, winter and spring fishing in Departure Bay and a study was begun of the stomach contents of fish caught in a variety of nearshore environments in the Strait of Georgia. This work is still in its initial stages and will near completion in March 1975.

Catch and stomach contents analyses were completed for early spring fish populations on the Nanaimo flats and in the mouth of the Nanaimo River. A pilot study was conducted to determine the feasibility of recovering marked juvenile salmon in an estuary in which 13,000 marked fish were released in the river. During the period June 25 to September 4, 1974, 120 marked chinook salmon smolts were caught in the Nanaimo estuary. A report on the experiment is in preparation. Several laboratory experiments were conducted to test the suitability of fluorescent pigment impregnation marks for marking juvenile salmon in estuaries. Initial mortality was found to be approximately 5% and the marks were retained for longer than 6 weeks.

Primary and heterotrophic production were estimated in the water column and on the intertidal sediments. Preliminary interpretations suggest that approximately 10 times the annual primary production of carbon is

recycled by heterotrophic activity suggesting an unknown allochthonous source of primary production. In collaboration with Dr. R. Foreman of U.B.C. two transects of the flats were made in each of the spring, summer and fall seasons to determine the character and change in biomass of the intertidal macroalgae. A week-long study of the surface currents of the Nanaimo estuary was carried out in late June and preliminary indications are that the information gained will prove helpful in the interpretation of fish distributions.

Alberni Inlet

Analysis of 1973 zooplankton collections were completed and reports on horizontal and vertical distribution of zooplankton in stratified inlets are in preparation. Two manuscripts on the importance of heterotrophic activity in Alberni Inlet were completed and are in press.

Environmental impact statements

Laboratory procedures and computer programs for use in the preparation of environmental impact statements were finalized. A full description of these procedures is in preparation. Data analyses were completed for Nanaimo River estuary, Campbell River estuary and Fraser River estuary (including Roberts Bank and Sturgeon Banks) environmental impact reports. A preliminary analysis was done for a Cowichan Bay report.

Development of new equipment

Design and selection of a high-speed shallow-draft vessel for use in estuaries was begun and is nearing completion. The possibility of a semi-automated system for measuring small fish was investigated. It was concluded that such a system would be practical and well used but that the cost of outside development and construction was prohibitive.

Nearshore resource ecology

R. J. LeBrasseur

A variety of fishing methods were employed in nearshore areas along the east coast of Vancouver Island. It was apparent that different pelagic species occupy the nearshore region for varying periods. For example, juvenile chum and pink salmon and larval herring were caught together during May and early June. These left the nearshore areas by July, and were largely replaced by perch and shiners. Adult and juvenile herring, stickleback and sandlance tended to be caught in areas close to deep water, i.e. off rocky bluffs as compared to shallow bays.

Currently these fish samples are being processed under a contract which terminates in March 1975, to assess species and stomach contents.

Calibration and testing of zooplankton sampling equipment and methods is continuing with the expectation that the work will be sufficiently advanced to mount a realistic field program in conjunction with the fishing in Strait of Georgia next spring.

Fishing and biological monitoring has continued at Ocean Station P. Currently these and earlier Strait of Georgia zooplankton data are being edited for errors and continuity.

Investigations on salmon-herring interactions continued as part of the thesis work of an SFU student. This past summer experience was gained in laboratory feeding experiments and handling the fish. The difficulties in obtaining reliable supplies of fresh plankton negated most of the growth and interraction studies. With respect to the latter experiments with juvenile herring and salmon, at low densities of small zooplankton, the salmon stopped feeding on plankton and started taking the herring, even though both species of fish were comparable in size.

Development of experimental methods for assessment of feeding relationships of larval fishes was initiated by Dr. R. J. Naiman, post-doctoral fellow. The work is intended to provide links between field observations of food availability, fish diets and survival.

Work on characterization of nearshore habitats and communities in certain areas of the Strait was supported by a contract with the University of British Columbia.

Pelagic resource ecology — R. J. Beamish

A project to study the pelagic fishes in the Strait of Georgia commenced in August 1974. It was of immediate interest to examine the distribution of salmon in the Strait and initiate a study of the population dynamics of Pacific hake and pollock. As of November 1974 four cruises on the A. P. KNIGHT have been completed; 67 bottom hauls were made among the Gulf Islands and as far north as Kahashan Pt.; and 50 purse-seine hauls were completed among the Gulf Islands and across the Strait. Since all personnel were new to this project, these cruises also served to familiarize everyone with the handling of gear and sampling of fishes. Currently, monthly sampling trips are being conducted to monitor hake and pollock stocks, provide ovary samples for studies of the market value of roe and obtain samples to determine the feasibility of the automatic sexing of hake and pollock. From January to March 1975 attempts will be made to estimate the biomass of hake and pollock stocks in the Strait of Georgia.

At present no firm conclusions have been drawn from the data. However, for the purposes of this report the data have been summarized but it is stressed that interpretations may change as more information is collected. Hake in Georgia Strait appear to grow rapidly but do not achieve the older ages or large sizes characteristic of offshore populations. They move from deep basins after spawning in the spring to midwater depths over the slope area. Here they actively feed on euphausiids and lesser amounts of fish. During the day some hake are found at all depths but the largest concentrations occur in dense schools at depths of 70 to 110 m. Young-of-the-year hake occupy the deeper waters below 90 m during the day and do not appear to concentrate in schools. Young hake were also found in the deeper basins in the northern area of the Gulf Islands. Adult hake in this area were larger than adults in the open Strait. These growth differences may

result from different diets as well as from an isolation of this stock from the main population in the open Strait. In November hake appear to leave the inshore areas and return to the deeper basins. Movement coincides with the onset of ovarian maturation.

Pollock catches were small suggesting that during the summer months pollock were not associated with hake in the southwest sector of the Strait. Pollock also were fast growing but were smaller and younger than pollock resident in areas in the North Pacific. In contrast to hake, young-of-the-year pollock were abundant in all nearshore areas. In general there appeared to be a separation of stocks of both young and adult hake and pollock in the Strait during the summer.

All species of salmon were captured during the purse-seining operation. Coho and chinook in their first saltwater year were most abundant followed by pinks and chums. Larger catches of chinook were obtained among the islands while coho predominated in the open Strait but close to the islands. In some areas catches were remarkably similar suggesting homogeneous distributions. The largest catches of salmon occurred close to shore on both sides of the Strait. Very few salmon were captured in the middle of the Strait. River lamprey were common in most hauls and young dogfish were captured in the open surface waters.

As part of this study, methods of age determination of hake, pollock and lingcod were examined. Otoliths seemed satisfactory for age determinations of hake. When scales can be found they are useful for the confirmation of otolith "ages." Scales and pectoral finrays were the most suitable structures for age determinations of pollock. Length frequencies appear useful for assigning ages to young hake and pollock. It was found that lingcod could readily be aged from transverse sections from the first six rays of the second or soft dorsal fin. Ages obtained by this method were consistently greater than ages obtained from scales for the larger individuals. Comparison of the elapses of growth curves of commercial catches produced using scale-age and fin-age methods indicated that significant differences occur for the larger individuals. It remains to demonstrate the marks counted as annuli on fin-ray sections are indeed produced each year.

Larval and juvenile fish

W. E. Barraclough and
D. G. Robinson

A preliminary analysis of the growth of juvenile salmon and other species of fish was determined from the many Data Reports issued from 1966 to 1969 on previous studies in the Strait of Georgia.

In each of the 4 yr, chum salmon caught leaving the mouth of the Fraser River weighed 0.35 g and reached a weight of 20 g 4 months later in the Active Pass area near shore. Pink salmon which weighed 0.2 g as they left the Fraser River, attained a weight of 15 g by July in the inshore waters near Active Pass. Little change in growth could be determined for sockeye salmon, suggesting a rapid exit of the stocks from the near-surface waters of the Strait of Georgia. Data indicates that these salmon caught in Saanich Inlet appear to be migrating through the Inlet in their movement seaward. The size composition follows the same change in size distribution of sockeye

salmon leaving a lake: the largest appeared first, followed by large numbers of smaller fish, then an increase in size as the season progressed.

Food studies of all juveniles and larval fish in particular in the near-surface waters of the Strait of Georgia show, in general, a specific size preference for food at different stages in their growth. As one example only, pollock (Theragra chalcogrammus) at 5 mm long fed exclusively on copepod nauplii less than 0.5 mm; at 12-14 mm long no nauplii were found in their stomachs, only small copepods; at 22 mm about 60% of their food consisted of large copepods.

Literature compilation

B. McGinnis and H. Godfrey

The preliminary annotated computerized Strait of Georgia fisheries bibliography with about 1,400 references, has been completed and is ready for publication.

EFFECTS OF ENVIRONMENTAL CHANGE ON AQUATIC RESOURCES

D. W. Narver

The major activity under this program continued to be the Logging and Stream Ecology study at Carnation Creek. The Babine Environmental Change study continued through 1974 at a low monitoring level except for special late winter production work and a study on copper complexing. The Impact Assessment sub-program is not a research activity but comprises contributions to Ministerial Task Forces or special committees, Departmental working groups, and to Ministerially requested proposals for major environmental impact studies.

Logging and streams

D. W. Narver

The Carnation Creek Experimental Watershed Study is a long term, interdisciplinary study in which seven Federal and Provincial agencies and MacMillan Bloedel Ltd. are participating. The Pacific Biological Station is responsible for conducting the research on the aquatic system as well as coordinating all aspects of the study. The broad objectives are:

1. to develop a better understanding of how undisturbed coastal rainforest-salmonid stream ecosystems work in order to:

2. explain and quantify the impacts of timber production on stream environments and their capacity to produce salmonid fishes in sufficient detail to:

3. provide continuous input to the further development of integrated resource management guidelines.

Prelogging baseline studies have been conducted continually from 1970 through 1974 and are now essentially complete. Initial road building and logging begins in 1975.

All fish migrating in and out of Carnation Creek were counted and sampled at the trapping fence located at the head of tide. The 1974 downstream migration was 137,600 chum fry, 21,600 coho fry, 2,500 coho smolts, 78 steelhead smolts (>100 mm), 179 (<100 mm) steelhead, 57 cutthroat trout (48 >100 mm), 338 Cottus asper and 313 Cottus aleuticus. Compared with the outmigrations of the previous 3 years, 1974 had slightly more coho smolts, fewer steelhead smolts and more cutthroat. The adult return was 65 jack coho, 91 large male coho, 68 female coho, 3,000 chums (60 above the fence) and about 10 steelhead. The low number of chum above the fence was a result of prolonged low water; when the delayed fish did come in on the first freshet they were so mature that spawning occurred in the intertidal zone.

The summer resident fish populations were sampled three times from May to September at seven study sections in Carnation Creek for density, biomass and growth. In addition four control streams were sampled in early September. The late summer populations were similar to those reported in previous Annual Reports and in FRBC MS Report No. 1303.

A study of the relative roles of autochthonous and allochthonous production pathways leading to invertebrate fish food was initiated in Carnation Creek in 1974. Sampling was done in relation to the boundaries of the proposed first logging on opposite sides of the stream with "clearcut and burn" to the stream margin. Of primary interest after logging, with increased radiation and decreased leaf litter, is how the trophic pathways change to affect the qualitative and quantitative aspects of the resulting fish food. It was found that autochthonous production (mainly diatoms) was generally very low and limited by the available solar radiation and by freshets >70 cfs. Two periods of rapid growth and high biomass accumulation were noted -- April-May and September-October. The latter was related to clear, dry weather. During the period April to October diatoms were utilized by some species of immature insects. An adjacent watershed that was clearcut and burned 7 years ago had stream primary production much higher than in Carnation Creek. Likewise primary production (epiphyton) in the estuary was much higher than in the stream under the canopy. Insect food habitat studies in Carnation Creek show that most production is based on the allochthonous pathway based on leaf litter from streamside deciduous species such as alder and salmonberry (Alnus and Rubus). In 1974 we started measuring the quantity and quality of litter fall, the fraction entering the stream, the portion retained in the substrate and the portion transported out of the system. Total fall from April 27 to November 25 within one chain of the stream was estimated as 13.7 metric tons of deciduous leaves and 10.2 tons of coniferous needles.

Another 24-hr coho and trout food monitoring study was completed in 1974. This completes the series of five, one for each month of the growing season May-September. Two of these were analysed this year. The data indicated that coho feed mainly on aquatic insects during the spring, but by August they were utilizing mainly terrestrial insects.

Water chemistry studies begun in 1971 are continuing. The basic prelogging conclusions are that: (1) sulphate, chloride and sodium comprise 80% of the atmospheric fallout, (2) much of the summer chloride inputs are stored on the canopy until the first autumn rains, (3) the concentrations of the major stream ions -- bicarbonate, calcium, sulphate, chloride, sodium, silicate, magnesium, potassium and nitrate were inversely related to discharge, and (4) the concentration of some ions was also inversely related to the previous hydrological flux, thereby producing a seasonal pattern having an inverse relationship between concentration and discharge.

The Carnation Creek Coordinating Committee, charged with project surveillance and senior level coordination among agencies, met on April 7, 1974. A major agenda item was the set of recommendations prepared by the Working Group regarding needs in logging-fisheries studies in general, as well as Carnation Creek in particular. The Committee approved Working Group recommendations to seek improved support for synoptic surveys of watersheds and stream resources in various stages of logging and reforestation and for use of experimental streams in quantifying certain logging impacts under controlled conditions. The answers received in response to correspondence were favourable in principle. Responses were received from industry, the Province and Universities. Responses from Federal Fisheries agencies and the DOE Board of Regional Directors were conspicuous by their absence, despite the fact that logging and related activities constitute one of the Pacific Region's major threats to salmonid freshwater habitat.

D. W. Narver spent 5 months at the Biological Station, St. Andrews, New Brunswick on a professional development transfer where he participated in a synoptic survey of logging and agriculture impacts on small salmonid nursery streams. The synoptic survey approach for rapidly obtaining environmental impact data has been considered for B.C. but never really developed. The New Brunswick experience indicated that this was a good method of developing an overview of impact problems and first order estimates of measurements for watershed management guidelines. Forty 2,000-acre watersheds were selected; about 1/3 were recently clearcut, 1/3 grew potatoes and 1/3 was forested (controls). All measurements were made in late summer or fall in the lowest 100 m section of each stream and consisted of fish density including age and species composition, fine sediment accumulation, insect population density, and stream morphology. Although the analyses are not complete it is apparent that intensive cultivation of potatoes in the upper St. John River valley has a strong impact on stream via silt, pesticides and fertilizers. Some streams were found to have neither fish nor insect life. Impact of logging on small streams seemed to be related mainly to poor road and culvert construction and poor maintenance.

Impact assessment — C. D. McAllister

Activities recorded here include non-research contributions to Task Forces, other Ministerial and Departmental committees and responses to ad hoc requests, all concerned with impacts of impending or potential impacts of environmental change on fisheries resources.

1. Nanaimo Port Alternatives Task Force

The report of this Task Force was completed in 1974 and released in Nanaimo by the Minister during April.

2. Improvements to Harmac outfall

Comments requested by EPS on proposed changes to the Harmac outfall were elicited (F. C. Withler, D. W. Narver), compiled and submitted via Fisheries Operations.

3. Minister's "Symposium" re Fraser River intertidal zone

The report of a special Departmental committee on the value of Fraser intertidal lands was negotiated and submitted, based in significant part on contractual work proposed, funded and interpreted by Nanaimo staff.

4. Vancouver Airport Extension Task Force

Field work by Nanaimo staff (Dr. F. Bernard), interpretation of existing data and support of work done from P.E.I. contributed to this Task Force.

5. The Estuary Working Group

Through chairmanship, financing and review activities P.B.S. supported production of contracted evaluation of existing data on the estuaries of the Fraser and Squamish Rivers.

6. Northwest British Columbia Steering Committee

Participation in the above committee led to a 6.7 million dollar Fisheries Operations -- R & D proposal for baseline studies in N.W. British Columbia. The proposal, as part of a total Federal-Provincial submission has been received by the DOE Management Committee.

7. Proposed Canada-U.S. Bilateral West Coast Environmental Protection Agreement

Research proposals, associated budgets and other contributions were made to the F.M.S. position in Canada-U.S. negotiations regarding threats posed by Alaska tanker traffic and other sources of marine contamination.

8. Impacts of proposed kelp harvest on federally managed marine resources

Responses to preliminary overtures from the Province on the above were made.

9. Tissue banks re detection of pollutants in Biota

With Drs. D. Alderdice, T. Evelyn and L. Margolis a Fisheries position regarding OAA proposals for a tissue bank was developed and transmitted, several times.

BABINE WATERSHED CHANGE

H. D. Smith

Sockeye Production and Babine Watershed Change programs were consolidated under the latter title in 1974 when the Fisheries Operations Directorate assumed responsibility for much of the continuing work on sockeye production and population studies at Babine Lake.

The Babine Watershed Change Program began in 1972 and the bulk of field studies recommended at that time by the Steering Committee were completed in 1973 and 1974. Major reports are being prepared by participants from the Marine Sciences Directorate, Pacific Environment Institute, Institute of Animal Resource Ecology at University of British Columbia, and the Atmospheric Environment Service.

A standardized monitoring program for Babine Lake waters was initiated in 1974. This follows the large lake monitoring schedule adopted by the World Organization for Economic Cooperation and Development (O.E.C.D.), which receives copies of the data. It is jointly funded and implemented by several Federal and Provincial participants in the Babine program.

The Steering Committee recommended several small field projects which were completed in 1974. These included a study of the copper complexing capacity of Babine Lake water and possible toxic effects of copper on algal growth. This work was undertaken by Dr. Y. K. Chau from the Canadian Centre for Inland Waters at Burlington and largely funded by Granisle Copper and Noranda (Bell Copper Division) mines, the two operating mining companies at Babine Lake.

The Regional Board, Pacific Region, has authorized a continuation of the Babine Watershed Change Program through 1975/76.

BABINE LAKE SOCKEYE DEVELOPMENT

J. McDonald

In 1971 and 1972, sockeye fry produced in the artificial spawning channel No. 2 at Fulton River were marked and released into the lake. Subsequent recovery of these fish as smolts going to sea and as returning adults provides measures of the lake's capacity to support the increased lake population resulting from the development program and of the contribution of channel-produced sockeye to the fishery.

Marked smolts were recovered in 1972 and 1973. In 1973, and again in 1974, spawning ground surveys were carried out to recover marked adults. This year nearly 59,000 sockeye at the Babine River counting fence, Fulton River, and other major spawning grounds were examined for marks; 221 were recovered. Scale and otolith samples were taken to determine the age of each marked fish so that it could be assigned to its release group.

Recovery of marked adults in 1975 and 1976 will be required to complete returns from the two markings and to allow estimates of channel adult production to be made.

S T A F F L I S T

All employees are listed who were on strength as at December 31, 1974. The arrangement of investigations and services applies to the major portion of the year.

Director	W. E. Johnson, Ph.D.
Assistant Director	K. S. Ketchen, Ph.D.
Executive Assistant	W. E. Reynolds
Chief Scientist (H.Q. Staff)	W. E. Ricker, Ph.D., F.R.S.C.
Director's Secretary	Ruth Gale (Ann Thompson acting from September 19, 1974)

Office of the Director

Director	W. E. Johnson, Ph.D.
Assistant Director	K. S. Ketchen, Ph.D.
Executive Assistant	W. E. Reynolds

Personnel

J. F. Griffin (Transferred April 1/74)
Laura Rasmussen (Resigned March 9/74)
T. Margetish

Fisheries Biology Group

S. J. Westrheim, M.Sc. (Group Head)
E. Eleanor Kehler (Group Secretary)

Groundfish

S. J. Westrheim, M.Sc.
W. A. Kennedy, Ph.D.
C. R. Forrester
W. R. Harling
D. Davenport
M. S. Smith
R. M. Wowchuk
Doris E. Chilton
Janice E. Smith

Pelagic Fishes	F. H. C. Taylor, Ph.D. D. N. Outram, B.A. L. W. Barner C. W. Haegele, B.Sc. J. S. Rees R. S. K. Isaacson E. Stolzenberg
Marine Invertebrates	N. F. Bourne, Ph.D. F. R. Bernard, Ph.D.
Shrimp and Crab	T. H. Butler, M.A. A. N. Yates
Lobsters	C. T. Shoop
Populations Biology	A. S. Hourston, Ph.D.
Sablefish Culture	W. A. Kennedy, Ph.D.
Salmon Management & Development Group	J. McDonald, M.A. (Group Head) R. Ann Thompson
Salmon Hybridization and Culture	F. C. Withler, M.A. R. B. Morley, B.Sc. Patricia L. Miller
Chinook and Coho	H. Godfrey, M.A. E. A. R. Ball
Salmon Stock Assessment	H. T. Bilton, B.A. D. W. Jenkinson

Babine Sockeye Ecology	J. McDonald, M.A. A. S. Coburn J. R. Scarsbrook
Babine Sockeye Assessment	H. W. D. Smith, M.Sc. F. P. Jordan J. Martell I. Miki, B.A.
Babine Environmental Quality	H. W. D. Smith, M.Sc.
Experimental Hatcheries	R. A. Bams, Nat, Phil, Drs. D. G. Crabtree
International Salmon Studies	K. V. Aro, B.A.
Experimental Biology & Pathology Group	L. Margolis, Ph.D. (Group Head) L. Mavis Colclough
Parasitology	L. Margolis, Ph.D. Z. Kabata, D.Sc. N. P. Boyce, M.Sc. T. E. McDonald, B.Sc.
Physiology	J. R. Brett, Ph.D., F.R.S.C. J. E. Shelbourn, M.Sc. D. B. Sutherland G. D. Heritage, B.Sc.
Mariculture	J. R. Brett, Ph.D.
Microbiology-Disease	G. R. Bell, Ph.D. T. P. T. Evelyn, Ph.D. G. E. Hoskins, B.Sc.

Physiological Ecology	D. R. Alderdice, Ph.D. F. P. J. Velsen
Ethology	C. Groot, Ph.D. C. E. Turner
Ecological Genetics	J. R. Calaprice, Ph.D. R. M. Hungar A. J. Solmie
Chemical Tags	J. R. Calaprice, Ph.D.
Environmental Research Group	C. D. McAllister, Ph.D. Beulah Smith
Lake Fertilization	C. D. McAllister, Ph.D. O. D. Kennedy, B.Sc. K. V. C. Stephens D. G. Robinson
Biological Oceanography	R. J. LeBrasseur, Ph.D. W. E. Barraclough, M.A. J. D. Fulton, B.Sc.
Marine Impoundments	R. J. LeBrasseur, Ph.D. K. V. C. Stephens
Fisheries Oceanography	W. P. Wickett, M.A. J. I. Manzer, M.A.
Stream Ecology	J. H. Mundie, Ph.D. D. E. Mounce, B.Sc.

Ecology & Production of Freshwater Fish	J. C. Mason, Ph.D.
Crayfish Culture	J. C. Mason, Ph.D.
Estuarine Pollution	R. R. Parker, Ph.D. (Resigned March 9, 1974) Beverley A. Kask, B.Sc. T. J. Brown, M.Sc.
Logging and Stream Ecology	D. W. Narver, Ph.D. J. C. Scrivener, B.Sc. B. C. Andersen, B.Sc.
Administration & Program Support Services	W. E. Reynolds S. L. Marcus (Resigned April 1/1974) P. Childs
Library	Emily A. Young, B.A., B.L.Sc. S. Dixon (Resigned March 12, 1974) J. Nott
Fish Culture	R. M. Humphreys
Fish Culture - Nanaimo	W. Griffioen D. Pozar
Fish Culture - Rosewall	G. E. Johnston E. W. H. Moore
Histology	J. W. Bagshaw

Publications and Information	Ethel E. Robinson Beverly Rumsby A. A. Denbigh C. Morley Barbara Korsvoll Terezia Beg P. Childs Gloria D. Melluish
Computations	J. A. C. Thomson, M.Sc. F. W. Nash, B.Sc. Arlene Sandnes (Resigned January 1974) Kathleen R. Mitchell
Equipment Research & Development	J. S. Ford, B.A.Sc., P. Eng. (Resigned June 29, 1974) M. C. Armstrong R. A. Cooke (Resigned September 21, 1974) G. T. Atkinson D. J. Redman
Office & Material Services	O. O. Morgan J. R. Hancock
Financial Management	L. Noon (Resigned December 1974) D. Bright S. C. Grando Margaret K. Philp Mary Arbanas J. G. Naysmith I. Linda Riddell
Buildings, Grounds & Services	H. G. Reinstein F. E. Drader H. W. Gulich M. H. Shillington M. B. Waddell A. Brown (Resigned October 1974) T. Gillies J. M. McArthur

Shops & Services	J. H. Brennan M. Ilich
Vessels	
G. B. REED	J. Liston R. May J. Swindell W. H. Colp W. H. Craigie W. S. Sutherland A. J. Fletcher D. Housego A. J. Ranger J. R. Selsby R. H. McLaughlin R. P. Marshall H. J. Rothwell E. C. Ryan G. A. Wiseman W. E. Wolden W. P. Rowbottom J. J. Backmann J. W. Young M. A. MacLean K. J. Goodman F. Kreger L. E. McLeod
A. P. KNIGHT	E. R. Pollard W. P. Winstanley R. H. McLaughlin J. W. Young A. Gow (Resigned July 13, 1974) J. Selsby
CALIGUS	R. C. Page
INVESTIGATOR NO. 1	J. T. Ferguson
Marine Support Services	C. Stewart (Resigned May 28, 1974) J. T. Ferguson W. D. Nichol L. V. M. Soper R. B. Coomber (Resigned February 16, 1974)

Personnel from the Arctic Unit	M. A. Bigg, Ph.D. I. B. MacAskie

NON-STAFF RESEARCH WORKERS

Honorary Research Associate	R. E. Foerster, Ph.D.
Honorary Research Associate	F. Neave, Ph.D.

P U B L I C A T I O N S

1. Primary publications

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